Kyneton WRP

Discharge Risk Assessment

Coliban Region Water Corporation

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The Power of Commitment

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Executive summary

An assessment of environmental risk and impacts to beneficial uses of the Campaspe River from discharging treated wastewater from the Kyneton Water Reclamation Plant (WRP) to the river was undertaken. A baseline scenario of a current worst-case discharge was developed to allow comparison of additional discharge scenarios. The baseline discharge scenario consisted of both biological nutrient removal (BNR) treated wastewater and some Lagoon 4 (trade waste) wastewater. The additional scenarios were based on estimated 2022 and 2036 discharges to the river and consisted of only BNR treated wastewater– which is of improved quality when compared to the combined BNR / trade waste wastewater used in the baseline scenario.

The EPA licence for Kyneton (74405) states that 'discharge from the premises must not exceed 20 percent of receiving surface water flow rate' which is a 'streamflow-to-discharge' ratio of 5:1, with streamflow being measured at Redesdale gauge (some 40 km downstream of the discharge point). A range of 'streamflow-to-discharge' ratios have been investigated and have used streamflow data from the recently installed gauge at Kyneton (1 km upstream of the discharge point). The 'streamflow-to-discharge' ratio selected for this report was a ratio of 1:2 (i.e. for every megalitre of streamflow in the river, two megalitres of discharge occurred, also termed as a proportion of 66.7%). Whilst this was considerably different than the 5:1 discharge ratio in the licence, it was shown that risks, mixing zones and loads to the Campaspe River were substantially lower than the baseline scenario. The 'streamflow-to-discharge' of 1:2 has been used within 2022 and 2036 scenarios in this report.

A risk assessment of the Kyneton WRP discharge to the identified environmental values of the Campaspe River was undertaken using different (but aligned) methods: using the EPA's 'Guidelines for Risk Assessment of Wastewater Discharges to Waterways' (EPA publication 1287) (for both high concentration / low frequency risks and low-mid range concentrations but high frequency risks) and also a 'Daily Risk Tool'. As part of the risk process, environmental values of the Campaspe River were identified and included: aquatic ecosystems (slightly to moderately modified), primary and secondary recreation, aesthetic enjoyment, indigenous cultural and spiritual values, agriculture and irrigation, human consumption after appropriate treatment and human consumption of fish, crustacea and molluscs.

With regards to the assessment of high concentration but low frequency risks, an investigation of maximum recorded concentrations within the BNR discharge was undertaken for ammonia as N (ammonia) and biological oxygen demand (BOD) for the discharge scenario at a ratio of 1:2, using the risk methodology set out in EPA guideline 1287. An assessment of the 'pre-control risk' (inherent risk) for ammonia and BOD resulted in a 'medium' risk being determined for these parameters to the Campaspe River at the discharge point. However, once controls are put in place for ammonia ('interlock' devices that divert out-of-specification discharge water to storage rather than the Campaspe River), the 'post controlled risk' (residual risk) for ammonia shows considerably lower concentrations for ammonia and then once discharged to the Campaspe River, it results in as 'low' risk to the receiving environment (reduced down from a 'medium' risk in the pre controlled risk assessment).

With respect to BOD, whilst an interlock arrangement is not feasible, using the dissolved oxygen sensor in the BNR plant, high risk releases with respect to BOD could be identified and appropriately managed.

