Picton WRP Licence Variation - Water quality assessment

Part B - Proposed discharge regimes and their potential impacts on water quality

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Sydney Water

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Executive summary

Picton Water Recycling Plant (WRP) is currently exceeding its capacity to treat, store and recycle its wastewater due to growing development in its catchment. Sydney Water has explored different options to vary the WRP's Environmental Protection Licence (EPL) to allow a continued discharge into Stonequarry Creek whilst it seeks to 1) maximise reuse to handle higher inflows, and 2) and implement new treatment processes to improve the quality of effluent discharged to Stonequarry Creek.

A suite of technical water quality reports has been commissioned to accompany a Licence Variation Application (LVA). These reports include:

- **Part A** (Sydney Water, 2021), which focused on existing impacts using real monitored data, was delivered to the EPA in January 2021, and
- **Part B** (this report) which uses advanced modelling and statistical approaches to predict water quality resulting from future discharge regimes.

This report informs supporting analysis on the predicted impacts of the proposed 'worst case' discharge regimes on hydrology (Aurecon, 2021) and waterway values (CT Environmental, May 2021).

Objectives and hypotheses

Part A of this investigation focused on understanding the influence of the current Picton WRP discharge regime on receiving water quality using real monitored data (see Part A, Section 1.3).

This report (**Part B**) focuses on evaluating the effect of modelled discharge regimes on water quality in Stonequarry Creek and Nepean River. The modelled discharge regimes were separated into the following 'Scenarios':

- Scenario A: modelled existing discharges (including compliant and non-compliant discharges)
- Scenario B: modelled compliant discharges
- Scenario C1: future inflows with the current regime
- Scenario C2: future inflows with reduced discharge frequency at higher volumes
- Scenario C3: future inflows with increased discharge frequency at lower volumes

Specifically, this report aims to evaluate the following hypotheses/questions:

- Hypothesis 5: Does increasing discharge to Stonequarry Creek impact water quality? To what magnitude?
- Hypothesis 6: Which future regime for Stonequarry Creek discharges leads to the least change to water quality?

Key outcomes

- Flow was a significant determinant of water quality, with generally higher levels of nutrients associated with higher creek flows. This is likely due to the confounding effects associated with stormwater runoff from various land uses across the catchment
- Consistent with existing data (Part A), total nitrogen and oxidised played a more significant role in water quality changes when compared with total phosphorus and soluble reactive phosphorus
- The effect of nutrients was much less pronounced and only marginally different between different discharge scenarios in the Nepean River compared to Stonequarry Creek
- Of the modelled scenarios, Scenario C2, which is defined by reduced frequency discharges at higher volumes, resulted in a lesser change to water quality compared to other future scenarios (Scenarios C1 and C2), evidenced by both broad descriptive trends and statistical analysis.

1 Introduction

1.1 Background and context

The Picton Water Recycling Plant (WRP) is situated in the Wollondilly Shire Council local government area, approximately 70 km south west of Sydney CBD and in the Upper Nepean catchment. The WRP was constructed in 2000 and currently services 16,000 people in the townships of Picton, Thirlmere, Tahmoor and the villages of Bargo and Buxton. Growth in the catchment is forecast to increase to approximately 25,000 people by 2036.

On average, 3 megalitres (ML) of wastewater is treated daily at the WRP with a current capacity to treat approximately 4 ML/day. However, the management (ie. reuse and licensed discharge) of this recycled water is limited on average to 2.2 ML/day. This is achieved by the irrigation of 119 hectares on Picton Farm adjacent to the WRP and licensed precautionary discharges to Stonequarry Creek (subject to flow conditions in the creek including flows in excess of 8 ML/day). Due to these limitations, excess recycled water is discharged under an Emergency Operating Protocol (EOP) to prevent on-site storage dams from spilling. In addition, the WRP has been unable to accept new wastewater connections to the WRP despite increasing development in the catchment.

Extensive planning efforts have been made to address the problem such as applications for licence variations since 2015 and conducting pollution reduction studies. This includes monitoring for changes in Stonequarry Creek, source control investigations to reduce inflows and infiltrations to the network, investigations to expand reuse options and pilot wetland trials to further reduce nutrients and improve effluent quality for discharge into Stonequarry Creek.

1.2 The LVA proposal

The overall goal of the proposal is to increase recycled water management capacity to match the current WRP treatment capacity of 4ML/day in order to enable servicing future growth to 2026.

The proposal objectives are to:

- allow new wastewater connections into the WRP,
- resolve current non-compliances to the Environmental Protection Licence (EPL),
- maximise beneficial reuse of recycled water where feasible, and
- minimise discharges and maintain community waterway values.

The proposal would involve:

- continuing reuse of treated water for irrigation at the Picton farm
- improving effluent quality through upgrades of the WRP treatment process

- seeking flexibility to the current EPL including increasing discharges to Stonequarry Creek.

1.3 Objectives and hypotheses – technical studies

The purpose of this investigation is to support Picton WRP's LVA by conducting a range of water quality and ecological technical studies, analysing existing and modelled scenario data, to determine waterway health impacts into receiving waters from both current discharges (Part A), and proposed future discharges (Part B).

The specific objectives of the overall study (Part A and B) are:

- To understand the existing water quality and ecological health of Stonequarry Creek and Nepean River under current licensed discharge conditions (WQ, algae, fishes, macrophytes, macroinvertebrates, and threatened species)
- To establish waterway objectives and values for Stonequarry Creek and Nepean River to assess waterway health into the future, and
- To explore the potential impacts of modelled LVA scenarios on water quality and ecological health of Stonequarry Creek and the Nepean River

This report (**Part B**) focuses on the impacts of modelled LVA in water quality in the study area. The specific hypotheses explored in this assessment are:

- Hypothesis 5: Does increasing discharge to Stonequarry Creek impact water quality? To what magnitude?
- Hypothesis 6: Which future regime for Stonequarry Creek discharges leads to the least impact to water quality?

1.4 Outcomes from existing impacts study (Part A)

- Picton WRP discharges had a temporary and localised impact on the hydrology and water quality of Stonequarry Creek as evident through descriptive and statistical modelling approaches. Long term impacts were not observed (impacts greater than a few days post-discharge were considered negligible)
- Picton WRP discharges increased nutrients in downstream Stonequarry Creek (N911) above upstream/baseline levels, particularly total nitrogen. The extent of impact of discharges was flow dependent. Greater impact is typically associated with relatively low creek flow conditions (less than 1.5 ML/day)
- Most Picton WRP discharges (51%) occurred in very high flows (above 5.3 ML/day). During these flows, on average, the WRP only had a minor contribution (14%) to total Stonequarry Creek flows. Around 24% of all discharges occurred in very low flows (<0.3 ML/day). Here, Stonequarry Creek was dominated by effluent (91%). Despite this, case studies have shown that there is rapid dissipation of effluent and recovery within a day in Stonequarry Creek

- Evidence suggests that despite increased nutrients downstream of the discharge in Stonequarry Creek, water quality changes from Picton WRP discharges were not typically detected in the Nepean River
- Picton WRP discharged 25% of the time during the six-year study period (2014-2020). Of this percentage, 5% was considered compliant and 20% was non-compliant, with respect to creek flow (as per the EPL). Non-compliant discharges had greater influence on Stonequarry Creek nutrient levels than compliant discharges
- Case studies that monitored Stonequarry Creek after discharge events revealed that downstream total nitrogen can rapidly revert to upstream levels (within one day) even under low flow conditions. Further sites are being established along Stonequarry Creek to better understand spatial recovery.

1.5 Simulated scenarios and Source modelling

Background

To continue servicing future growth, different effluent management schemes were explored using Source eWater Catchment Modelling ('Source'). Stochastic modelling of water quality and hydrology parameters was conducted, due to limitations in statistical modelling to adequately characterise the dynamic nature of catchment inflows, antecedent conditions, and systematically assess the feasibility of future discharge regimes. As such, Source modelling was used as the primary tool for predicting changes to water quality as it was deemed to be the most comprehensive, representative, and robust method available (Alluvium, 2020).

Options were assessed systematically, such that parameters relating to discharge volumes, proportion of creek flow and creek flow thresholds were varied until three feasible future servicing scenarios were selected for further assessment. The discharge regime to waterways would continue to intermittently release effluent from the Western Storage Dam within the Picton WRP (rather than continuous discharge). The three discharge regimes assessed vary in the frequency of discharge (from 50% to nearly 90% of the time). Key analytes of concern were modelled. Namely, total nitrogen (TN), total phosphorus (TP), oxidised nitrogen (NOx) and soluble reactive phosphorus (SRP). These analytes were selected due to a well-established understanding of elevated nutrients in wastewater.

Overall, Source modelling was used to:

- Simulate the flow and waterway nutrient concentrations in Stonequarry Creek
- Simulate the inflow, treatment, storage and reuse of water at the Picton WRP and farm
- Simulate the discharge to waterways under various configurations and the resulting changes to water quality and creek flow.

Two modelled baseline scenarios and three modelled future options are detailed in Table 1-1 and summarised as follows:

- Scenario A: modelled existing discharges (including EOP discharges)

- Scenario B: modelled compliant discharges
- Scenario C1: future inflows with the current regime ('EOP-like' regime)
- Scenario C2: future inflows with reduced frequency discharges at higher volumes
- Scenario C3: future inflows with increased frequency discharges at lower volumes

Table 1-1 Summary of modelled scenarios

Metric	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
	Existing	Compliant	'EOP-like'	Less frequent	Less proportion
Storm discharges	25% at 8MLD	25% at 8MLD	25% at 8MLD	200% at 5MLD	50% at 5MLD
'Excess' discharges	100% at <8MLD	NIL	100% at 3MLD	NIL	50% at 0.5MLD
Relative to current EPL 'compliance'	**32%** of discharge when flows below 8 ML/d	**3%** of discharge when flows below 8 ML/d	**34%** of discharge when flows below 8 ML/d	**26%** of discharge when flows below 8 ML/d	**31%** of discharge when flows below 8 ML/d
Inflow to WRP (ML/d)	2.7	2.25	4.0	4.0	4.0
Discharge to SQ (ML/yr)	451	395	915	932	926
Annual discharge freq	42%	30%	70%	50%	87%
TN load/yr	1,803	1,578	2,288	2,330	2,316
TP load/yr	23	20	46	47	46
Effluent TN (mg/L)	4.0	4.0	2.5	2.5	2.5
Effluent TP (mg/L)	0.05	0.05	0.05	0.05	0.05
Effluent NOx (mg/L)	3.2	3.2	0.6	0.6	0.6
Effluent SRP (mg/L)	0.005	0.005	0.005	0.005	0.005

Comprehensive details of the Source model configuration, assumptions and outcomes are provided in separate technical reports (Alluvium, 2020 and Sydney Water & Alluvium, 2021).

Modelled sites

Sites of interest were simulated in the Source model and mirrored Sydney Water's existing monitoring sites within Stonequarry Creek and the Nepean River. A drone flythrough of the study area is available online, courtesy of CT Environmental. All modelled sites and their significance are described in Table 1-2 below and mapped in Figure 1-1.

Table 1-2 Description of modelled sites

Site code	Description	Significance
N911B	Stonequarry Creek upstream of WRP discharge	Water quality control site upstream of Picton WRP's discharge into lower Stonequarry Creek
N911	Stonequarry Creek downstream of WRP discharge	Site downstream of Picton WRP's discharge into lower Stonequarry Creek, used as impact site
N92	Nepean River at Maldon Weir	Site upstream of confluence Stonequarry Creek and Nepean River
N91	Nepean River at Maldon Bridge downstream of Stonequarry Creek confluence	Site downstream of Stonequarry Creek confluence, to characterise Stonequarry Creek's influence on Nepean River

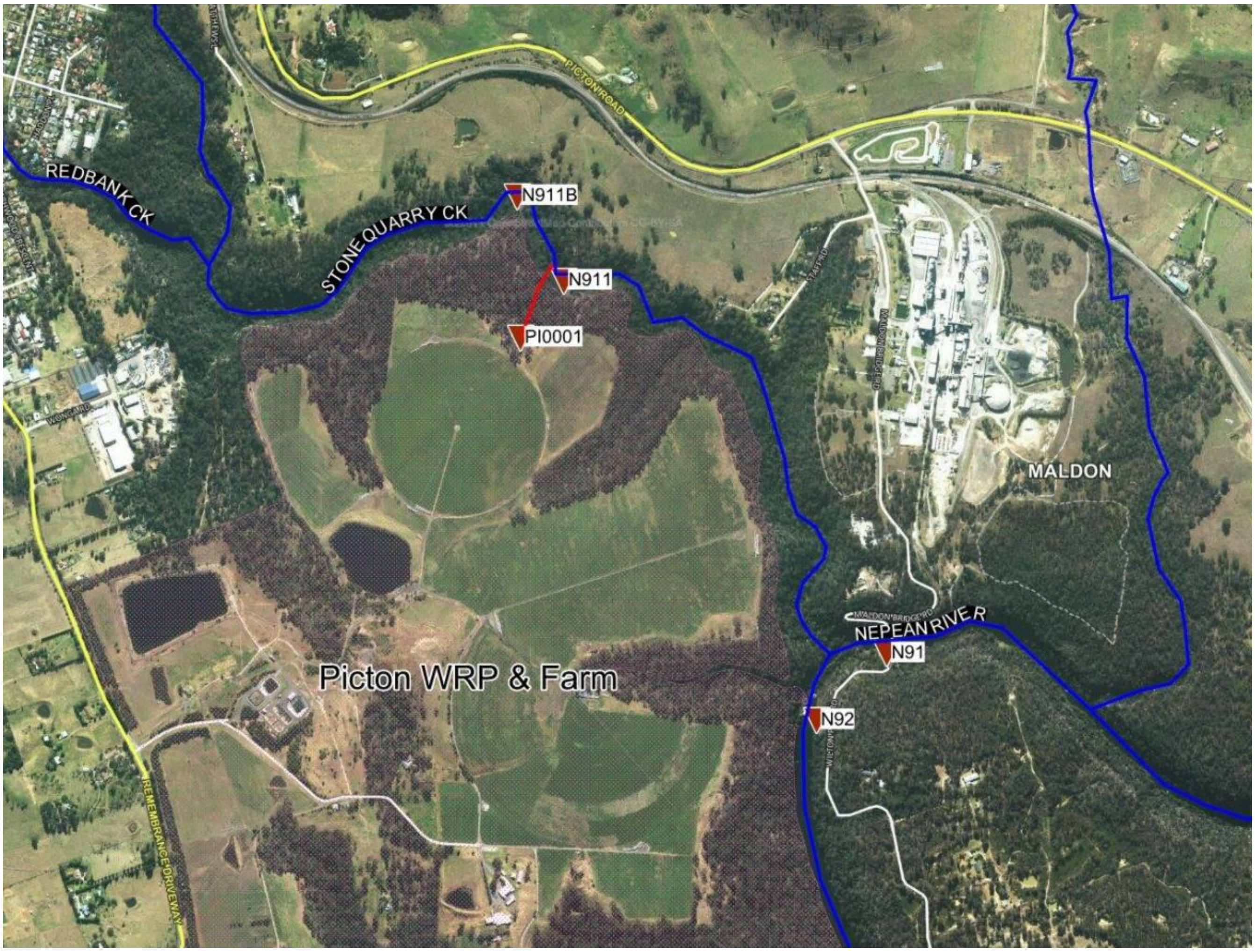

Figure 1-1 Map of modelled sites, relative to Picton WRP and discharge point

2 Methodology

The Source model outputs included flow (ML/day), TN (mg/L), TP (mg/L), NOx (mg/L) and SRP (mg/L) data that were used to assess potential changes in water quality.

Scenario A represents an ‘existing scenario’ with the greatest similarity to conditions in the 2014-2020 period in terms of inflow to the WRP and discharge to Stonequarry Creek. Given the challenges in representing complex and dynamic environmental conditions using stochastic models, results cannot be compared directly to the existing environment. However, by making relative comparisons *between* scenarios, insights can be gained to inform future management approaches.In this study, Scenarios A (existing) and B (compliant) are compared to future scenarios C1 to C3 to evaluate relative rather than absolute changes in Stonequarry Creek and Nepean River water quality. These relative changes are critical in estimating magnitude of change and potential future impact on waterway values. Where comparisons were made with existing monitoring data (ie. Part A of this study), only percentage or magnitude differences were compared, rather than absolute concentrations or flows.

2.1 Data pre-processing

For the purposes of this water quality assessment, modelled flow and water quality measurements were summarised from hourly to daily (12am to 12am) data. Modelled data from a 30-year period was filtered to a 10-year period (2009 – 2018) to ensure that results were consistent with the recent decade of water quality data and to minimise statistical noise.

Data was then categorised into ‘Site’, ‘Scenario’, ‘Flow’ and ‘Discharge’ factors. ‘Discharge’ and ‘Flow’ were highly collinear and confounding, therefore it was deemed appropriate to use the ‘Flow’ over ‘Discharge’, as discharges were determined by creek flows and would be inherently embedded into the ‘Flow’ category.

Flow categories (Table 2-1) were developed based on creek flow thresholds (0.5, 3, 5 and 8 ML/day) pertinent to the modelled scenario configurations (see Section 1.5). Of note, the flow categories in Part B (based on scenario configurations) are different from those used in Part A analysis (based on monitored creek flow percentiles). The use of the thresholds in Part B allowed clear comparison of the management regimes considered.

Table 2-1 Flow categories adopted for modelled data

Flow category	Range of values (ML/day)	Significance
Very Low	<0.5	Critical low flows
Low	[0.5 – 3.0)	Scenario C3 threshold value
Medium	[3.0 – 5.0)	Scenario C1 excess threshold value
High	[5.0 – 8.0)	Scenario C2 threshold value
Very High	≥8	Scenario B threshold value

Zero values were converted to half of the lowest recorded value for each analyte. Data was also $\log_{10}$ transformed whenever appropriate for visualisation and statistical analysis.

2.2 Data limitations

Limitations on Source modelled data are described in the Alluvium calibration report provided to the EPA in November 2020 (Alluvium, 2020). The modelling data presented some challenges for statistical analysis and interpretation. The limitations include:

- Uncertainty in modelled data at low flows (ie. below 0.5 ML/d within the 'Very Low' flow category) due to gauging issues). This is related to model calibration and described in detail in the model calibration report (Alluvium, 2020)
- NOx and SRP data were estimated via linear regression from TN and TP (Sydney Water & Alluvium, 2021). Given the complexity of nutrient speciation and transformation in aquatic environments, the modelled NOx and SRP concentrations at the upstream site (N911B) may not be wholly representative of bioavailable nutrient dynamics, therefore should be interpreted with caution. Given this, whilst both NOx and SRP are included in analyses, greater emphasis is placed on TN and TP when describing water quality outcomes.

Because uncertainties were not quantifiable, data pertaining to very low flows and NOx/SRP were interpreted with caution.

2.3 Data analysis

Guidelines and objectives

Both Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) and a localised site-specific guideline (Pheasants Nest Weir N86) were used in this study, in line with comparisons made for Part A (existing environment analysis, Sydney Water, 2021).

For ANZG 2018 guidelines, sites were compared to the ANZG lowland (<150m) tributary default guideline values (DGVs) for east-flowing rivers. A summary of these guidelines is provided below in Table 2-2. The local reference (N86) guideline value highlights the lower concentrations of phosphorus and higher concentrations of oxidised nitrogen can be expected in the local area. Sydney Water is endeavouring to establish a suitable tributary reference site for the region.

For simplicity, the majority of outcomes in this report are compared to ANZG guidelines (as per Part A).