For the low-mid range concentrations but higher frequency discharge risk assessment, using the EPA framework guided by a threat/consequence process derived from the 'AVIRA' publication for assessing risks to waterways, most parameters within the BNR discharge showed low risks associated with them, with respect to the aquatic ecology values of the Campaspe River. Exceptions were total nitrogen (total N) and total phosphorus (total P), which had high risks in the form of eutrophication of the waterway (i.e. a secondary effect rather than direct toxicity). These elevated nutrient concentrations in the Campaspe River as a result of the discharge from the WRP are contained within a mixing zone (i.e. a distance downstream at which the concentrations return to upstream or Environment Reference Standard (ERS) guideline limits). Risks from ammonia and biological oxygen demand in the BNR discharge to aquatic ecology under the low-mid range concentrations were calculated as being low (a similar risk to the 'post controlled risk' (residual risk) for ammonia and BOD for high concentration / low frequency discharges). For primary and secondary contact, the risk assessment showed that there were low risks from the WRP discharge associated with *E. coli* in the Campaspe River, given that the concentrations of the discharge (post March 2021) are lower than the river (note that discussions on other pathogen risks are presented below). For irrigation, there were some medium risks associated with total P; however, the consequences of this are considered to be low. For stock watering, results for all parameters showed that there was low risk, including the risks associated with *E. coli*.

A risk assessment of the baseline, 2022 and 2036 scenarios, using the 'Daily Risk Tool' was undertaken over a 3-year period, from July 2017 to June 2020, to align with recent data available for the Kyneton WRP in terms of discharge quality and volume, and to utilise newly-available streamflow data for the Campaspe River at the Kyneton streamflow gauge.

The 2022 and 2036 scenarios considered only domestic (also known as BNR) discharges (i.e. there were no Lagoon 4 trade waste wastewater discharges, as per the baseline scenario). Discharge volumes to the Campaspe River under the 2022 and 2036 scenarios were determined using a water balance model, which took into account newly commissioned infrastructure at the Kyneton WRP.

The 'Daily Risk Tool' allowed risks associated with the Kyneton WRP discharge on values of the Campaspe River (aquatic ecology, primary and secondary contact, irrigation and stock watering) to be calculated on the resulting water quality in the river on a daily basis, and compared that with available guideline values, including the state's Environment Reference Standard (ERS 2021). The BNR discharge water quality and Campaspe River water quality were characterised using 2015-2020 data, except for *E. coli* which used data post February 2021 when a new ultraviolet (UV) disinfection unit was installed.

Key outcomes of the risk assessment were:

– New streamflow data for the Campaspe River at Kyneton was used (located much closer to the discharge point than the Redesdale gauge station) and the streamflow record used has been extended from a recently completed rainfall runoff model. Modelled streamflow data for Kyneton gauging station shows a step change (i.e. a considerable reduction of greater than 50%) in median annual streamflow volume after 1997. A similar step change was noted for Ashbourne gauging station, also on the Campaspe River, upstream of the Kyneton gauge.
– Water quality data available for the Campaspe River upstream and downstream of the discharge point, showed that the background water quality was compliant with some, but not all, parameters when compared to guideline values from the ERS (2021). Non-compliances with the ERS (2021), both upstream and downstream were noted for total nitrogen and total phosphorus, and *E. coli* data showed exceedance of guideline values for primary contact recreation (i.e. swimming), both upstream and downstream of the discharge point.
– The third 'Index of Stream Condition' assessment published in 2013 by the Victorian Government for all significant waterways across Victoria, showed that a number of waterways in the Campaspe River catchment above Lake Eppalock were reported as being in 'very poor', 'poor' and 'moderate' condition, when assessed for hydrology, physical form, streamside zone, water quality and aquatic life. The Campaspe River below Kyneton, and above Lake Eppalock, was assessed as 'very poor' and this is typical of other waterways in the local catchment area, such as Pipers Creek (assessed as 'poor') and Jews Harp Creek (assessed as 'very poor').
– The ecological condition of the Campaspe River within the vicinity of the Kyneton WRP discharge point has been monitored over multiple years. A range of results are available from macroinvertebrate (water bug) monitoring which indicate that stream health is impacted at all sites (both upstream and downstream of the Kyneton WRP discharge point). Recent monitoring by Aquatic Environmental Stress (AQUEST) Research Group, which is part of RMIT University, indicates that the site directly below the discharge point showed more degradation than other sites upstream, however it is noted that this site is located within the known mixing zone of the discharge. Nearby tributaries of the Campaspe River: Post Office Creek and Snipes Creek showed the most degradation, likely to be caused by urban, industrial and agricultural runoff.
– A platypus monitoring program undertaken by Cesar Australia showed there is likely to be only a sparse population present in the upper Campaspe River upstream and downstream of the Kyneton WRP discharge point. There was no evidence of negative impacts from WRP discharges on platypus populations, the low numbers are likely a reflection of overall poor habitat condition of the Campaspe River, due to the modified catchment and seasonal cease-to-flow events.