Table 2-2 Summary of water quality guidelines used in this study

Analyte	ANZG 2018 (Lowland < 150 m)	Pheasants Nest N86 (80%ile)
Total nitrogen (mg/L)	0.35	0.31
Total phosphorus (mg/L)	0.025	0.010
Oxidised nitrogen (Nitrate and Nitrate as NOx-N) (mg/L)	0.04	0.14
Soluble reactive phosphorus (mg/L)	0.020	0.002

Summaries and trends

Trends and summary statistics were analysed to understand differences in modelled scenarios. Median (50th percentile) values and sample counts (n) were compared to relevant site-specific and default guideline values where applicable. Box and whisker plots were generated for each analyte, scenario, site and flow category. The lower and upper whiskers represent the 10th and 90th percentile, respectively. The box is drawn from the 25th to 75th percentile. The horizontal line in the middle of the box denoted the 50th percentile (median). Dots represent outliers or exceptionally high and low values.

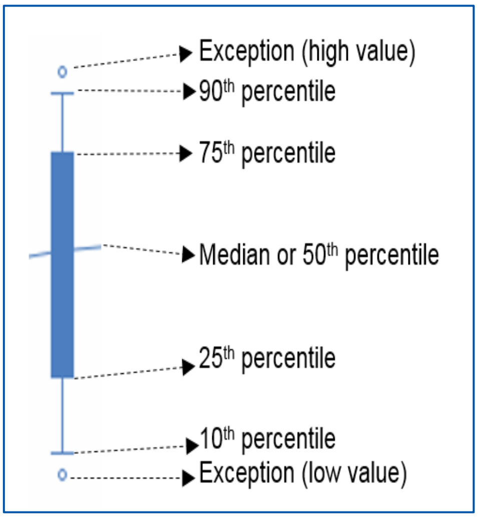

Figure 2-1 Example of box plot representation

General Linear Models

While the stochastic model dynamically predicted creek flow and water quality, further analysis was needed to compare scenarios under different flow conditions. This was achieved using a general linear model (GLM) analysis approach (function "lm" from R package "stats" in R Studio Version 1.4.1106). GLMs helped to determine the magnitude of impact of scenarios on water quality. Various predictor combinations were systematically assessed to determine the most logical and appropriate model fit. GLM development is discussed Appendix 6.1. The primary GLM used in this assessment is described in Equation 2-1:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_1 X_2 + \beta_5 X_1 X_3 + \beta_6 X_2 X_3 + \beta_7 X_1 X_2 X_3 + \varepsilon$$ Equation 2-1

Where the Y is TN, TP, NOx, or SRP ($\log_{10}$ transformed), X_1 is Site (N912, N914, N911B, N911, N92, and N91), X_2 is Scenario (as a categorical variable, ie, Scenario A, B, C1, C2, and C3), X_3 is Flow (Very Low, Low, Medium, High, Very High), β_0 is the intercept, $\beta_{1\text{-}7}$ are regression coefficients for the main effects and 2- and 3-way interactions, and ε is the error or residual term. For brevity, Equation 2-1 is expressed as *Y ~ Site x Scenario x Flow* from here onwards.

The Analysis of Variance (ANOVA) results for the type II sums of squares from the GLM were obtained to determine the significance of the contribution of individual terms ($p<0.01$ was considered significant) in explaining the variability in the analyte results.

The effects were estimated by evaluating the least-squares mean or "adjusted geometric mean" (R package "emmeans") calculated from the GLMs. The magnitudes of impact of discharge on water quality were estimated by "contrasting", ie. obtaining the difference of the adjusted geometric means of data groups. Back-transforming the difference provided the estimated ratio of the two groups (eg. A *vs* B), as shown below:

$$\log A - \log B = x$$ Equation 2-2

$$\log \frac{A}{B} = x$$ Equation 2-3

$$\frac{A}{B} = 10^x$$ Equation 2-4

Ratios equal to one (1) denote complete similarity. The lower and upper 95% confidence levels were also calculated to determine the range of plausible ratios. Note that confidence intervals are not symmetrical around the estimated ratios.

3 Predicted impacts on water quality

3.1 Summaries and trends

Water quality parameters (TN, TP, NOx and SRP) were assessed descriptively (this section), then statistically (Section 3.2) to determine impacts of each modelled scenario on water quality. Water quality was first assessed holistically (across all discharge and flow regimes), between upstream and downstream paired sites in Stonequarry Creek and the Nepean River.

Stonequarry Creek analytes were also assessed with respect to flow categories (as established in Section 2.1), to understand water quality dynamics in various flow regimes. For TN and TP, results in each scenario were further summarised into frequency of ANZG DGV exceedances, to make relative comparisons between scenarios.

Summary statistics across sites and scenarios are included in Appendix 6.1.

- Flow was a significant determinant of water quality, with generally higher levels of nutrients associated with higher flows. This is also observed for the sites upstream of the discharge and is likely due to the confounding effect of catchment inputs such as untreated stormwater runoff
- Consistent with existing data (Part A), TN and NOx played a more significant role in water quality changes when compared with TP and SRP
- Overall, Scenario C2 resulted in a lesser change to water quality compared to Scenarios C1 and C3, with respect to median values and ANZG guideline exceedances.

Stonequarry Creek

Modelled **total nitrogen and oxidised nitrogen** results for Stonequarry Creek were assessed descriptively for broad trends.

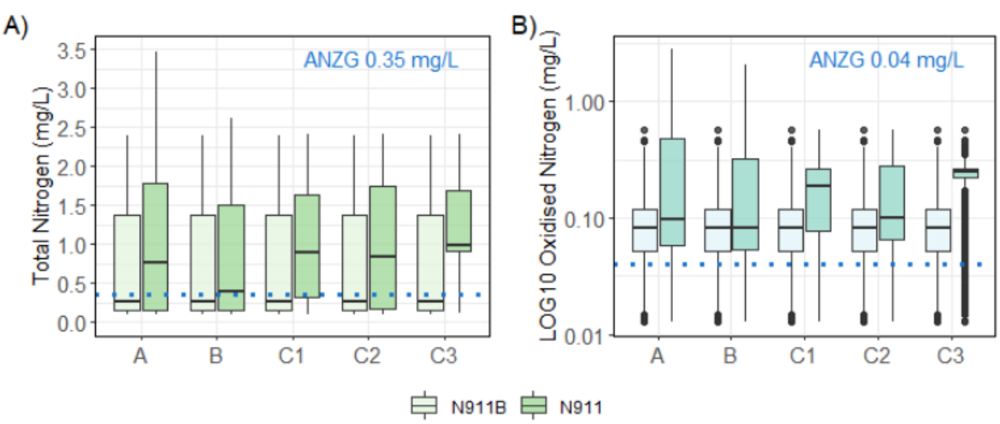

Figure 3-1 Modelled TN and NOx levels for upstream (N911B) and downstream (N911) Stonequarry Creek sites, across scenarios

Broad TN results indicated that:

- Upstream median TN levels at site N911B (0.27 mg/L) met both the ANZG (0.35 mg/L) and local (0.31 mg/L) objectives in all scenarios (Figure 3-2)
- Downstream median TN concentration at site N911 (0.76 mg/L) across all flows was approximately twice that of N911B levels in Scenario A (current modelled conditions). This is consistent with existing monitoring data (see Part A).

Scenarios were then assessed in greater detail with respect to flow at the downstream site N911 (Figure 3-2 and Figure 3-3).

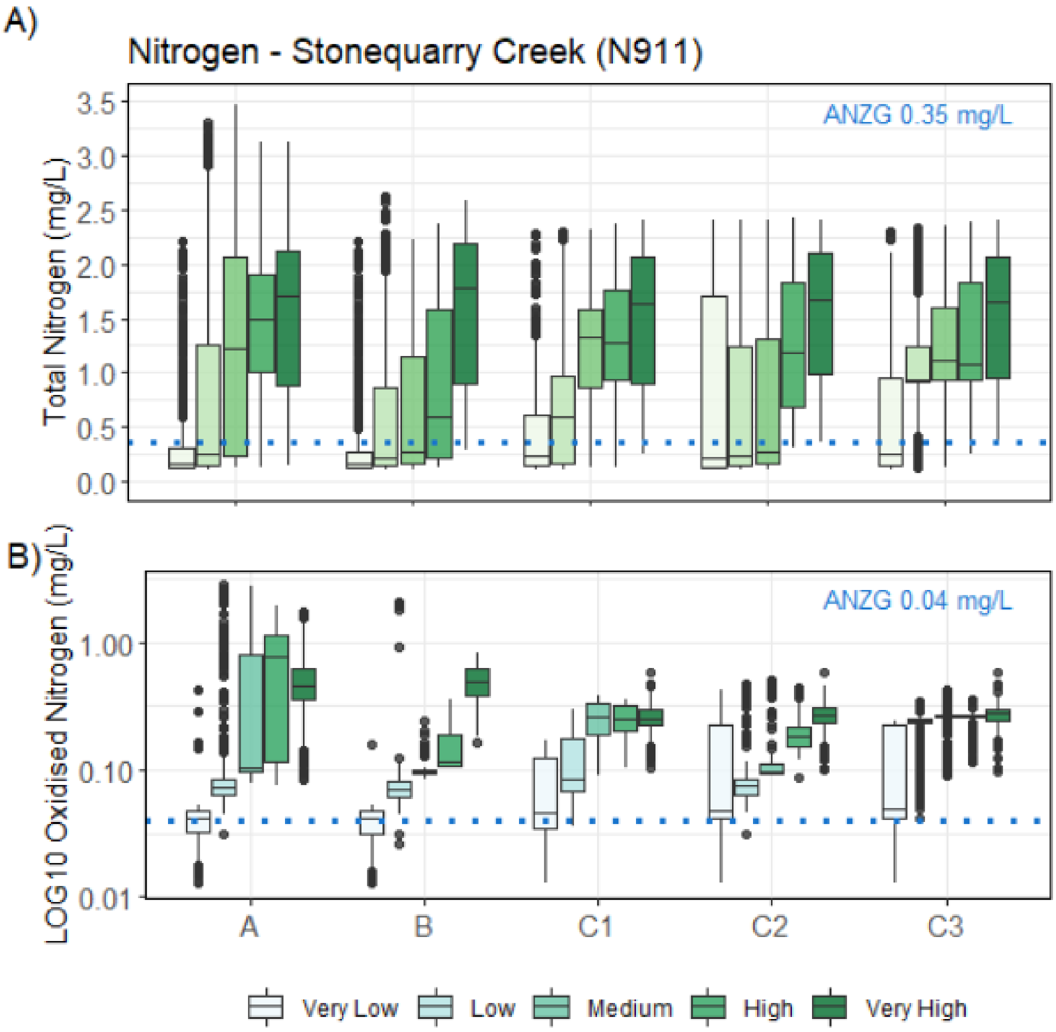

Figure 3-2 Modelled TN and NOx levels for Stonequarry Creek site downstream of the discharge (N911), across scenarios and flow categories

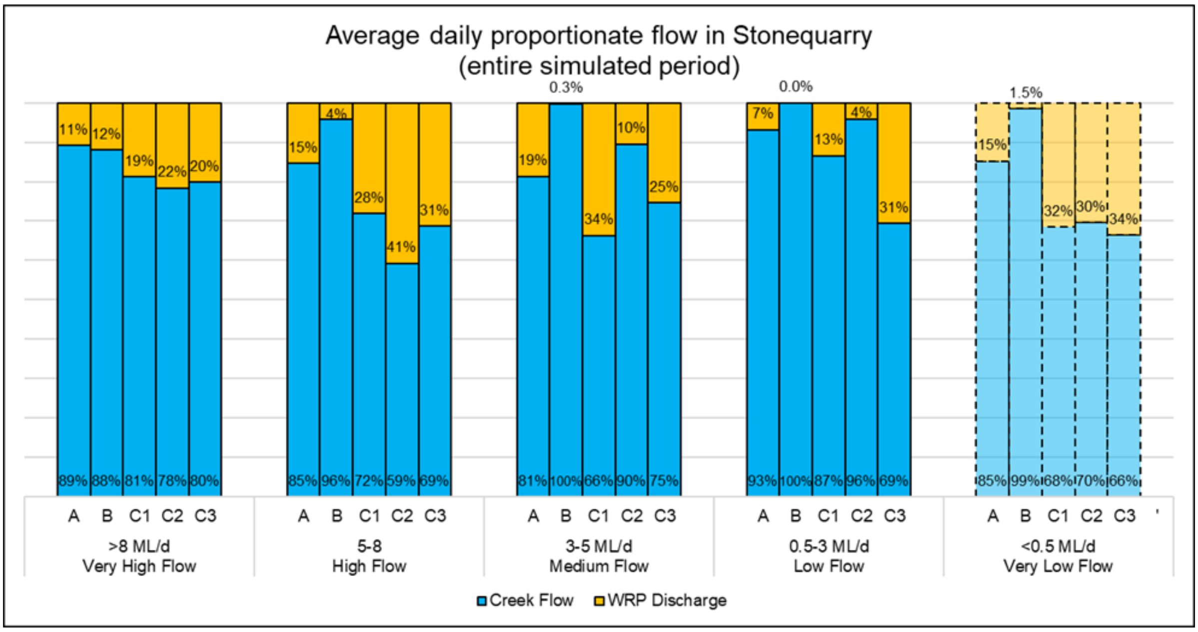

Figure 3-3 Average daily proportionate flow in Stonequarry Creek
Source: Aurecon, 2021

TN and NOx trends across flows showed that:

- Changes to TN and NOx levels at the downstream site (N911) were highly dependent on the magnitude of upstream creek flows, with higher levels observed during higher flow events (Figure 3-2), likely due to the confounding effect of stormwater runoff
- Extreme values of both TN and NOx levels (expressed as upper quartile and outliers in boxplots) decreased in magnitude in Scenarios C1 to C3 relative to existing Scenario A at N911, likely due to modelling of denitrification processes at Picton WRP
- Overall, future scenarios C1 to C3, which modelled elevated total inflows (4 ML/day, relative to 2.2 and 2.7 in the baseline scenarios), had similar TN and NOx levels at N911 in higher flow regimes compared to existing Scenario A and baseline Scenario B. Future scenarios C1 to C3 showed that:
  - Scenario C1 trends were most similar to Scenario A, which was expected as it was modelled with the same discharge regime, but with increased inflows, increased discharge (volumes, frequency) and an increased proportion of flow in Stonequarry Creek (Figure 3-3). Despite this increase, TN median values at all flow regimes were either the same or marginally higher in C1 relative to Scenario A.
  - Scenario C2 had similar TN levels to baseline scenario B in almost all flow regimes, with the exception of 'High' flows, due to the effect of the discharges in this flow regime for C2 (discharges when creek flow >5ML/d). Similarly, NOx was generally consistent between the two scenarios, however levels in C2 were slightly lower than baseline (B) due to improved NOx treatment.
  - Scenario C3 had the most distinct flow-concentration profile, with elevated TN and NOx levels across lower flow regimes. This was expected, due to the more frequent

discharges modelled across the flow range, and discharge 31 - 34% of creek flows in 'Very Low' to 'Low' flows (Figure 3-3).

Each scenario was then assessed against frequency of ANZG DGV exceedances (Table 3-1) and results showed:

- TN levels upstream site at N911B surpassed the ANZG DGV nearly half of the time in all scenarios. The exceedances at the downstream site at N911 were higher than upstream N911B owing to the influences of the discharge.
- Impacts of Picton WRP's potential future discharge regimes on Stonequarry Creek water quality and risks with exceeding ANZG DGV were further assessed by looking at the change in N911 exceedance rates relative to Scenarios A and B:
  - If EOP-like conditions were maintained (Scenario C1), TN exceedance rates at N911 are expected to increase by 21 - 44%. This is a considerable increase from baseline compliant conditions.
  - A higher proportion but lower frequency regime (Scenario C2) would increase exceedances by 4% relative to existing conditions (Scenario A), and 23% relative to compliant conditions (Scenario B), despite greater inflows. This increase is considered marginal and it is expected these changes would not degrade current water quality conditions.
  - With the most frequent discharge conditions (Scenario C3), N911 exceedance rates are expected to increase by 43 - 69%. The near constant discharge (87% of the time) results in the greatest exceedances of the ANZG DGV for the scenarios considered.

Table 3-1 Percent exceedance of TN DGVs at Stonequarry Creek paired sites, across all scenarios

	TN Guideline exceedances at Stonequarry Creek (%)				
	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Site N911B	45.6				
Site N911	61.2	51.5	74.3	63.4	87.4
Change in N911 exceedances relative to Scenario A	-	16% decrease	21% increase	4% increase	43% increase
Change in N911 exceedances relative to Scenario B	18% increase	-	44% increase	23% increase	69% increase

Modelled **total phosphorus and soluble reactive phosphorus** results for Stonequarry Creek were assessed descriptively for broad trends.

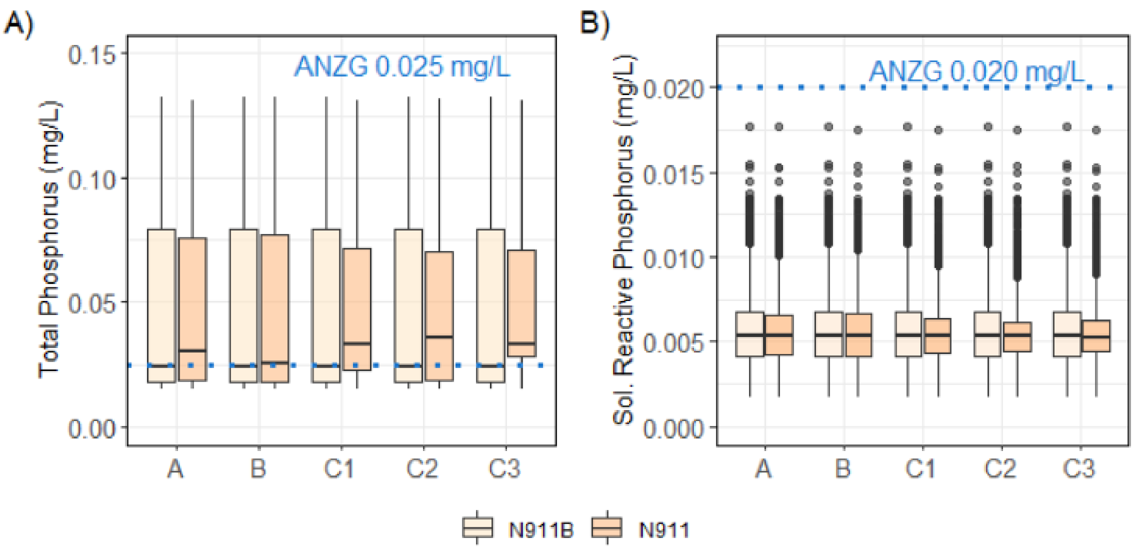

Figure 3-4 Modelled TP and SRP levels for upstream (N911B) and downstream (N911) Stonequarry Creek sites, across scenarios

TP trends showed that:

- In all scenarios, the median TP concentration in Stonequarry Creek at the upstream site N911B (0.024 mg/L) met the ANZG guideline (0.025 mg/L), but exceeded the more stringent local reference site objectives (0.010 mg/L) (Figure 3-4)
- Scenario A (current baseline) showed marginally higher median TP concentration downstream of the discharge point (median 0.030 mg/L in comparison to N911B median of 0.024 mg/L). In contrast, median TP levels were similar in both upstream and downstream sites in Scenario B.
- Levels of SRP were more or less the same across all future scenarios, and between upstream and downstream Stonequarry sites. In addition, SRP was well below ANZG guidelines, consistent with existing conditions (see Part A)

Scenarios were then assessed in greater detail with respect to flow categories at the downstream site N911 (Figure 3-5).

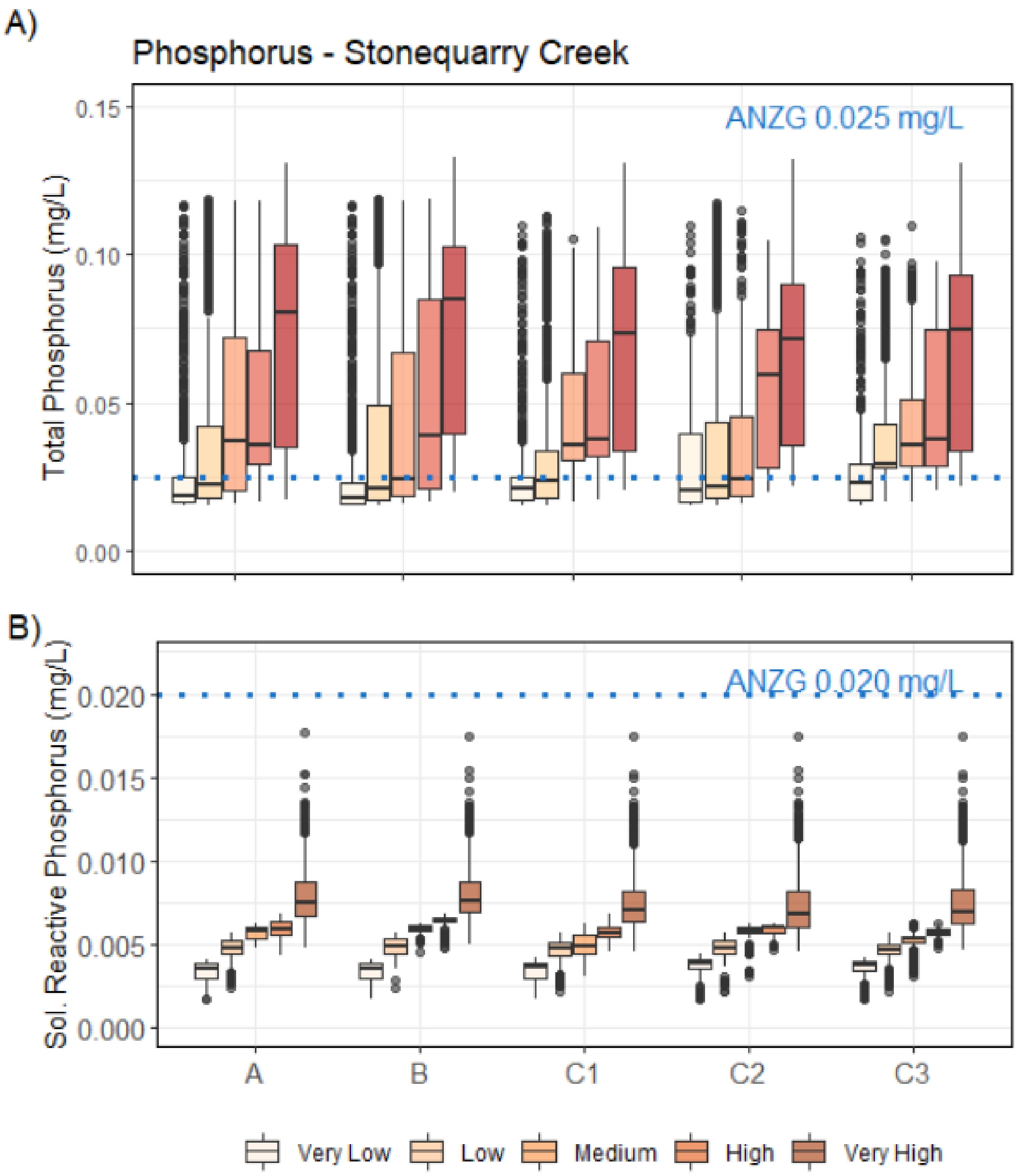

Figure 3-5 Modelled TP and SRP levels for Stonequarry Creek site downstream of the discharge (N911), across scenarios and flow categories

TP trends across flows showed:

- Much like nitrogen species, TP and SRP levels were heavily dependent on localised creek flow fluctuations. However, unlike TN and NOx, phosphorus did not show a distinct difference between scenarios
- Despite increased future modelled inflows, TP in future scenarios did not vary to a high degree above current or compliant conditions. Nonetheless, some differences in median levels were observed:

- If discharge configurations were kept the same (Scenario C1), TP levels would be similar in Stonequarry Creek
- Discharging less frequently but at higher proportions (Scenario C2) would result in lower TP levels in critical lower flow ranges, with an increase beyond baseline (Scenario B) levels in 'High' flows only, by up to 19%
- Discharging in lower flows more frequently and across all flow categories (Scenario C3) would reduce TP levels under higher flow ranges, however would likely compromise water quality under lower flow ranges, marginally above DGV guidelines

With respect to phosphorus guideline exceedances (Table 3-2):

- Upstream site (N911B) exceeded DGV triggers about 49% of the time, and was comparable with the downstream site (N911) during compliant discharges (Scenario B), which exceeded DGVs approximately 50% of the time. These figures provide some context into the baseline/catchment-related exceedances that occur in this tributary, regardless of Picton WRP discharges
- Scenario C1 and Scenario C2 were similar, with a 23 – 29% increase in TP levels at N911, relative to a compliant baseline (Scenario B)
- Scenario C3 (85.6%) TP exceedances were far higher than other future scenarios, likely due to a higher frequency of discharges (ie. discharges occur 87% of the time in Scenario C3, see Table 1-1 in Section 1.5).

Table 3-2 Percent exceedance of TP DGVs at Stonequarry Creek paired sites, across all scenarios

	TP Guideline exceedances at Stonequarry Creek (%)				
	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Site N911B	48.7				
Site N911	58.5	51.3	66.2	63.4	85.6
Change in N911 exceedances relative to Scenario A	-	12% decrease	13% increase	8% increase	46% increase
Change in N911 exceedances relative to Scenario B	14% increase	-	29% increase	23% increase	66% increase

Nepean River

Modelled **total nitrogen and oxidised nitrogen** results for Nepean River were assessed descriptively for broad trends. Flow distinctions have been included in Appendix 6.1.

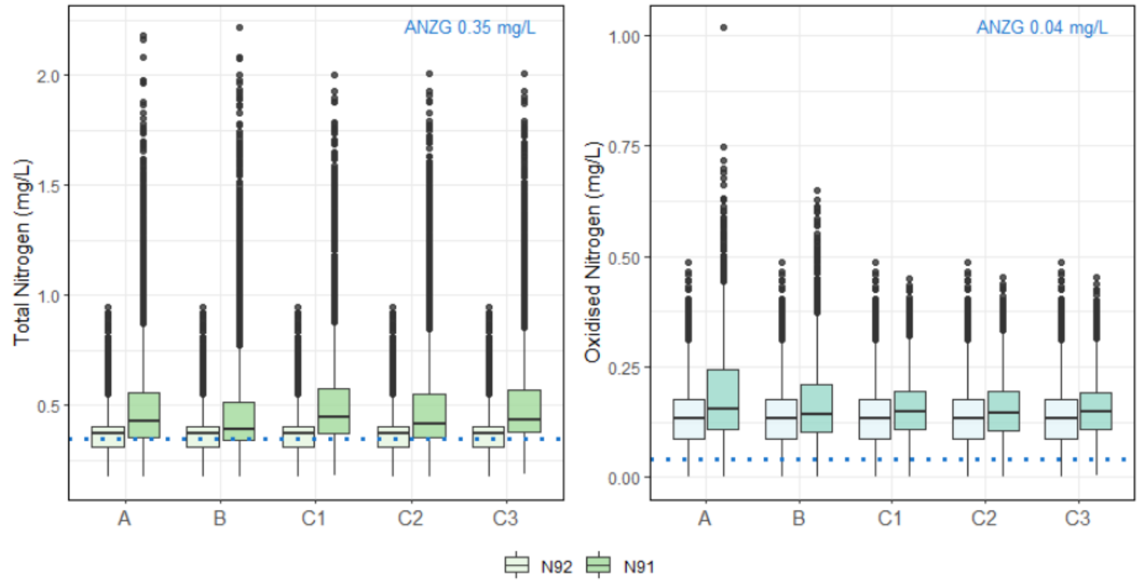

Figure 3-6 Modelled TN and NOx levels for upstream (N92) and downstream (N91) Nepean River sites, across scenarios

TN and NOx trends in the Nepean River showed that:

- The upstream site of the proposed WRP discharge (N92) had a median TN concentration of 0.37 mg/L, marginally above the ANZG (0.35 mg/L) objective, and 19% above the more stringent reference site objectives (N86, 0.31 mg/L) (Figure 3-6)
- All TN levels at the Nepean River site downstream of the discharge point and Stonequarry confluence (N91) were above upstream (N92) values, regardless of scenario. This is consistent with the existing monitoring data. The exceedance can be attributed to various influences, such as catchment inputs entering from the Stonequarry Creek confluence which is between these sites, localised influences, contributions from Picton WRP discharge during lower flows, etc. (see Part A).
- While TN and NOx levels were heavily dependent on flow categories, differences between scenarios at the downstream Nepean River site (N91) were considered marginal due to overlapping boxplots (Appendix 6.1). In addition, the Picton WRP discharge had a marginal to contribution to overall Nepean River flows (Figure 6-3 in Appendix 6.1)
- As with Stonequarry Creek conditions, extreme values of TN and NOx (expressed as upper quartile and outliers in boxplots) appeared to decrease in magnitude in Scenarios C1 to C3 relative to Scenario A at N91, likely due to additional denitrification at Picton WRP
- All future scenarios (C1 to C3) were comparable with Scenario A (existing). They were 5 – 13% above Scenario B (compliant baseline). Of the three future scenarios:

- Scenario C2 had the lowest overall median value, with 0.42 mg/L TN. This was about 6% greater than the compliant baseline (Scenario B), and 2% lower than modelled existing conditions (Scenario A)
- Scenario C1 had the highest median value, at 0.45 mg/L TN. Despite this, the median value only represents a 4% increase above current modelled conditions (Scenario A).

Assessment of TN DGV exceedances (Table 3-3) on the Nepean River showed that:

- Exceedances occurred around 64% of the time at upstream site N92, reflecting baseline catchment conditions and varying land use inputs into the river system
- DGVs were exceeded 76% of the time at N91 in current (Scenario A) conditions, marginally (4%) above compliant baseline conditions (Scenario B)
- Of the future scenarios, Scenario C2 resulted in the least ANZG exceedances overall (76% of the time). These exceedances were equivalent with modelled existing conditions (0.1% above Scenario A) and only marginally higher than preferred baseline conditions (6% above Scenario B)

Table 3-3 Percent exceedance of TN DGVs at Nepean River sites, across all scenarios

	TN Guideline exceedances Nepean River (%)				
	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Site N92	64.4				
Site N91	75.9	72.7	81	76	81.8
Change in N91 exceedances relative to Scenario A	-	4% decrease	7% increase	0.1% increase	8% increase
Change in N91 exceedances relative to Scenario B	4% increase	-	11% increase	6% increase	13% increase

Modelled **total phosphorus and soluble reactive phosphorus** results for Nepean River were assessed descriptively for broad trends. Flow distinctions have been included in Appendix 6.1.

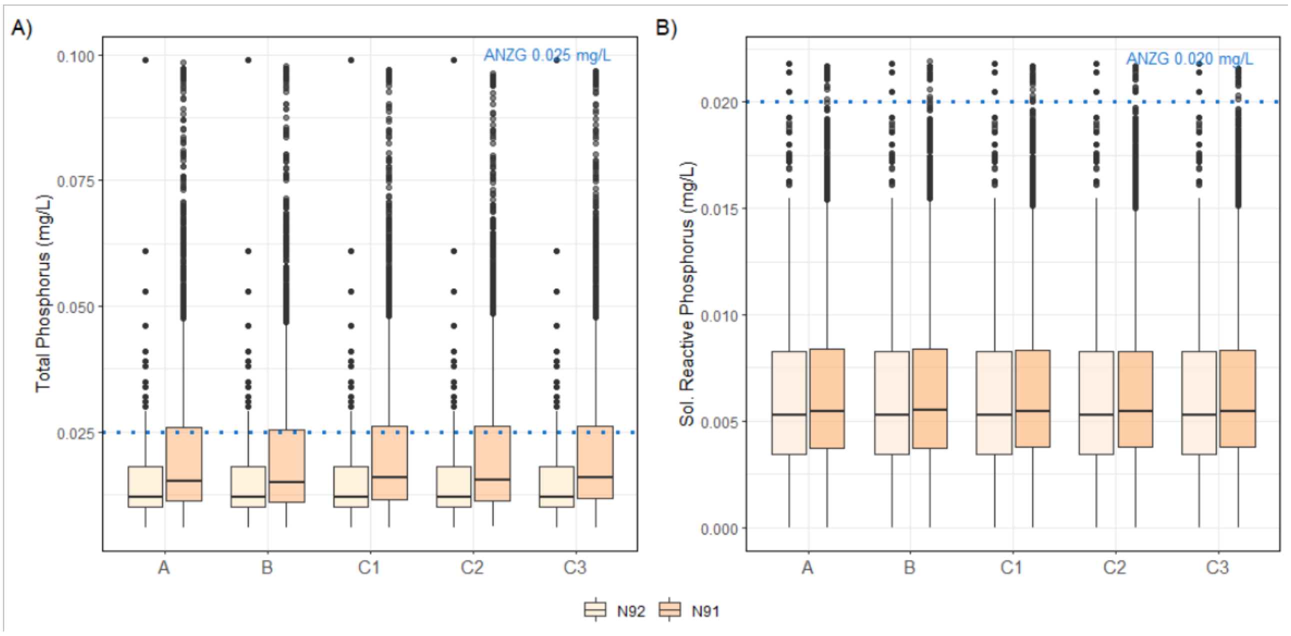

Figure 3-7 Modelled TP and SRP levels for upstream (N92) and downstream (N91) Nepean River sites, across scenarios

TP trends in the Nepean River showed that:

- The Nepean River site upstream of the proposed WRP discharge (N92) had a median TP concentration of 0.012 mg/L, meeting the ANZG (0.025 mg/L) but 20% above the more stringent Nepean River reference site objectives (N86, 0.010 mg/L) (Figure 3-7)
- As with TN, all TP levels at the site downstream of the discharge point and Stonequarry Creek confluence (N91) were elevated relative to the upstream (N92) values, likely due to a range of inputs and influences at this site. Modelled current conditions (Scenario A) at site N91 were around 27% higher than site N92, however these differences were only marginally elevated in comparison to exceedance during compliant conditions (Scenario B, 25%)
- While TP and SRP levels were heavily dependent on creek flow categories, differences between scenarios at the downstream site (N91) were marginal and indistinguishable. (Appendix 6.1)
- All future scenario TP levels were above current and baseline conditions, however not to a large magnitude:
    - Scenario C1 had the highest median values at 0.016 mg/L, likely due to low flows exacerbating the effect of the WRP discharges

    - Scenario C2 had the overall lowest median values at 0.015mg/L, similar to both current (Scenario A) and baseline (Scenario B) conditions
- There was no immediate or obvious difference in SRP between upstream and downstream sites, or across all scenarios

Guideline exceedances for TP showed that:

- TP trends were much less pronounced than TN, as with existing water quality summaries (see Part A, Section 5.1).
- Similar to modelled TN, all scenarios above the baseline conditions (Scenario B) resulted in an increase in DGV exceedances, however only to a marginal and negligible degree (Table 3-4):
    - Scenario C2 had the smallest magnitude of increase (3%) relative to compliant baseline conditions
    - Both Scenario C1 and C3 had a 6% increase in exceedances relative to compliant conditions
    - Changes to TP exceedances at N91 are considered negligible, and are consistent with existing monitoring which suggest minimal impacts to the Nepean River during typical WRP discharges

Table 3-4 Percent exceedance of TP DGVs at Nepean River sites, across all scenarios

	TP Guideline exceedances Nepean River (%)				
	Scenario A	Scenario B	Scenario C1	Scenario C2	Scenario C3
Site N92	12.3				
Site N91	25.7	25.4	26	26.5	26.8
Change in N91 exceedances relative to Scenario A	-	1% decrease	5% increase	3% increase	4% increase
Change in N91 exceedances relative to Scenario B	1% increase	-	6% increase	4% increase	6% increase

3.2 General linear models

- Analyte levels in Stonequarry Creek generally increased with flow. An exception was observed at higher flow categories in future scenarios (C1, C2, and C3), which exhibited reduced downstream NOx levels due to simulation of lower NOx levels in the WRP discharge (enhanced denitrification). NOx reduction in downstream Stonequarry Creek was not observed at lower flow categories.
- There were more pronounced changes in levels of nitrogen species at different scenarios than in phosphorus species
- Overall, Scenario C2 resulted in a lesser change (~20%) to water quality compared to Scenarios C1 and C3 (up to 70%), with respect to baseline scenarios
- Future modelled scenarios generally have a small effect on the Nepean River

A GLM analysis approach was used to compare scenarios at different flow conditions. The GLM used in this analysis is *Y ~ Site x Scenario x Flow*. The factors are described in Section 2.3. The development of GLMs is discussed in finer detail in Appendix 6.2. Briefly, prototypic models were systematically evaluated to determine those that best fit TN, an analyte that is highly sensitive to discharge and flow variations as observed in real monitored data (see Part A). Preliminary analysis showed that categorical 'Discharge' and 'Flow' factors were significant predictors of TN. However, they were highly correlated because discharge depended on creek flow in the modelled scenarios. Therefore, they had confounding effects on TN when combined in one model. Generally, results showed that the impacts of scenarios on water quality were best visualised and estimated using *Y ~ Site x Scenario x Flow*.

Stonequarry Creek

TN levels in upstream (N911B) and downstream (N911) sites in Stonequarry Creek (Figure 3-8) were analysed using the GLM approach described in Section 2.3.