- Risks assessed using the EPA framework and the 'Daily Risk Tool' showed alignment of results – i.e. the key risks identified by both methods were around total N and total P risks to aquatic ecology, and that these risks were essentially contained within a mixing zone.
- The baseline scenario of existing Kyneton WRP discharges to the Campaspe River from July 2017 to June 2020 showed an average annual discharge of 485 ML/year, and on days of discharge (which were approximately 52% of all days), the median daily discharge volume was 2.5 ML/day. Median mixing zones of 3.31 km for total N and 5.29 km for total P were noted for the baseline scenario, as was an average annual load to the river of 5,056 kg/year for total N and 2,040 kg/year for total P.
- Under the 2022 and 2036 scenarios, the highest risks in the WRP discharge were associated with total N and total P, and their impact on aquatic ecology values in the receiving waters (in the form of eutrophication of the waterway). Total N and total P risks were also associated with irrigation (bio-clogging of irrigation equipment), although the consequences of these risks are deemed low given the asset life of most irrigation equipment.
- The impact of the discharge to the environment is essentially an increased but manageable risk of eutrophication of the receiving waterway within the mixing zone on days of discharge only, which is typical of other reclaimed water discharges to inland waterways across Victoria.
- An assessment of *E. coli* data available for the Campaspe River upstream and downstream of the discharge point showed that all sites are in 'Category D' (using the ERS (2021) methodology) and, therefore, suitable for secondary recreation only (not primary contact, such as swimming). The BNR discharge is typically of considerably better quality than the Campaspe River with regards to *E. coli* concentrations, and post February 2021 the discharge would be consistent with the quality requirements of 'Category A' (suitable for primary recreation).
- Inflows into the Kyneton WRP for the 2036 scenario are higher, compared to the 2022 scenario and, as such, there is more water available for discharge to the river. Higher total risk scores, mixing zone distances and loads were noted in the 2036 scenario, compared to the 2022 scenario.
- Mixing zones for the 2022 scenarios for total N were 0.88 km (median value) and 4.57 km (90th percentile), and for the 2036 scenario for total N 1.28 km (median value) 6.07 km (90th percentile), compared to a baseline of 3.31 km (median) and 13.21 km (90th percentile). That is, there were decreases in the mixing zone in comparison to the current baseline, for the 2022 and 2036 scenarios.
- Mixing zones for the 2022 scenario for total P ranged from 0.28 km (median value) and 1.8 km (90th percentile), and for the 2036 scenario for total P 0.44 km (median) and 2.45 km (90th percentile) compared to the baseline of 5.29 km (median) and 30.6 km (90th percentile). As for total N, there were decreases in mixing zone distances for the 2022 and 2036 scenarios when compared to the baseline.
- There is a considerable reduction in risk scores, mixing zone distances and loads of total N and total P to the river for the 2022 and 2036 scenarios, when compared to the baseline scenario. This is due mainly to the improved quality of BNR discharge compared to the combined BNR/Lagoon 4 discharge that was used in the current baseline scenario.
- A pathogen risk assessment, using a quantitative microbial risk assessment (QMRA) methodology, showed potential risks from *Cryptosporidium*, Norovirus and *Campylobacter* to identified beneficial uses downstream. However, confidence in this style of risk assessment is relatively low and characterisation of pathogen risks are speculative, given the lack of measured data available for log reduction values for pathogens through the BNR plant and that no data was available for the Campaspe River upstream of the discharge point to validate existing risks to the identified beneficial uses of the waterway. The new, high performance UV system that was installed at Kyneton during February 2021, reduces risks associated with pathogens within the discharge.
- Under normal operating conditions, the upgraded UV unit at the Kyneton WRP is likely to result in significant inactivation of a range of human infectious viruses and other pathogens. It was estimated that the pathogen risks from primary contact recreation are being managed to an acceptable level, due to the small exposure volumes associated with recreation, and because discharges to the river do not normally occur at times when recreation is likely to also be occurring. Signage downstream of the discharge to warn any swimmers of potential risks is also an appropriate risk reduction method.
- An 'infected traveller' scenario was investigated to assist in answering questions about the risk of helminths to the Campaspe River (and then cattle drinking that water), should an 'infected traveller' arrive in Kyneton. Results from the scenario include that the risk to cattle is highest during periods when the Kyneton WRP inflow is at its lowest, as this results in the least dilution of any (rare) shedding cases in the sewerage