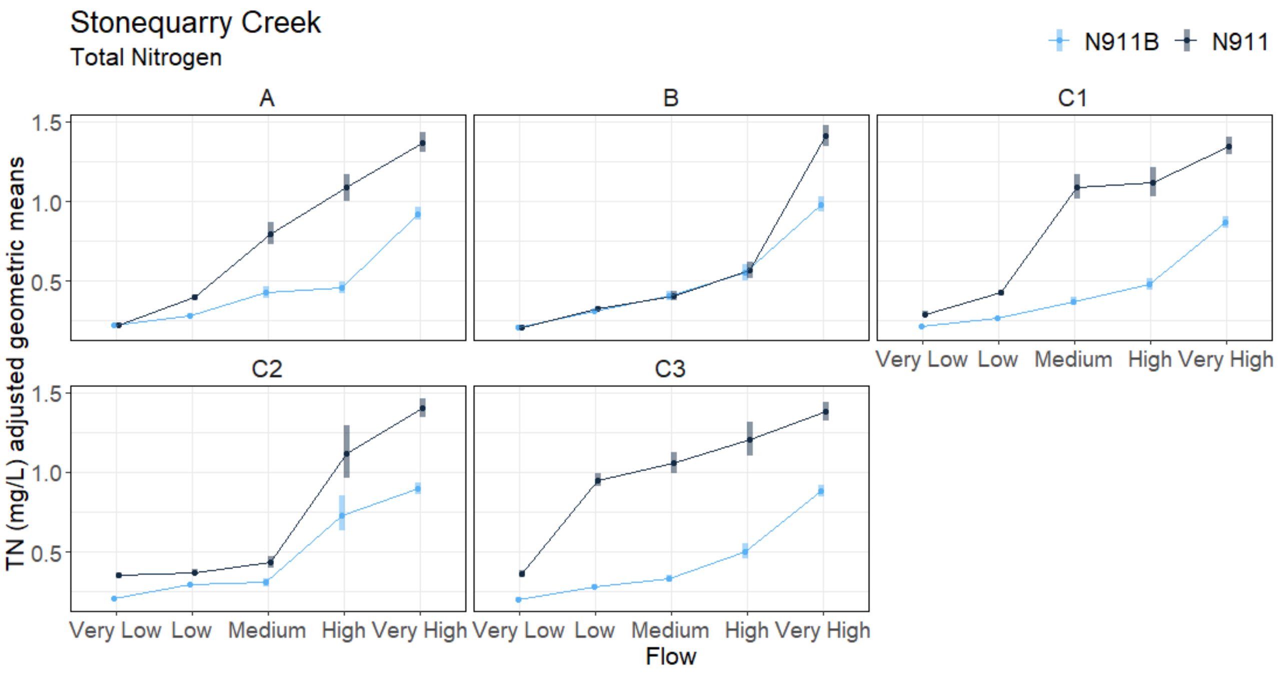

Figure 3-8 Adjusted geometric means of TN levels (back-transformed) in upstream (N911B) and downstream (N911) sites in Stonequarry Creek across flow categories and scenarios

The adjusted geometric means of **total nitrogen and oxidised nitrogen** in Stonequarry Creek show that:

- TN levels increased as creek flow increased. They sharply increased when flow was 'Very High' (Figure 3-8). The extent of increase was similar in the future scenarios (C1, C2, and C3).
- In Scenario A, downstream TN levels were higher than upstream levels by 30-60% during most flow conditions. On the other hand, in Scenario B, upstream and downstream TN were nearly identical for all flow categories except at 'Very High' flow (Figure 3-8). This suggests that increasing the average inflow to Picton WRP (2.7 vs 2.25 ML/day) had drastic effects on downstream nitrogen levels. Given that future inflow is expected to increase further, it is unlikely that a discharge regime that limits impacts to those predicted for Scenario B could be realistically achieved.
- All future scenarios were elevated above baseline conditions at different flow categories. This is consistent with trends seen in descriptive analysis (Section 3.1):
  - Scenario C1's downstream TN levels were relatively elevated during 'Medium' to 'Very High' flows (Figure 3-8)

- Compared to Scenario C1, Scenario C2 maintained lower downstream TN levels at 'Low' to 'Medium' flows. TN only became elevated during 'High' to 'Very High' flows (Figure 3-8)
- Scenario C3's downstream TN levels were relatively high throughout most flow conditions. The is likely due to the frequent discharge across all flow ranges with the treated water with elevated TN concentrations being higher proportion of creek flows relative to the other scenarios in the lower flow categories (Figure 3-3).

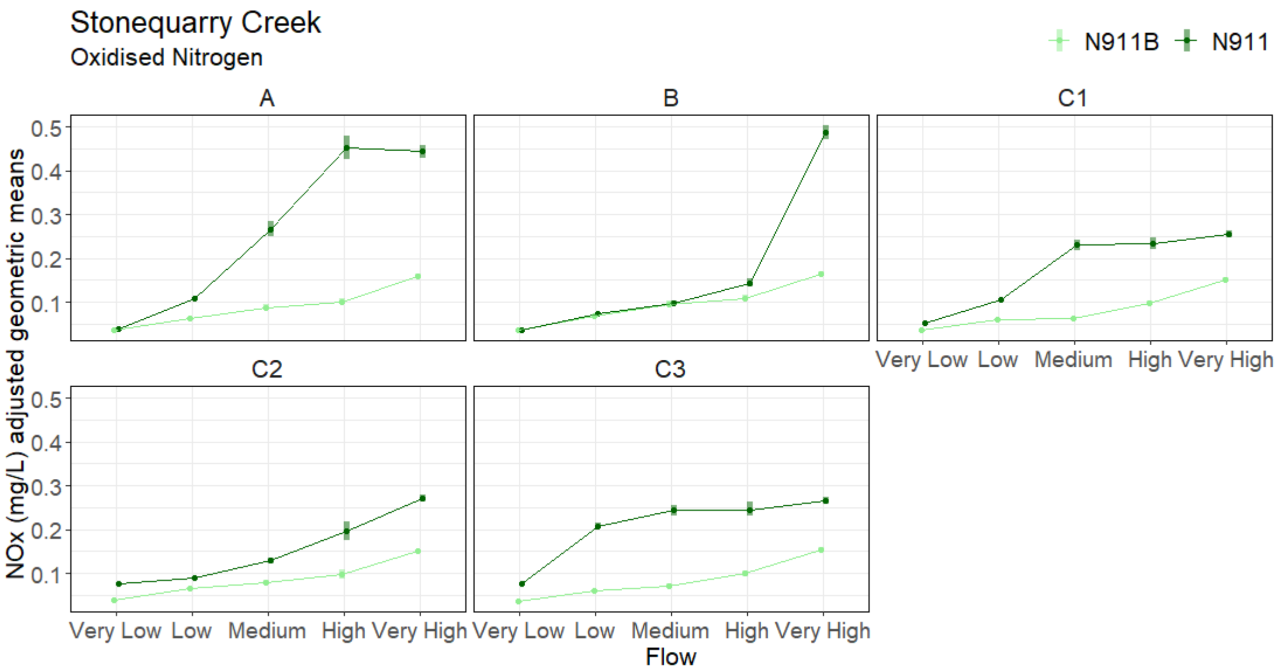

Figure 3-9 Adjusted geometric means of NOx levels (back-transformed) in upstream (N911B) and downstream (N911) sites in Stonequarry Creek across flow categories and scenarios

- NOx levels (Figure 3-9) followed similar trend as TN
- The downstream NOx levels in future scenarios (maximum ~0.25 mg/L) were lower than those in baseline scenarios (maximum ~0.5 mg/L) due to the simulated discharge concentrations with additional denitrification. Of note, these NOx values must be interpreted with caution (Section 2.2)

To determine magnitude of impact of each scenario on study sites, the adjusted TN and NOx geometric means of upstream and downstream sites were compared. The same approach was used on real monitored data (methods discussed in Part A Section 2.3 and Part B Section 2.3). The resulting downstream/upstream (N911/N911B) ratios and confidence intervals are presented in Table 6-9 in Appendix 6.3. To ease visual comparison, the ratios and confidence intervals are also presented in Figure 3-10 and Figure 3-11. Ratios that are close to 1 mean that the downstream and upstream water quality are similar. Higher ratios indicate to greater analyte concentrations downstream relative to the upstream site.

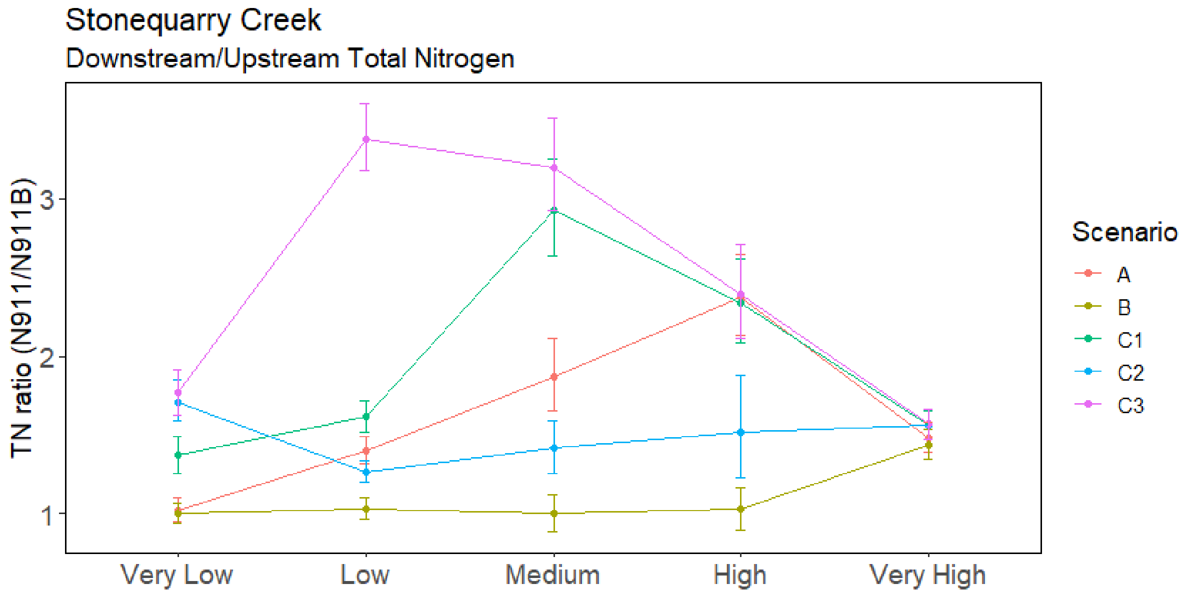

Figure 3-10 Downstream/upstream ratios of TN (adjusted geometric means) in Stonequarry Creek at different creek flow categories

The downstream/upstream TN ratios in Stonequarry Creek show that:

- In Scenario A, TN ratio increased with flow but sharply dropped at ‘Very High’ flow (Figure 3-10) likely due to stormwater runoff influences. This trend is different from GLM outputs of real monitored TN data (see Part A) wherein TN ratios generally decreased with flow regardless of discharge. One reason could be the confounding inputs and exacerbation of pollution at low flows in real monitored data. Another could be the simulated denitrification process that reduced TN in modelled data.
- In Scenario B, the TN ratio was close to 1 under most conditions but increased by about 50% at ‘Very High’ flow. This can be attributed to precautionary discharges at creek flow thresholds above 8 ML/day (Figure 3-10).
- At ‘Very High’ flows, all scenarios had similar TN ratios with overlapping confidence intervals (Figure 3-10) possibly due to the strong influence of stormwater runoff on the upstream site. The geometric means of TN shows that, at ‘Very High’ flows, the upstream site had greater magnitude of increase than the downstream site (Figure 3-8) even though the latter receives a maximum discharge of 14 - 15 ML/day across all scenarios
- In other flow categories:
  - Scenario C1’s TN ratio ranged from 1.4 - 2.9 (Table 6-9 in Appendix 6.3). The highest ratios occurred at ‘Medium’ and ‘High’ flows. This was probably because under these

flows, the WRP discharge proportionate flow (28-34%) of this scenario was relatively high (Figure 3-3).

- Scenario C2 had relatively low TN ratios (1.3 - 1.7) in most flow conditions (Table 6-9 in Appendix 6.3). The ratios were only moderately higher those of Scenario B (~20% increase). This is probably because Scenario C2 discharged less frequently at the lower flow categories when the creek was more susceptible to impacts of effluent.
- Scenario C3's TN ratios were the highest among future scenarios (Figure 3-8). The values indicate that downstream TN was up to 2-3 times greater than upstream levels. Scenario C3's highest TN ratio was observed at 'Low' flow when its WRP discharge proportionate flow (31%) was far higher than those of other scenarios (4 - 13%) (Figure 3-3).

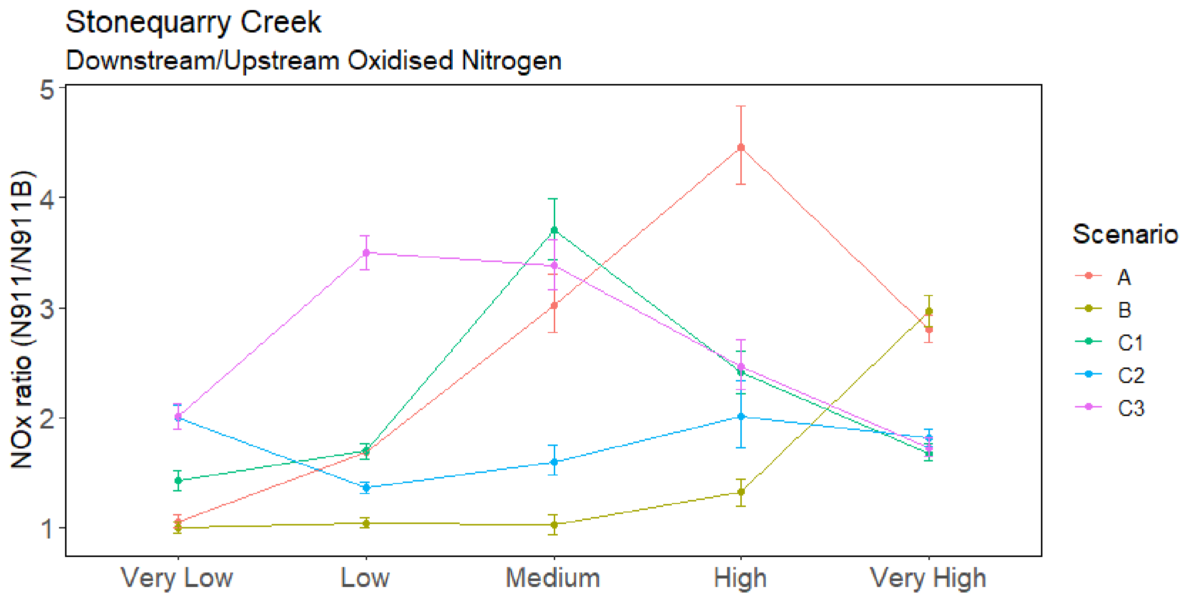

Figure 3-11 Downstream/upstream ratios of NOx (adjusted geometric means) in Stonequarry Creek at different creek flow categories

The downstream/upstream NOx ratios in Stonequarry Creek show that:

- The NOx ratio patterns of Scenario A and B (Figure 3-11) followed their respective TN ratio patterns. Also, like TN, the NOx ratios of these scenarios became similar at 'Very High' flow likely due to stormwater runoff influences
- At higher flow categories, the future scenarios had lower NOx ratios than the baseline Scenario A (Figure 3-11). For instance, the future scenarios' ratios (~2.5) were nearly half of that of Scenario A (~4.5) at 'High' flow (Table 6-9 in Appendix 6.3). This occurred although all future scenarios had much higher WRP discharge proportionate flow (~30%) in

than the baseline scenarios (4-15%) (Figure 3-3), indicating that enhanced denitrification benefitted downstream water quality in Stonequarry Creek.

- However, at lower flow categories, the future scenarios had similar or higher NOx ratio than the baseline scenarios (Figure 3-11). There seems to be a tradeoff in impact related to creek flow conditions. This is most apparent in Scenario C3, which had relatively high NOx ratio at 'Low' flows. This trend mirrored observations in TN, and was likely due to the high proportion of WRP discharge in the creek at this condition (Figure 3-3) .
- Compared with Scenario C1 and C3, Scenario C2 maintained lower NOx ratio at most flow categories (Figure 3-11). This trend mirrored observations in TN.

The **total phosphorus and soluble reactive phosphorus** of upstream (N911B) and downstream (N911) sites in Stonequarry Creek were analysed using the GLM approach.

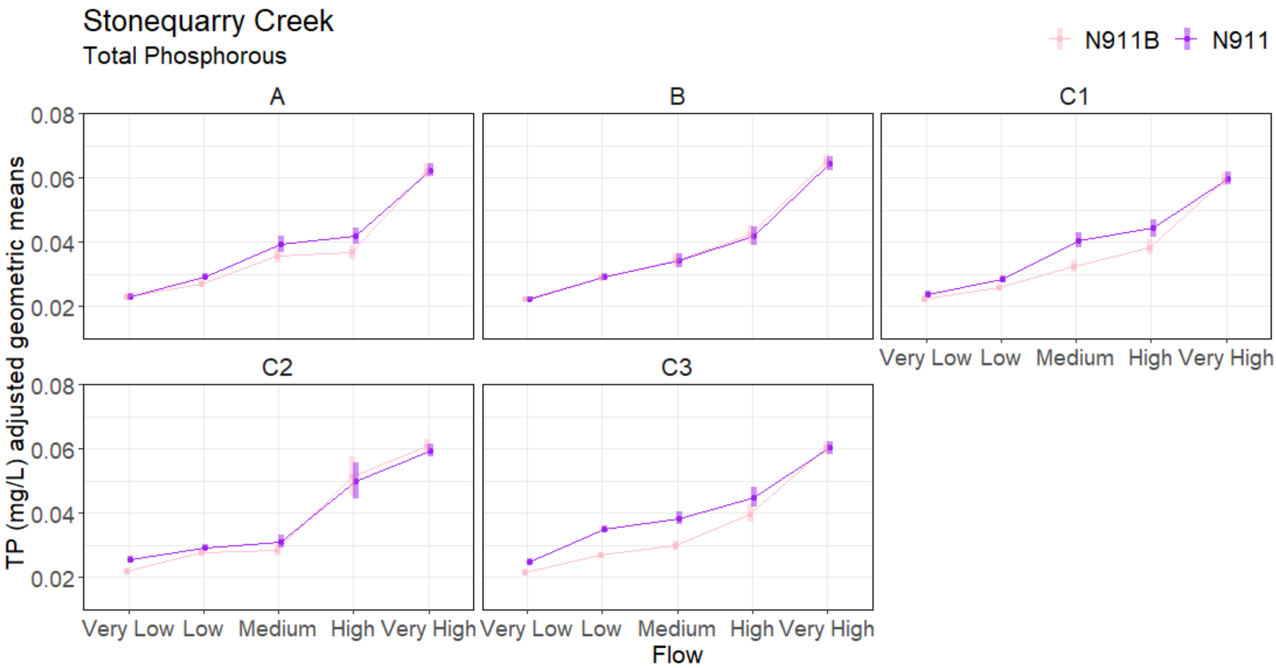

Figure 3-12 Adjusted geometric means of TP levels (back-transformed) in upstream (N911B) and downstream (N911) sites in Stonequarry Creek across flow categories and scenarios

Results of TP and SRP adjusted geometric means on Stonequarry Creek show that:

- In Scenario A and B, upstream and downstream TP levels both sharply increased at 'Very High' flow (Figure 3-12) likely due to stormwater runoff, consistent with TN trends in Stonequarry Creek. This pattern is similar in future scenarios regardless of discharge regime due to the strong influence of stormwater on the predicted TP levels.
- However, unlike TN, there were only smaller differences between upstream and downstream TP levels especially at the higher flow categories (Figure 3-12)

- Like TP, SRP levels in upstream and downstream sites both increased with flow and upstream and downstream sites only had minor differences at a given flow category (See Figure 6-8 in Appendix 6.3). Of note, like those of modelled NOx values, SRP values must be interpreted with caution (Section 2.2)

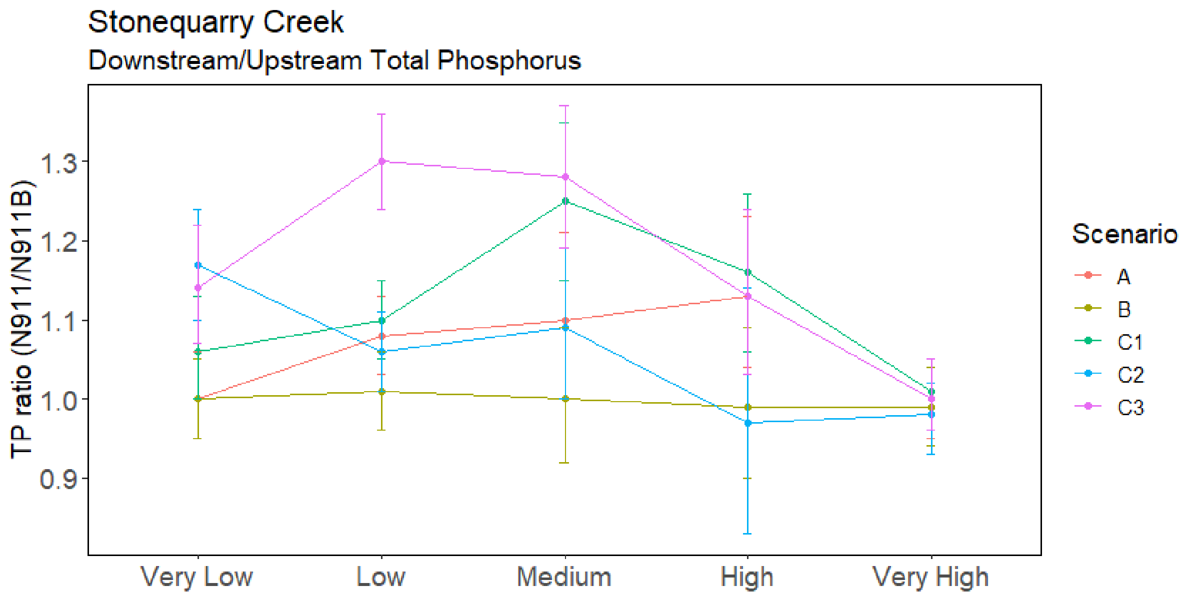

Figure 3-13 Downstream/upstream ratios of TP (adjusted geometric means) in Stonequarry Creek at different creek flow categories

Results of downstream/upstream TP ratios in Stonequarry Creek show that:

- The TP ratios of Scenario A slightly increased as flow increased, and then decreased at 'Very High' flow (Figure 3-13). This trend is comparable to the GLM outputs of existing TP data (see Part A). In Part A, the reduction in TP ratio at the highest flow category was attributed to the strong influence of stormwater runoff throughout the catchment. However, the magnitude of increase in the modelled data (~10% increase) was much lower than the real monitored data (up to 3-fold increase regardless of discharge and flow categories). The difference could be due to WRP process failures resulting TP elevation, stormwater runoff, and other confounding inputs in the real monitored data
- The TP ratios of Scenario B were similar regardless of flow category (Figure 3-13)
- For future scenarios, it was observed that:
  - The TP ratios of Scenario C1 and C3 both ranged from 1.0 - 1.3 (Table 6-10 in Appendix 6.3). The confidence intervals tended to overlap, hence differences in TP between these two scenarios cannot be ascertained. The only exception was observed at 'Low' flow when Scenario C3 discharged more often and had much higher WRP discharge proportionate flow than all other scenarios (Figure 3-3)

- Scenario C2 had relatively low TP ratios (1.0 - 1.1) in most flow conditions (Table 6-10 in Appendix 6.3). These ratios are only slightly higher (~10% increase) than Scenario B.

- Overall, SRP trends closely followed those of TP (See Figure 6-5 in Appendix 6.3), with small changes in TP ratios (~10% increase or decrease) and overlapping confidence intervals. This suggests that upstream and downstream sites across scenarios and flow categories likely have similar SRP levels.

Nepean River

The **total nitrogen and oxidised nitrogen** of upstream (N92) and downstream (N91) sites in Nepean River were analysed using the GLM approach.

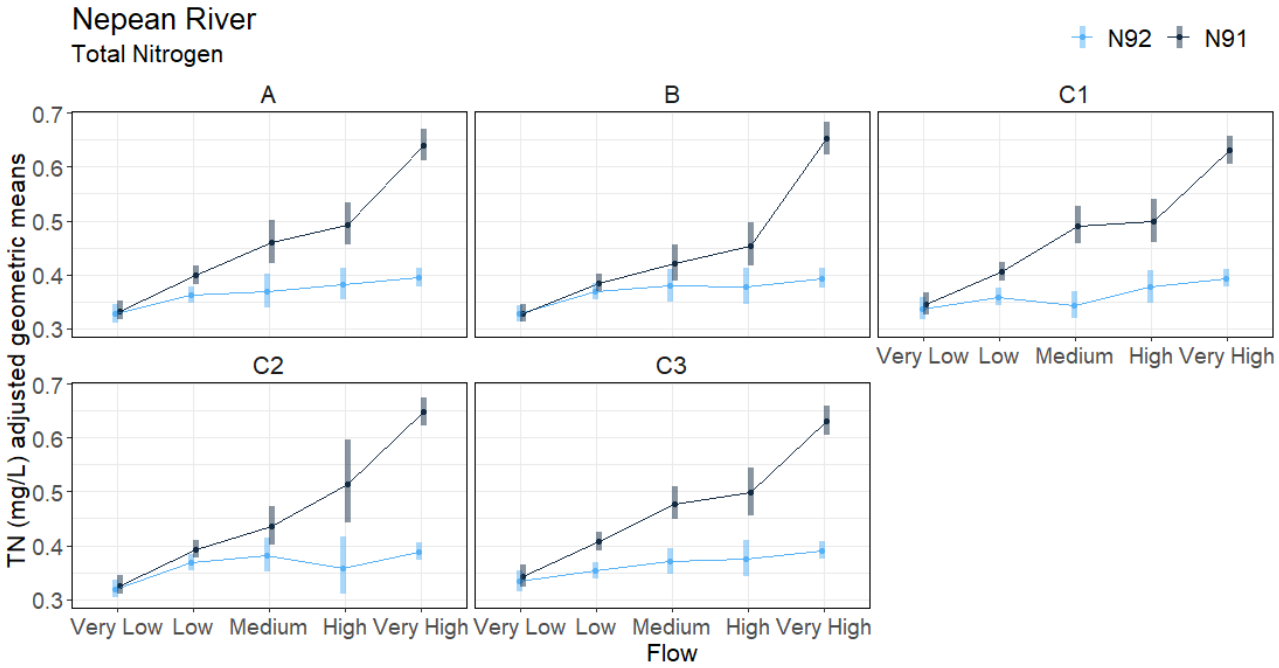

Figure 3-14 Adjusted geometric means of TN levels (back-transformed) in upstream (N92) and downstream (N91) sites in Nepean River across flow categories and scenarios

The TN and NOx adjusted geometric means in Nepean River show that:

- The upstream site (N92) had similar TN range and pattern across all scenarios, and there were only minor variations between scenarios (Figure 3-14)
- Similar to the trend observed in Stonequarry Creek, the TN levels in the downstream site (N91) generally increased with flow (Figure 3-14) with a sharp increase at ‘Very High’ flow, which can be mostly attributed to catchment influences from stormwater runoff
- The future scenarios had comparable downstream TN patterns (Figure 3-14). This indicates that variation in the Picton discharge regime had minimal influence on TN Nepean

River and is consistent with summaries and trends (Section 3.1) as well as existing conditions (see Part A)

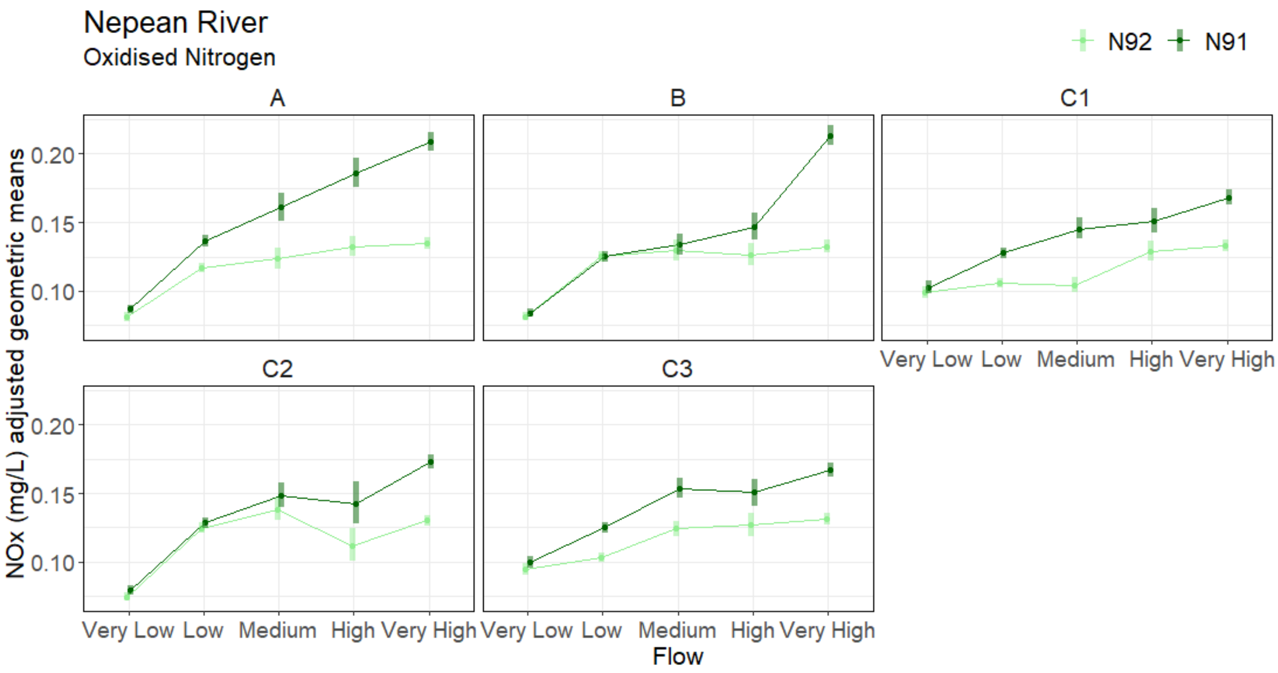

Figure 3-15 Adjusted geometric means of NOx levels (back-transformed) in upstream (N92) and downstream (N91) sites in Nepean River across flow categories and scenarios

- NOx trends mirrored those of TN (Figure 3-16), with influences on flow very apparent and the effect of additional denitrification observed in future modelled scenarios
- The downstream NOx levels in N91 in future scenarios (maximum ~0.17 mg/L) were very similar to baseline scenario levels (maximum ~0.21 mg/L). These concentrations must be interpreted with caution due to data limitations (explained in Section 2.2).

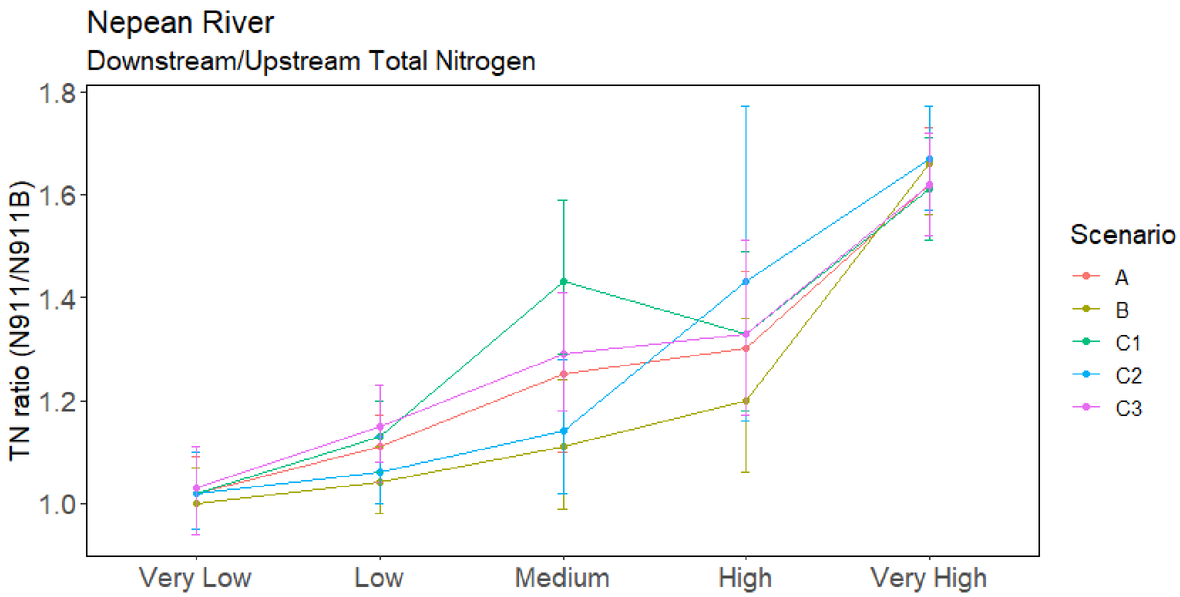

Figure 3-16 Downstream/upstream ratios of TN (adjusted geometric means) in Nepean River at different creek flow categories

Contrasts of downstream/upstream paired sites on Nepean River generally showed that:

- TN ratios of Scenario A increased by around 60% as flow increased from 'Very Low' to 'Very High' (Figure 3-16). This is different from GLM outputs of real monitored data in Nepean River, which did not exhibit a clear flow-dependent pattern (See Part A). The difference can be due to confounding inputs in real monitored data.
- TN ratios of future Scenarios C1 to C3 were similar to those of baseline Scenarios A and B. The overlapping confidence intervals indicate that different scenarios could have similar ratios at a given flow category. This implies that modifying the discharge regimes did not have large effect on Nepean River's downstream TN levels. This is consistent with existing trends (see Part A), which found that there are minimal fluctuations in Nepean River nutrient levels due to Picton WRP.

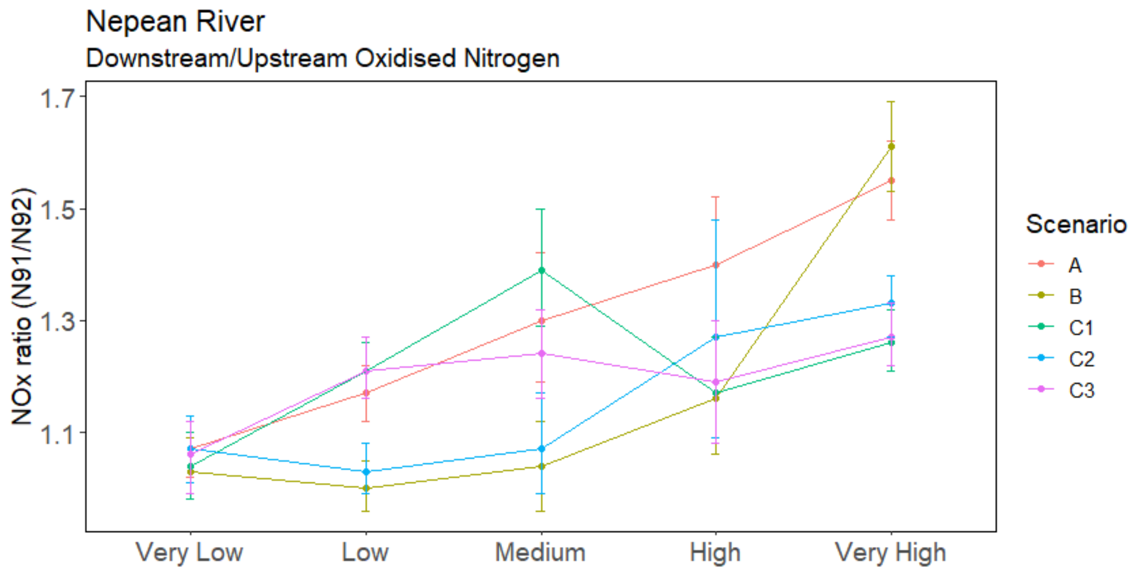

Figure 3-17 Downstream/upstream ratios of NOx (adjusted geometric means) in Nepean River at different creek flow categories

- Overall, enhanced denitrification had some effect on NOx patterns in the Nepean River when flow was 'Very High'. The NOx ratio in Scenario A and B generally increased as flow increased (Figure 3-17). In Scenarios C1 and C3, NOx ratios increased initially increased with flow but dropped at higher flow categories. In Scenario C2, the NOx ratio increased linearly with flow, but the highest NOx ratio was much lower than the baseline Scenarios A and B. The discrepancies among scenarios cannot be ascertained due to overlapping confidence intervals. The exception occurred at 'Very High' flows, where the NOx ratios of all future scenarios were distinctly lower baseline scenarios by approximately 30% (Figure 3-17).

The **total phosphorus and soluble reactive phosphorus** of upstream (N92) and downstream (N91) sites in Nepean River were analysed using the GLM approach. The TP and SRP adjusted geometric means for Nepean River sites indicated that:

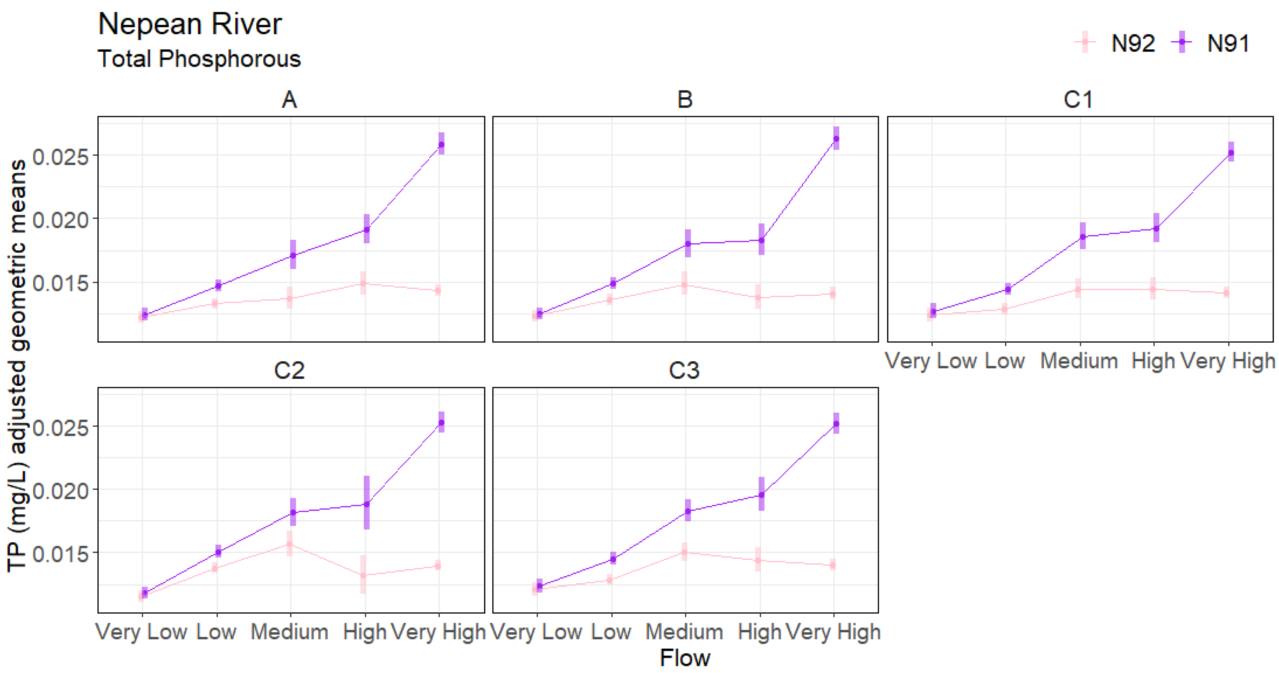

Figure 3-18 Adjusted geometric means of TP of sites upstream (N92) and downstream (N91) in Nepean River across flow categories and scenarios

- There were minor variations in upstream TP levels at site N92 at different flow categories, as seen in descriptive trends (Section 5.1 above)
- On the other hand, the downstream TP levels at site N91 increased with flow with a remarkable increase at 'Very High' flow. This might be due to various inputs to the downstream site including stormwater runoff and discharge.
- The TP levels at site N91 of future scenarios were very similar to those of baseline scenarios across flow categories
- Upstream and downstream SRP levels in Nepean River and likewise exhibited small variations at different flow categories. Like the pattern observed in TP, there was a sharp increase in downstream SRP levels when flow was 'Very High' that was observed at all scenarios (Figure 6-8 in Appendix 6.3).