catchment population. The conservative estimated waterway concentration of helminth eggs (HE) during worst-case conditions (2022 inflow, with the lowest treatment scenario for helminths with 1.5 log reduction value (LRV)) was 0.0114 HE/L, resulting from one infected person in the sewerage catchment, which is below the WHO guideline of 0.1 HE/L, and a more conservative threshold of 0.0167 HE/L. The risk threshold of 0.0167 HE/L will be exceeded when at least two, or more than two, people in the township are infected, under the 2022 scenario with 1.5 LRV at the WRP. However, this assessment is conservative: risks were determined as if the Kyneton WRP discharged to the Campaspe River every day (this would not occur in reality, particularly during periods of high irrigation demand) and the higher end of pathogen concentrations (i.e. 95th percentile values) were typically used for the assessment, and whilst this is accepted QMRA methodology, it may be considered overly conservative.

– An assessment of nutrient loads discharged to the Campaspe River for the 2022 and 2036 scenarios were undertaken and compared to loads from the baseline scenario (i.e. the difference being the ‘incremental’ load). For both the 2022 and 2036 scenarios, loads for total N were lower than the baseline load, due to the improved quality of BNR-only discharge compared to the baseline. This was also the case for total P, in which all scenarios had lower loads than the baseline. As such, none of the scenarios showed any incremental increase in nutrient load.
– Pathogen loads within the discharge for all scenarios were calculated using concentration data or estimated values from the literature, and compared to pathogen loads within the baseline scenario. There were no increases in annual loads to the Campaspe River for *Campylobacter*, *E. coli* and *Cryptosporidium* for the 2022 and 2036 scenarios i.e. there were no incremental increases in pathogen load. No reliable data was available for norovirus in cattle manure, so offsets were not able to be determined for this pathogen.
– Four sites (A, B C and D) of grazing land holdings adjacent to the Campaspe River above Kyneton WRP discharge point (with a combined total area of 568 hectares) are currently being utilised as nutrient and pathogen offset project sites. Land management practices are being applied at these sites (cattle exclusion from the waterway and revegetation of riparian zones), in order to offset future nutrient loads contributed to the river by the Kyneton WRP.
– Total nutrient and pathogen loads would be offset by the existing land management sites A-D (568 hectares of grazing land, with cattle exclusion and riparian revegetation), for both the 2022 and 2036 scenarios.
– Ongoing ecological monitoring of the Campaspe River being undertaken by Aquest is valuable and continues to provide additional lines of evidence with which to assess the risk of current and future Kyneton WRP discharges to the Campaspe River and to monitor improvements in the waterway due to the offset projects upstream of the discharge point.