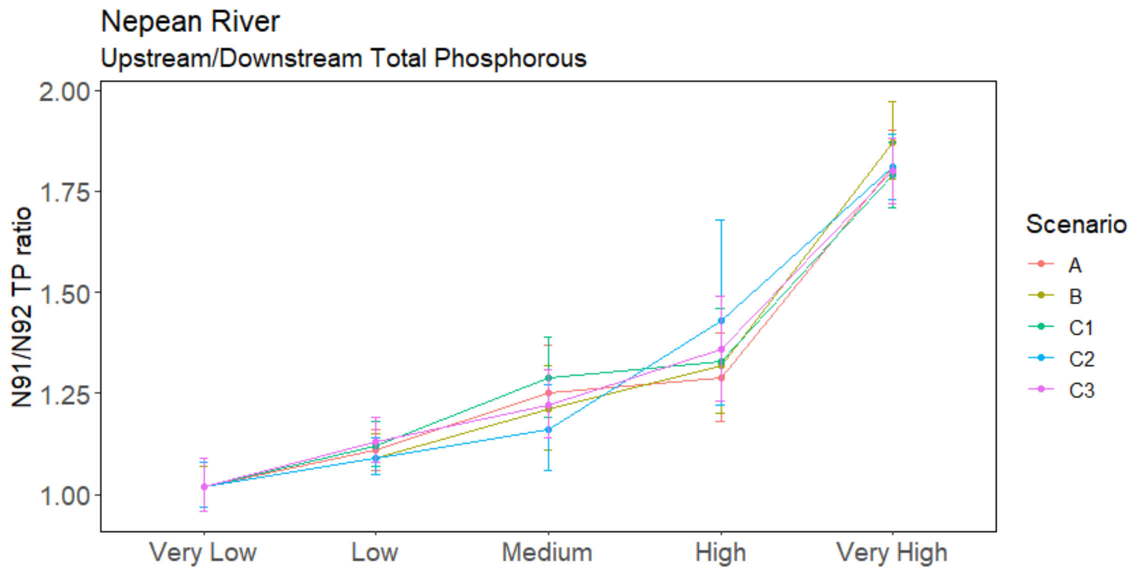

Figure 3-19 Downstream/upstream TN ratios of geometric mean concentrations in Nepean River at different creek flows

Comparisons of the downstream/upstream site pairs in Nepean River (Figure 3-19) showed that:

- The pattern of TP ratios were similar across scenarios (ie, all increased with flow). TP ratio increased by approximately 90% as flow increased from 'Very Low' to 'Very High' irrespective of discharge conditions from the WRP (compliant baseline or future scenarios). Of note, GLM outputs of real monitored TP data in Nepean River did not exhibit a flow-related pattern (See Part A) possibly due to various confounding inputs.
- Much like Stonequarry Creek, while TP is a limiting nutrient in these local waterways, the concentration differences in various scenarios are minimal, and therefore impacts to Nepean River are considered negligible. These patterns are consistent with those observed when analysing current conditions (see Part A).
- Like TP, there was minimal difference in SRP ratio in all scenarios at different flows (Figure 6-9 in Appendix 6.3). The future scenarios apparently had higher SRP ratio (about 10-20% increase) than baseline scenarios at 'Medium' flow. However, the adjusted geometric means were only within a small range (0.005-0.008 mg/L). Hence, the difference is considered minor.

4 Synthesis and conclusions

- Trends observed in Scenario A were relatively consistent with trends in existing monitoring data (Part A). Scenario B outcomes were also considered representative of creek flow conditions under a compliant scenario. Therefore, both Scenarios A and B were deemed suitable as relative baselines for comparison with future scenarios C1 to C3
- Flow was a significant determinant of water quality in all scenarios, with generally higher levels of nutrients associated with higher flows. This is likely due to the confounding effect of stormwater runoff and other catchment inputs
- Consistent with existing data (Part A), TN and NOx played a more significant role in water quality changes when compared with TP and SRP, in all scenarios
- The effect of nutrients was much less pronounced and only marginally different in the Nepean River compared to Stonequarry Creek, in all scenarios
- Overall, Scenario C2 resulted in a lesser change to water quality compared to Scenarios C1 and C3, evidenced by both broad descriptive trends and statistical analysis

Stonequarry Creek

- Nutrient levels generally increased with creek flow. Higher nutrient levels observed during higher flow events was likely confounded effect of stormwater runoff
- Extreme values of both TN and NOx levels decreased in magnitude in Scenarios C1 to C3 relative to existing Scenario A at N911, likely due to modelling of denitrification processes at Picton WRP
- Scenario C2 had similar TN levels to baseline Scenario B in most flow regimes with the exception of 'High' flows. This was due to the effect of the discharges in this flow regime for C2 (discharges when creek flow >5ML/d). Scenario C2's GLM ratios were only moderately higher those of Scenario B (14-20% difference)
- At higher flow categories, GLM outputs showed future scenarios (C1, C2, and C3) had lower NOx levels in downstream Stonequarry Creek relative to baseline scenarios due to simulation of lower NOx in the WRP discharge (enhanced denitrification). However, NOx reduction was not observed at lower flow categories.
- Despite increased future modelled inflows (at 4ML/day), there was only a small change in TP in future scenarios C1 to C3. TP did not increase much above current or compliant conditions. The change in TP ratio due to flow was relatively small (maximum 20% difference in all scenarios)
- Of the future scenarios, Scenario C2 resulted in the least ANZG exceedances equivalent to desired baseline conditions despite the increase in inflows to the WRP

Nepean River

- While TN and NOx levels were heavily dependent on creek flow regimes, differences between scenarios at the downstream site (N911) were marginal and indistinguishable
- Of the future scenarios, Scenario C2 resulted in the least ANZG exceedances equivalent to desired baseline conditions despite the increase in inflows to the WRP
- Scenarios C1 to C3 had comparable downstream TN and NOx patterns. This indicates that variation in the Picton discharge regime had minimal influence on the Nepean River
- Much like Stonequarry Creek, while TP is a limiting nutrient in these local waterways, the concentration differences in various discharges are minimal, and therefore impacts to Nepean River are considered negligible

Recommendations

- Modelled scenario outcomes were not directly comparable to real monitoring data. Therefore, they were primarily used to visualise patterns and estimate *relative changes* in analyte levels (as opposed to absolute values of concentrations). The relative difference between future and baseline scenarios provides useful information to inform further assessments on ecology and waterway values to ensure that Stonequarry Creek and Nepean River waterway health is protected and maintained.
- Further refinement of the Source model to capture additional analytes (eg. ammonia nitrogen, metals, and other potential toxicants) would be helpful in future ecology and waterway values assessments. Additionally, improvement of NOx and SRP estimations is essential to strengthen outcomes.
- More in-depth evaluation of various catchment influences and their effects on nutrient dynamics in Stonequarry Creek and Nepean River must be performed to guide holistic waterway management strategies.

5 References

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6 Appendix

6.1 Summaries and trends

Table 6-1 Summary statistics for Total Nitrogen across sites and scenarios

Total Nitrogen						
Site	Scenario	Min	Median	Mean	Max	Std dev
N911B	A	0.103	0.265	0.727	2.398	0.725
N911B	B	0.103	0.265	0.727	2.398	0.725
N911B	C1	0.103	0.265	0.727	2.398	0.725
N911B	C2	0.103	0.265	0.727	2.398	0.725
N911B	C3	0.103	0.265	0.727	2.398	0.725
N911	A	0.104	0.764	1.007	3.513	0.871
N911	B	0.103	0.397	0.815	2.617	0.791
N911	C1	0.105	0.892	1.016	2.401	0.711
N911	C2	0.104	0.842	0.992	2.419	0.791
N911	C3	0.107	0.985	1.17	2.401	0.622
N92	A	0.175	0.373	0.377	0.945	0.101
N92	B	0.175	0.373	0.377	0.945	0.101
N92	C1	0.175	0.373	0.377	0.945	0.101
N92	C2	0.175	0.373	0.377	0.945	0.101
N92	C3	0.175	0.373	0.377	0.945	0.101
N91	A	0.175	0.426	0.5	2.179	0.258
N91	B	0.175	0.393	0.479	2.216	0.261
N91	C1	0.183	0.445	0.516	2.002	0.248
N91	C2	0.175	0.415	0.504	2.008	0.271
N91	C3	0.187	0.438	0.514	2.008	0.249

Table 6-2 Summary statistics for Oxidised Nitrogen across sites and scenarios

Oxidised Nitrogen						
Site	Scenario	Min	Median	Mean	Max	Std dev
N911B	A	0.013	0.081	0.094	0.571	0.058
N911B	B	0.013	0.081	0.094	0.571	0.058
N911B	C1	0.013	0.081	0.094	0.571	0.058
N911B	C2	0.013	0.081	0.094	0.571	0.058
N911B	C3	0.013	0.081	0.094	0.571	0.058

N911	A	0.013	0.098	0.362	2.797	0.499
N911	B	0.013	0.082	0.195	2.076	0.236
N911	C1	0.013	0.188	0.183	0.572	0.101
N911	C2	0.013	0.101	0.181	0.573	0.133
N911	C3	0.013	0.246	0.224	0.572	0.083
N92	A	<0.001	0.132	0.141	0.487	0.078
N92	B	<0.001	0.132	0.141	0.487	0.078
N92	C1	<0.001	0.132	0.141	0.487	0.078
N92	C2	<0.001	0.132	0.141	0.487	0.078
N92	C3	<0.001	0.132	0.141	0.487	0.078
N91	A	<0.001	0.155	0.181	1.017	0.108
N91	B	<0.001	0.144	0.164	0.65	0.096
N91	C1	0.001	0.148	0.157	0.451	0.073
N91	C2	<0.001	0.145	0.154	0.451	0.077
N91	C3	0.002	0.148	0.156	0.451	0.073

Table 6-3 Summary statistics for Total Phosphorus across sites and scenarios

Total Phosphorus						
Site	Scenario	Min	Median	Mean	Max	Std dev
N911B	A	0.015	0.024	0.047	0.133	0.036
N911B	B	0.015	0.024	0.047	0.133	0.036
N911B	C1	0.015	0.024	0.047	0.133	0.036
N911B	C2	0.015	0.024	0.047	0.133	0.036
N911B	C3	0.015	0.024	0.047	0.133	0.036
N911	A	0.015	0.03	0.047	0.131	0.034
N911	B	0.015	0.026	0.046	0.132	0.034
N911	C1	0.015	0.033	0.046	0.131	0.03
N911	C2	0.015	0.036	0.046	0.132	0.03
N911	C3	0.015	0.033	0.048	0.131	0.028
N92	A	0.006	0.012	0.016	0.099	0.011
N92	B	0.006	0.012	0.016	0.099	0.011
N92	C1	0.006	0.012	0.016	0.099	0.011
N92	C2	0.006	0.012	0.016	0.099	0.011
N92	C3	0.006	0.012	0.016	0.099	0.011
N91	A	0.006	0.015	0.021	0.099	0.015
N91	B	0.006	0.015	0.021	0.098	0.015

N91	C1	0.006	0.016	0.021	0.097	0.015
N91	C2	0.006	0.015	0.021	0.096	0.015
N91	C3	0.006	0.016	0.021	0.097	0.015

Table 6-4 Summary statistics for Soluble Reactive Phosphorus across sites and scenarios

Soluble Reactive Phosphorus						
Site	Scenario	Min	Median	Mean	Max	Std dev
N911B	A	0.002	0.005	0.006	0.018	0.002
N911B	B	0.002	0.005	0.006	0.018	0.002
N911B	C1	0.002	0.005	0.006	0.018	0.002
N911B	C2	0.002	0.005	0.006	0.018	0.002
N911B	C3	0.002	0.005	0.006	0.018	0.002
N911	A	0.002	0.005	0.006	0.018	0.002
N911	B	0.002	0.005	0.006	0.017	0.002
N911	C1	0.002	0.005	0.006	0.018	0.002
N911	C2	0.002	0.005	0.006	0.017	0.002
N911	C3	0.002	0.005	0.006	0.018	0.002
N92	A	<0.002	0.005	0.008	0.066	0.009
N92	B	<0.002	0.005	0.008	0.066	0.009
N92	C1	<0.002	0.005	0.008	0.066	0.009
N92	C2	<0.002	0.005	0.008	0.066	0.009
N92	C3	<0.002	0.005	0.008	0.066	0.009
N91	A	<0.002	0.006	0.008	0.065	0.008
N91	B	<0.002	0.006	0.008	0.065	0.008
N91	C1	<0.002	0.006	0.008	0.065	0.008
N91	C2	<0.002	0.006	0.008	0.064	0.008
N91	C3	<0.002	0.006	0.008	0.064	0.008

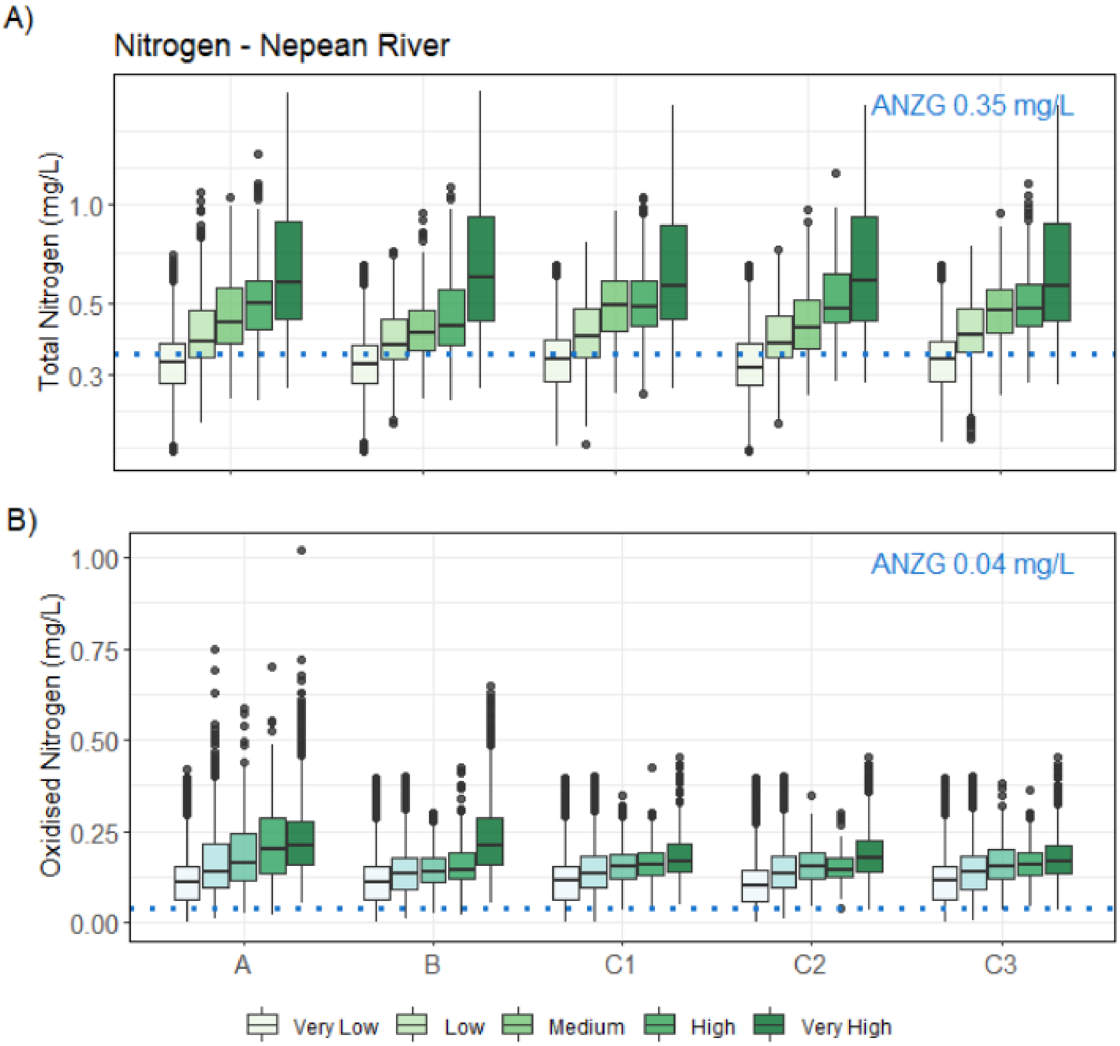

Figure 6-1 Modelled TN and NOx levels for Nepean River site downstream of the discharge (N91), across scenarios and flow categories

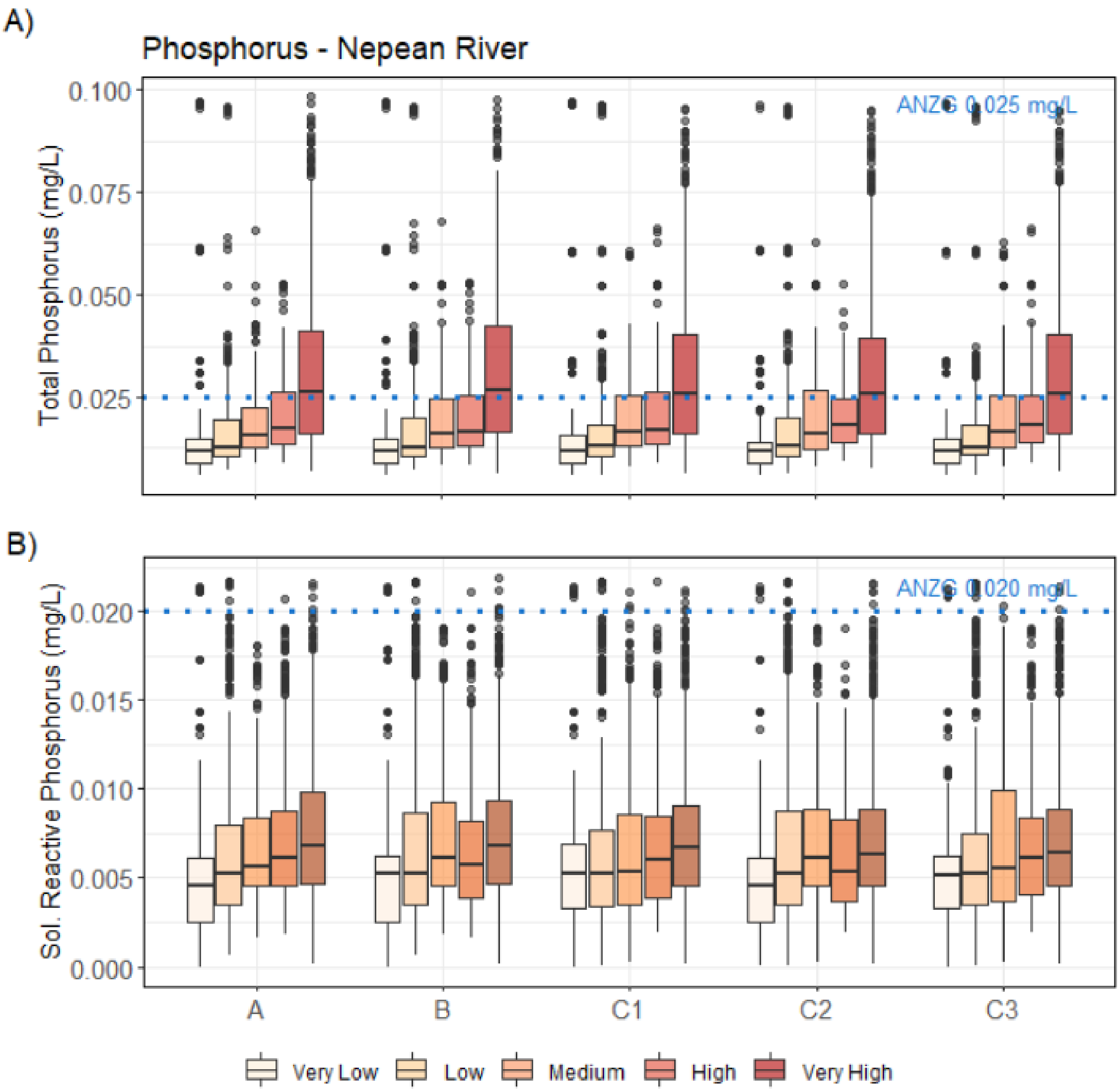

Figure 6-2 Modelled TP and SRP levels for Nepean River site downstream of the discharge (N91), across scenarios and flow categories

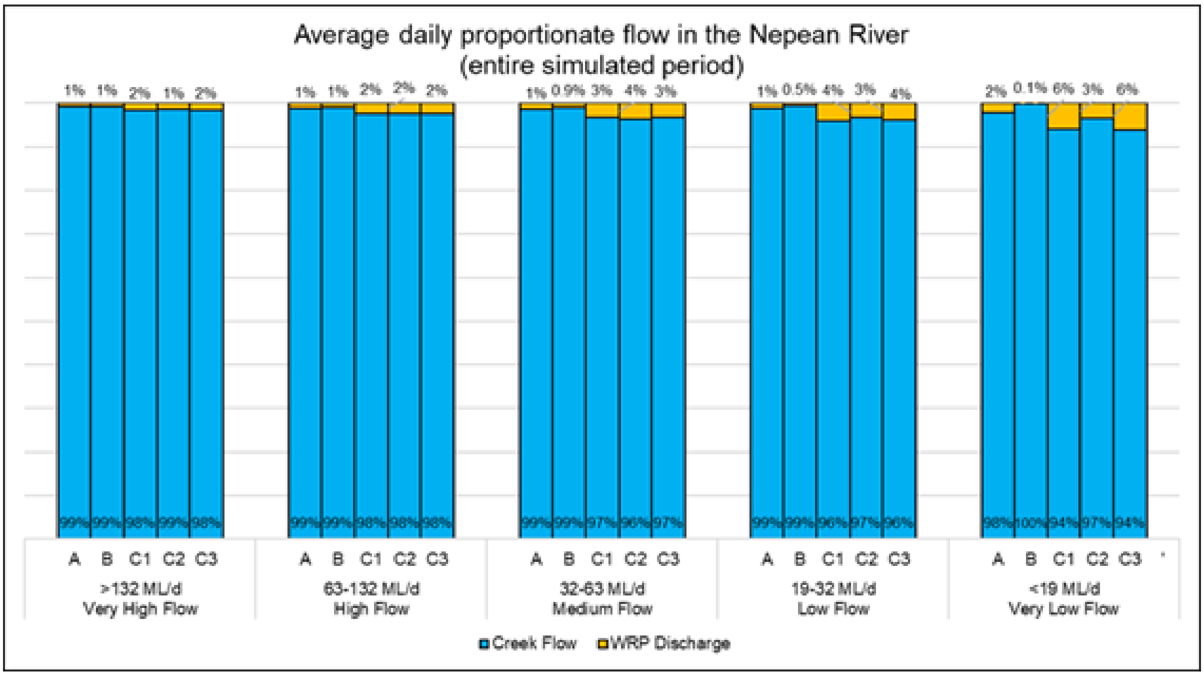

Figure 6-3 Average daily proportionate flow in Nepean River
Source: Aurecon, 2021

6.2 General linear model development

- **Several GLMs were evaluated to determine the most suitable regression model that described TN**
- **'Discharge' and 'Flow' (either continuous or categorical) have confounding impacts on TN given that Picton WRP discharge is triggered by creek flow conditions**
- **Multiple GLMS result in similar output in terms of change in downstream/upstream TN levels**

Several prototypic models were systematically assessed to determine the most appropriate regression model that described water quality. Each model was evaluated for consistency with visualised data descriptions and logical water quality patterns. In this exercise, TN ($\log_{10}$ transformed) was used as the representative analyte because previous analysis showed that TN was sensitive to changes in creek flow and discharges (see Part A).

The following GLMs were explored:

1. *TN ~ Scenario x Site x Flow_Cont*
2. *TN ~ Scenario x Site x Discharge x Flow_Cont*
3. *TN ~ Scenario x Site x Discharge x Flow_Cat*
4. *TN ~ Scenario x Site x Discharge*
5. *TN ~ Scenario x Site x Flow_Cat (preferred)*

The factors used here are identical to those described in Section 2.3, except that in this section, 'Flow_Cont' refers to flow as a continuous factor and 'Flow_Cat' refers to flow as a categorical factor.

GLM #1 (*TN ~ Scenario x Site x Flow_Cont*) produced logically sound arithmetic means on the log scale that were well supported by preliminary descriptive data analysis. The ANOVA results for the type II sums of squares of the GLM show that the three-factor interaction was significant ($p<0.01$) supporting the conclusion that the relationships between flow and site differed between scenarios (Table 6-5).

Table 6-5 ANOVA (Type II) of the GLM *TN ~ Scenario x Site x Flow_Cont*

```
Anova Table (Type II tests)

Response: log10(TN)
                    Sum Sq     Df   F value    Pr(>F)    
Scenario              38.7      4   73.0509 < 2.2e-16 ***
Site                3198.5      5 4835.9318 < 2.2e-16 ***
Flow                  13.0      1   98.0217 < 2.2e-16 ***
Scenario:Site        147.8     20   55.8649 < 2.2e-16 ***
Scenario:Flow          0.1      4    0.2559    0.9062    
Site:Flow            762.2      5 1152.4266 < 2.2e-16 ***
Scenario:Site:Flow    10.8     20    4.0836 2.058e-09 ***
Residuals          14127.5 106800                        
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

GLM #2 (*TN ~ Scenario x Site x Discharge x Flow_Cont*) had non-realistic outputs, thus it was rejected. In this model, the adjusted TN means downstream of Picton WRP *decreased* during discharge (data not shown here) – a pattern that was neither realistic nor supported by arithmetic means.

GLM #3 (*TN ~ Scenario x Site x Discharge x Flow_Cat*) was evaluated to determine if categorising creek flow would facilitate the analysis of TN data during discharge/no discharge conditions. Due to the absence of 'Discharge' data at certain 'Flow_Cat', adjusted geometric means across all categories could not be calculated (data not shown here). Therefore, GLM#3 was not practical for the purpose of this study.

Because of their confounding effects across the scenarios, 'Discharge' and 'Flow_Cat' could not be combined in a single model. The influence of discharge on TN ignoring flow was evaluated separately using GLM #4 (*TN ~ Scenario x Discharge*). The ANOVA of the GLM showed that all factors and interactions were significant ($p<0.01$), and that 'Site' and 'Discharge' are major contributors to TN given that they have the largest sum of squares ().

Table 6-6 ANOVA (Type II) of the GLM #4 (*TN ~ Scenario x Site x Discharge*)

```
Anova Table (Type II tests)

Response: log10(TN)
                         Sum Sq     Df   F value    Pr(>F)    
Scenario                  177.6      4   409.461 < 2.2e-16 ***
Site                     3185.6      5  5877.272 < 2.2e-16 ***
Discharge                2139.4      1 19735.299 < 2.2e-16 ***
Scenario:Site              81.1     20    37.404 < 2.2e-16 ***
Scenario:Discharge         32.7      4    75.306 < 2.2e-16 ***
Site:Discharge           1125.6      5  2076.668 < 2.2e-16 ***
Scenario:Site:Discharge    38.2     20    17.626 < 2.2e-16 ***
Residuals               11577.7 106800                        
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

GLM #4 further revealed that during 'No Discharge', upstream (N911B) and downstream (N911) adjusted TN means were identical (Figure 6-4). During 'Discharge', the upstream TN levels varied at different scenarios. This was consistent with preliminary observations (Section X.X). Furthermore, during "'Discharge', downstream TN levels increased.

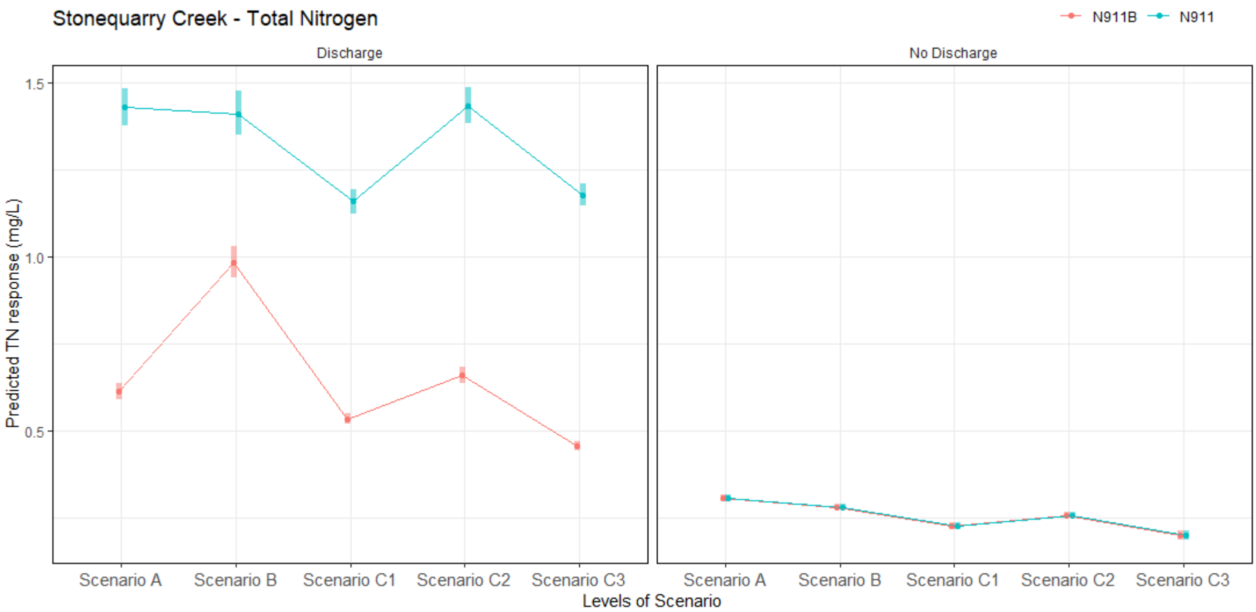

Figure 6-4 Adjusted geometric means of TN of GLM #4 (*TN ~ Scenario x Site x Discharge*)

The magnitude of increase in TN during 'Discharge' was determined by assessing N911B/N911 ratio (Table 6-7). Results show that relative to the compliant Scenario B, TN downstream in Scenarios A to C3. Among these scenarios, C3 has the greatest increase in TN downstream. This pattern mirrors the outputs obtained from GLM #4 (discussed in greater detail in Section 3.2).

Table 6-7 Analysis of GLM #4 (*TN ~ Scenario x Discharge*)

Discharge Category	Scenario	N911/N911B ratio	P
Discharge	A	2.33 (2.21, 2.46)	<0.01
	B	1.43 (1.35, 1.53)	<0.01
	C1	2.17 (2.08, 2.26)	<0.01
	C2	2.17 (2.06, 2.28)	<0.01
	C3	2.58 (2.48, 2.68)	<0.01
No Discharge	A	1.00 (0.95, 1.05)	1
	B	1.00 (0.96, 1.04)	1
	C1	1.00 (0.94, 1.07)	1
	C2	1.00 (0.95, 1.05)	1
	C3	1.00 (0.91, 1.10)	1

To better capture low flows and to reflect the flow categories in the GLM analysis, ‘Flow_Cat’ (df=4), GLM #5 (*TN ~ Scenario x Site x Flow_Cat*) was evaluated. The ANOVA results for the type II sums of squares of the GLM show that the three-factor interaction was significant ($p<0.01$) (Table 6-5). It also shows that ‘Flow_Cat’ and ‘Site’ are major contributors, like ‘Discharge’ and ‘Site’ in GLM #4, further providing evidence of possible confounding effects between ‘Discharge’ and ‘Flow_Cat’. More importantly, GLM #5, also produced logically sound arithmetic means that were well supported by preliminary descriptive data analysis. Like GLM #1 and GLM #4, GLM #5 shows that Scenario C3 has the greatest increase in TN downstream. The fact that different GLMs with varying combinations of “Discharge” and “Flow” factors all result in similar TN patterns show that these two factors are highly correlated or confounded. Moreover, this shows that multiple GLMs suitably explain TN patterns and they can be used for statistical analysis. For the purpose of this study, GLM #5 was primarily used because it clearly showed differences among Scenarios (which is the primary objective of the analysis) at different flow categories.

Table 6-8 ANOVA (Type II) of the GLM #5 (*TN ~ Scenario x Site x Flow_Cat*)

```
Anova Table (Type II tests)

Response: log10(TN)
                     Sum Sq     Df  F value    Pr(>F)    
Scenario                9.7      4   23.841 < 2.2e-16 ***
Site               3185.6        5 6295.145 < 2.2e-16 ***
FlowC              3017.3        4 7453.118 < 2.2e-16 ***
Scenario:Site       128.8       20   63.617 < 2.2e-16 ***
Scenario:FlowC       34.2       16   21.134 < 2.2e-16 ***
Site:FlowC          937.2       20  462.984 < 2.2e-16 ***
Scenario:Site:FlowC 124.8       80   15.418 < 2.2e-16 ***
Residuals         10800.0 106710                         
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

6.3 Supplementary GLM analysis

Stonequarry Creek

<u>NOx/TN</u>

Table 6-9 Comparisons of adjusted geometrics mean concentrations of TN and NOx upstream (N911B) and downstream (N911) of Stonequarry Creek

Stonequarry Creek					
Scenario	Flow Category	TN ratios (N911/N911B)	P	NOx ratios (N911/N911B)	P
A	Very Low	1.02 (0.95, 1.10)	0.565	1.05 (1.00, 1.11)	0.06
	Low	1.40 (1.32, 1.49)	<0.01	1.69 (1.62, 1.77)	<0.01
	Medium	1.87 (1.65, 2.11)	<0.01	3.02 (2.77, 3.30)	<0.01
	High	2.38 (2.13, 2.65)	<0.01	4.46 (4.12, 4.83)	<0.01
	Very High	1.48 (1.39, 1.58)	<0.01	2.80 (2.68, 2.93)	<0.01
B	Very Low	1.00 (0.94, 1.07)	0.976	1.00 (0.95, 1.05)	0.941
	Low	1.03 (0.97, 1.10)	0.285	1.04 (1.00, 1.09)	0.051
	Medium	1.00 (0.89, 1.12)	0.982	1.02 (0.94, 1.11)	0.619
	High	1.03 (0.90, 1.17)	0.682	1.32 (1.20, 1.44)	<0.01
	Very High	1.44 (1.35, 1.54)	<0.01	2.97 (2.83, 3.11)	<0.01
C1	Very Low	1.37 (1.26, 1.49)	<0.01	1.43 (1.34, 1.52)	<0.01
	Low	1.62 (1.52, 1.72)	<0.01	1.70 (1.62, 1.77)	<0.01
	Medium	2.93 (2.64, 3.25)	<0.01	3.71 (3.44, 3.99)	<0.01
	High	2.34 (2.09, 2.62)	<0.01	2.41 (2.22, 2.61)	<0.01
	Very High	1.56 (1.47, 1.65)	<0.01	1.68 (1.61, 1.76)	<0.01
C2	Very Low	1.71 (1.59, 1.85)	<0.01	2.00 (1.90, 2.12)	<0.01
	Low	1.27 (1.20, 1.34)	<0.01	1.36 (1.31, 1.42)	<0.01
	Medium	1.42 (1.26, 1.59)	<0.01	1.60 (1.48, 1.75)	<0.01
	High	1.52 (1.23, 1.88)	<0.01	2.01 (1.73, 2.34)	<0.01
	Very High	1.56 (1.47, 1.66)	<0.01	1.81 (1.74, 1.89)	<0.01
C3	Very Low	1.77 (1.63, 1.92)	<0.01	2.01 (1.89, 2.13)	<0.01
	Low	3.38 (3.18, 3.60)	<0.01	3.50 (3.34, 3.66)	<0.01
	Medium	3.20 (2.93, 3.51)	<0.01	3.39 (3.17, 3.62)	<0.01
	High	2.39 (2.11, 2.71)	<0.01	2.47 (2.26, 2.71)	<0.01
	Very High	1.57 (1.47, 1.66)	<0.01	1.73 (1.65, 1.81)	<0.01

Other observations on TN and NOx in Stonequarry Creek are:

- Scenario C1's downstream TN (1.0-1.3 mg/L) and NOx (0.23-0.25 mg/L) were relatively elevated during 'Medium' to 'Very High' flows. The difference between upstream and downstream TN levels during this period ranged from 30-60% for TN and 40-70% for NOx (Table 6-9). Generally, in this scenario, greater downstream/upstream discrepancy occurred at moderate flows

- Unlike Scenario C1, Scenario C2 maintained low downstream NOx (0.07 to 0.1 mg/L) levels at the lower flow categories. Scenario C2's downstream nitrogen levels only became elevated (0.2-0.3 mg/L for NOx) at 'High' to 'Very High' flows. During this period, downstream/upstream difference for NOx was about 44-50%
- Scenario C3's NOx (0.2-0.3 mg/L) were relatively high throughout most flow conditions ('Low' to 'Very High'). Moreover, compared to other scenarios, the downstream/upstream difference was remarkably high (40-70% for NOx) especially at the lower creek flows (Table 6-9)

SRP

Generally, like TP, there was minimal change (approximately 5% increase/decrease) in downstream SRP in Stonequarry Creek.

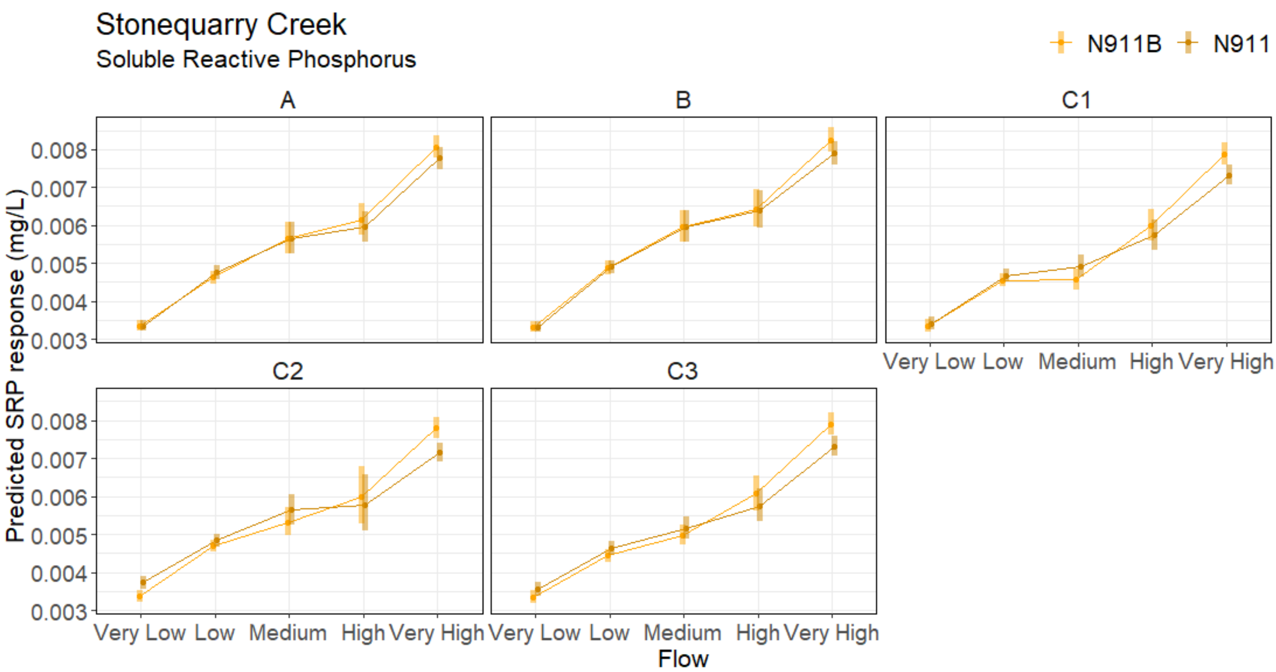

Figure 6-5 Adjusted geometric means of SRP in upstream (N911B) and downstream (N911) Stonequarry Creek across flow categories and scenarios

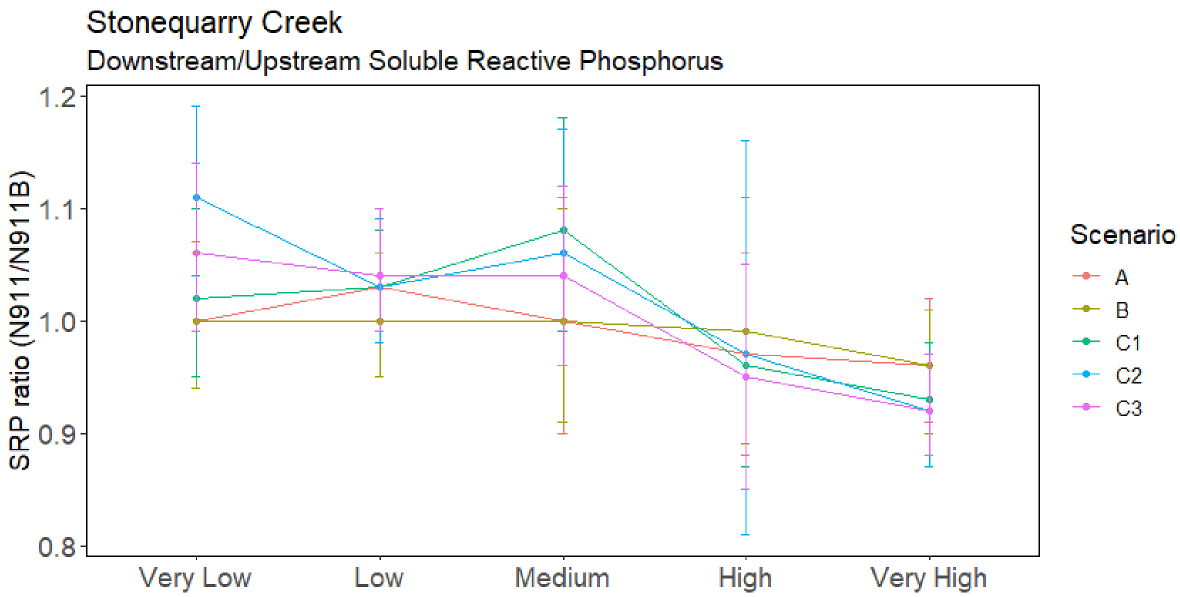

Figure 6-6 Downstream/upstream SRP ratios of geometric mean concentrations in Stonequarry Creek at different creek flow categories

Table 6-10 Comparisons of adjusted geometrics mean concentrations of TP and SRP upstream (N911B) and downstream (N911) of Stonequarry Creek

Stonequarry Creek					
Scenario	Flow Category	TP ratios (N911/N911B)	P	SRP ratios (N911/N911B)	P
A	Very Low	1.00 (0.95, 1.06)	0.94	1.00 (0.94, 1.07)	0.97
	Low	1.08 (1.03, 1.13)	<0.01	1.03 (0.98, 1.08)	0.27
	Medium	1.10 (1.00, 1.21)	0.043	1.00 (0.90, 1.11)	0.99
	High	1.13 (1.04, 1.23)	<0.01	0.97 (0.88, 1.06)	0.49
	Very High	1.00 (0.95, 1.05)	0.94	0.96 (0.91, 1.02)	0.16
B	Very Low	1.00 (0.95, 1.05)	0.99	1.00 (0.94, 1.06)	0.99
	Low	1.01 (0.96, 1.06)	0.71	1.00 (0.95, 1.06)	0.91
	Medium	1.00 (0.92, 1.09)	0.99	1.00 (0.91, 1.10)	0.99
	High	0.99 (0.90, 1.09)	0.86	0.99 (0.89, 1.11)	0.93
	Very High	0.99 (0.94, 1.04)	0.67	0.96 (0.90, 1.01)	0.12
C1	Very Low	1.06 (1.00, 1.13)	0.07	1.02 (0.95, 1.10)	0.59
	Low	1.10 (1.05, 1.15)	<0.01	1.03 (0.98, 1.08)	0.30
	Medium	1.25 (1.15, 1.35)	<0.01	1.08 (0.99, 1.18)	0.09
	High	1.16 (1.06, 1.26)	<0.01	0.96 (0.87, 1.05)	0.37
	Very High	1.01 (0.96, 1.05)	0.80	0.93 (0.88, 0.98)	<0.01
C2	Very Low	1.17 (1.10, 1.24)	<0.01	1.11 (1.04, 1.19)	<0.01
	Low	1.06 (1.01, 1.11)	0.01	1.03 (0.98, 1.09)	0.20
	Medium	1.09 (1.00, 1.19)	0.05	1.06 (0.96, 1.17)	0.25
	High	0.97 (0.83, 1.14)	0.72	0.97 (0.81, 1.16)	0.70

	Very High	0.98 (0.93, 1.02)	0.32	0.92 (0.87, 0.96)	<0.01
C3	Very Low	1.14 (1.07, 1.22)	<0.01	1.06 (0.99, 1.14)	0.09
	Low	1.30 (1.24, 1.36)	<0.01	1.04 (0.99, 1.10)	0.12
	Medium	1.28 (1.19, 1.37)	<0.01	1.04 (0.96, 1.12)	0.36
	High	1.13 (1.03, 1.24)	0.01	0.95 (0.85, 1.05)	0.32
	Very High	1.00 (0.96, 1.05)	0.99	0.92 (0.88, 0.97)	<0.01

Nepean River

NOx

Table 6-11 Comparisons of adjusted geometrics mean concentrations of TN and NOx upstream (N92) and downstream (N91) of Nepean River

Nepean River					
Scenario	Flow Category	TN ratios (N91/N92)	P	NOx ratios (N91/N92)	P
A	Very Low	1.02 (0.94, 1.09)	0.68	1.07 (1.02, 1.13)	0.01
	Low	1.11 (1.04, 1.17)	<0.01	1.17 (1.12, 1.22)	<0.01
	Medium	1.25 (1.10, 1.41)	<0.01	1.30 (1.19, 1.42)	<0.01
	High	1.30 (1.16, 1.45)	<0.01	1.40 (1.30, 1.52)	<0.01
	Very High	1.62 (1.52, 1.73)	<0.01	1.55 (1.48, 1.62)	<0.01
B	Very Low	1.00 (0.94, 1.07)	0.91	1.03 (0.98, 1.09)	0.18
	Low	1.04 (0.98, 1.11)	0.17	1.00 (0.96, 1.05)	0.96
	Medium	1.11 (0.99, 1.24)	0.07	1.04 (0.96, 1.12)	0.39
	High	1.20 (1.06, 1.36)	<0.01	1.16 (1.06, 1.27)	<0.01
	Very High	1.66 (1.56, 1.77)	<0.01	1.61 (1.53, 1.69)	<0.01
C1	Very Low	1.02 (0.94, 1.11)	0.58	1.04 (0.98, 1.10)	0.23
	Low	1.13 (1.06, 1.20)	<0.01	1.21 (1.16, 1.26)	<0.01
	Medium	1.43 (1.29, 1.59)	<0.01	1.39 (1.29, 1.50)	<0.01
	High	1.33 (1.18, 1.49)	<0.01	1.17 (1.08, 1.27)	<0.01
	Very High	1.61 (1.51, 1.71)	<0.01	1.26 (1.21, 1.32)	<0.01
C2	Very Low	1.02 (0.95, 1.10)	0.615	1.07 (1.01, 1.13)	0.02
	Low	1.06 (1.00, 1.13)	0.038	1.03 (0.99, 1.08)	0.14
	Medium	1.14 (1.02, 1.28)	0.025	1.07 (0.99, 1.17)	0.10
	High	1.43 (1.16, 1.77)	<0.01	1.27 (1.09, 1.48)	<0.01
	Very High	1.67 (1.57, 1.77)	<0.01	1.33 (1.27, 1.38)	<0.01
C3	Very Low	1.03 (0.94, 1.11)	0.539	1.06 (0.99, 1.12)	0.08
	Low	1.15 (1.08, 1.23)	<0.01	1.21 (1.16, 1.27)	<0.01
	Medium	1.29 (1.18, 1.41)	<0.01	1.24 (1.16, 1.32)	<0.01
	High	1.33 (1.17, 1.51)	<0.01	1.19 (1.08, 1.30)	<0.01
	Very High	1.62 (1.52, 1.72)	<0.01	1.27 (1.22, 1.33)	<0.01

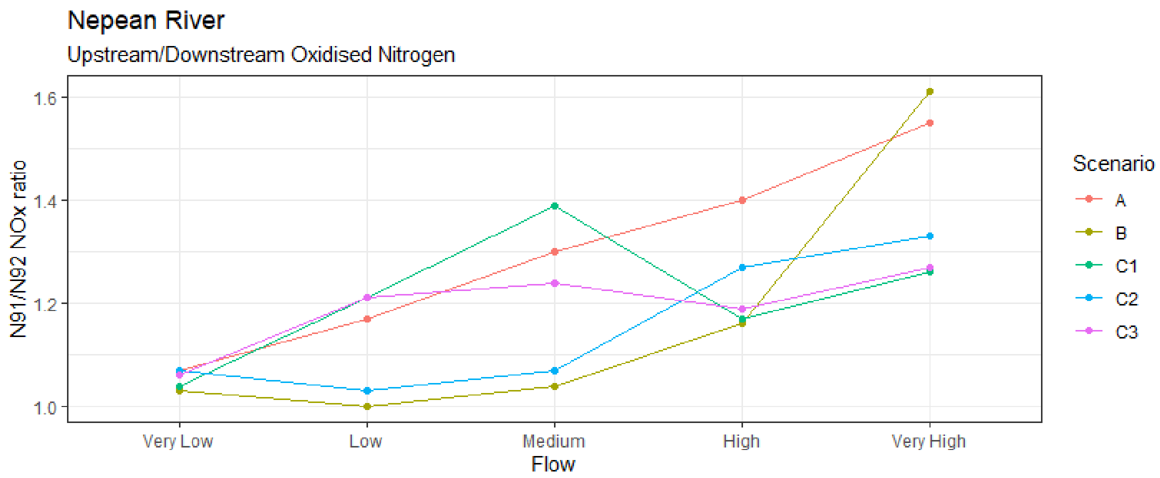

Figure 6-7 Downstream/upstream NOx ratios of geometric mean concentrations in Nepean River at different creek flows

<u>SRP</u>

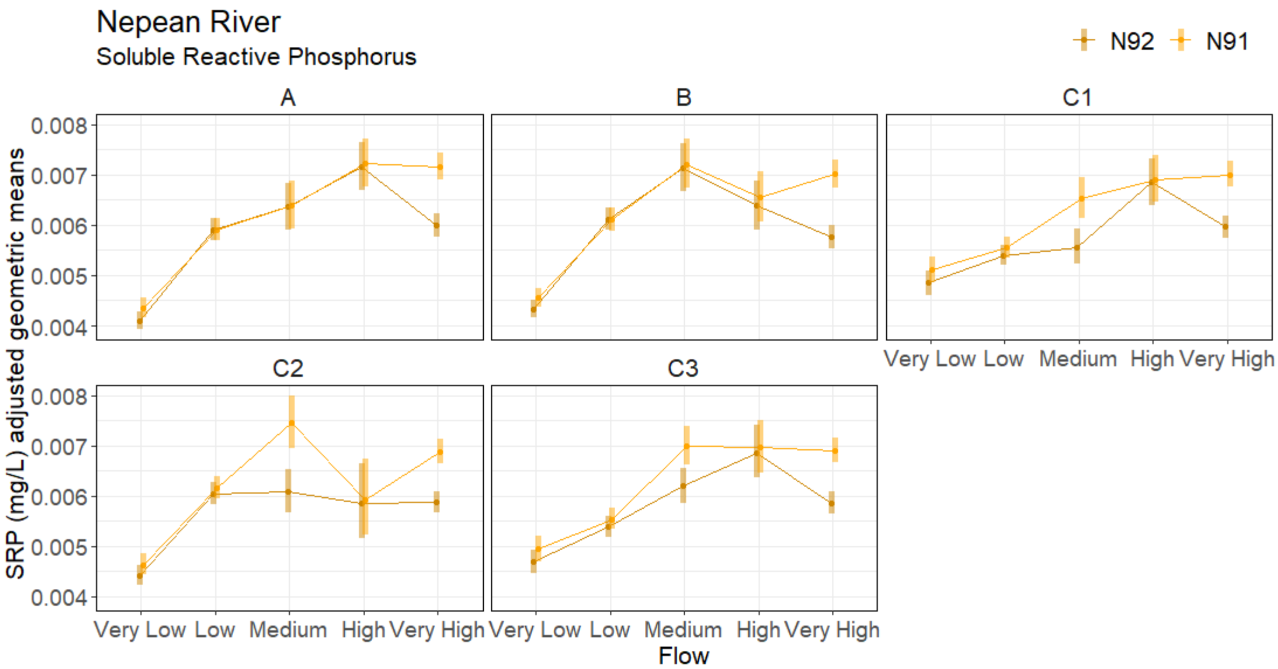

Figure 6-8 Adjusted geometric means of SRP upstream (N92) and downstream (N91) of Nepean River

Table 6-12 Comparisons of adjusted geometrics mean concentrations of TP and SRP upstream (N92) and downstream (N91) of Nepean River

Nepean River					
Scenario	Flow Category	TP ratios (N91/N92)	P	SRP ratios (N91/N92)	P
A	Very Low	1.02 (0.96, 1.08)	0.48	1.06 (1.00, 1.13)	0.06
	Low	1.11 (1.06, 1.16)	<0.01	1.00 (0.95, 1.05)	0.99
	Medium	1.25 (1.14, 1.37)	<0.01	1.00 (0.91, 1.11)	0.93
	High	1.29 (1.18, 1.40)	<0.01	1.01 (0.92, 1.11)	0.85
	Very High	1.81 (1.72, 1.90)	<0.01	1.20 (1.13, 1.26)	<0.01
B	Very Low	1.02 (0.96, 1.07)	0.57	1.05 (0.99, 1.11)	0.09
	Low	1.09 (1.05, 1.15)	<0.01	1.00 (0.95, 1.05)	0.98
	Medium	1.21 (1.11, 1.32)	<0.01	1.01 (0.92, 1.11)	0.82
	High	1.32 (1.20, 1.46)	<0.01	1.03 (0.92, 1.14)	0.64
	Very High	1.87 (1.78, 1.97)	<0.01	1.22 (1.15, 1.29)	<0.01
C1	Very Low	1.02 (0.96, 1.09)	0.49	1.05 (0.98, 1.13)	0.15
	Low	1.12 (1.07, 1.18)	<0.01	1.03 (0.97, 1.08)	0.32
	Medium	1.29 (1.19, 1.39)	<0.01	1.17 (1.08, 1.28)	<0.01
	High	1.33 (1.22, 1.46)	<0.01	1.01 (0.92, 1.11)	0.86
	Very High	1.79 (1.71, 1.87)	<0.01	1.18 (1.12, 1.24)	<0.01
C2	Very Low	1.02 (0.97, 1.08)	0.43	1.05 (0.98, 1.12)	0.15
	Low	1.09 (1.05, 1.14)	<0.01	1.02 (0.97, 1.07)	0.46
	Medium	1.16 (1.06, 1.27)	<0.01	1.22 (1.11, 1.35)	<0.01
	High	1.43 (1.22, 1.68)	<0.01	1.01 (0.85, 1.21)	0.90
	Very High	1.81 (1.73, 1.89)	<0.01	1.17 (1.11, 1.23)	<0.01
C3	Very Low	1.02 (0.96, 1.09)	0.47	1.05 (0.98, 1.13)	0.15
	Low	1.13 (1.08, 1.19)	<0.01	1.03 (0.97, 1.08)	0.32
	Medium	1.22 (1.14, 1.31)	<0.01	1.13 (1.04, 1.22)	<0.01
	High	1.36 (1.23, 1.49)	<0.01	1.02 (0.91, 1.13)	0.78
	Very High	1.80 (1.72, 1.88)	<0.01	1.18 (1.12, 1.24)	<0.01

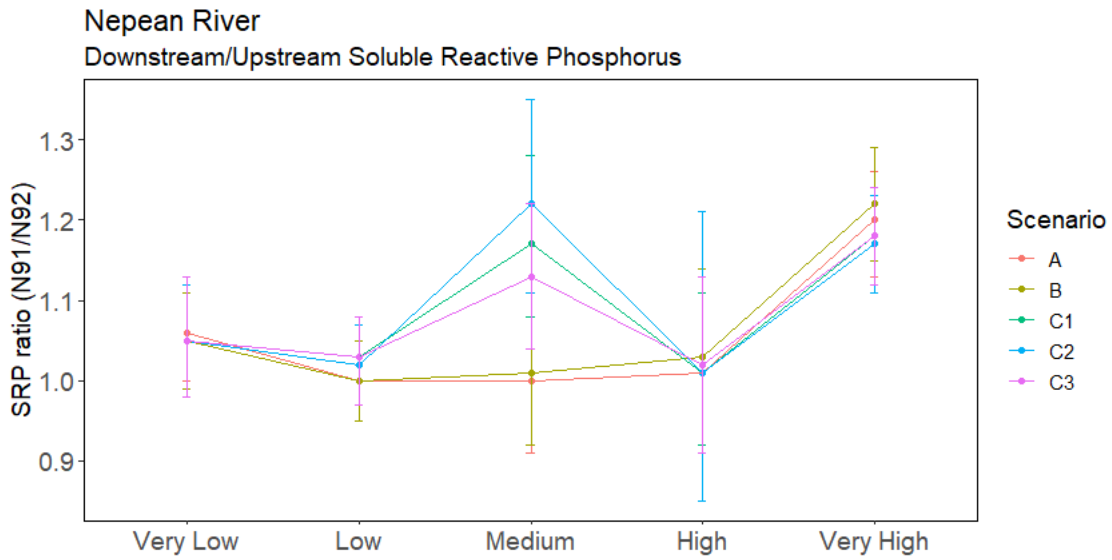

Figure 6-9 Downstream/upstream SRP ratios of geometric mean concentrations in Nepean River at different creek flows