In summary, discharging only BNR-treated wastewater from Kyneton WRP to the Campaspe River with a ‘streamflow-to-discharge’ ratio of 1:2 (a proportion of 66.7%) and using streamflow measured at the Kyneton gauging station provides a significant improvement to the receiving environment, when compared to the baseline scenario. Improvement is shown for key metrics: a reduction in risks to the waterway, a reduction in mixing zone distances for nutrients, and a reduction in nutrient and pathogen loads to the river. The nutrient and pathogen loads to the Campaspe River under the proposed scenarios are shown to be offset by upstream riparian works, representing a significant improvement compared to the baseline scenario.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.3 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Introduction

This report details a risk assessment of proposed future discharge scenarios to the beneficial uses of the Campaspe River, and provides an update of mixing zone calculations and load determinations using newly available streamflow data from the Kyneton gauging station. Nutrient and pathogen offsets available from a number of upstream properties, using riparian revegetation and cattle exclusion, are also considered in the report. This report forms part of a licence amendment application for the Kyneton WRP.

It is proposed that future Kyneton WRP discharges to the Campaspe River will consist of Biological Nutrient Removal (BNR) water only (in the recent past there was both BNR and BNR-Lagoon 4 combined discharges – i.e. treated domestic and treated trade waste combined) which is consistent with the current EPA licence for Kyneton (74405) (i.e. discharges must comply with the 'Discharge to Water Table – Discharge Limits' in the licence).

1.2 Purpose of this report

To present an assessment of the current baseline (2017-2020 discharge) and to compare that to a BNR-only discharge (in 2022 and 2036) to the Campaspe River under a preferred streamflow-to-discharge ratio (1:2), and to consider the environmental impact, loads and mixing zones of each scenario. An investigation of available nutrient and pathogen offsets for the proposed discharge is also presented.

1.3 Scope and limitations

This report: has been prepared by GHD for Coliban Region Water Corporation and may only be used and relied on by Coliban Region Water Corporation for the purpose agreed between GHD and Coliban Region Water Corporation as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Coliban Region Water Corporation arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Coliban Region Water Corporation and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.4 Assumptions

The key assumptions within this report are as follows:

- The 2015-2020 treated wastewater discharge data for the BNR discharge (and post February 2021 data for *E. coli*) used in the risk assessment is representative of future discharges.
- Water quality data collected available for waterways and the Kyneton WRP provides an accurate picture of actual water quality conditions.

- Streamflow estimated for the Campaspe River using modelled streamflow (details are set out in the supporting ‘Kyneton WRP Hydrology and Water Balance’ report), is an accurate representation of actual streamflow.
- Decay rates for nutrients that have been estimated for discharges in the Campaspe River, using in-stream water quality data and an estimate of streamflow velocity, are reasonable representations of actual decay rates.
- The risk analysis assumes that the higher the concentration of a parameter above a relevant guideline value, the higher the risk (with a linear response).
- Calculation of offsets for nutrients and pathogens for different sites and management practices are representative of the actual offsets available.
- The pathogen risk assessment has used assumptions about log removal of pathogens through the BNR plant, based on a literature review, it is assumed these are reasonable estimates. A range of other assumptions associated with the pathogen risk assessment are set out in that section of the report.

2. Characterisation of the receiving environment

2.1 Overview of the Campaspe River catchment

The Campaspe River is part of the Murray-Darling catchment, with the river flowing 150 km from the northern slopes of the Great Dividing Range near Trentham to the Murray River at Echuca (Peter Cottingham and Associates and SKM 2011). The lower Campaspe River system (below Lake Eppalock) is regulated to supply water to meet environmental, agricultural and urban demands.

Land use along the river generally consists of nature and conservation environments, natural vegetation which is grazed, dryland agriculture and plantations, irrigated agriculture and plantations, and residential uses.

There are a number of storages on the Campaspe River, including the Campaspe Reservoir (owned and operated by Greater Western Water with a capacity of 262 ML and supplies the township of Woodend) and a significant storage of Lake Eppalock (304 GL), from which key diversions occur for urban water supply occur (Bendigo and Heathcote) and for irrigation downstream at Rochester (Davies et al., 2012).

The Sustainable Rivers Audit conducted between 2008-2012 classified the ecosystem health of the Campaspe Catchment as very poor (Davies et al., 2012). Many expected fish species are absent, with exotic species more prevalent throughout the system (Davies et al., 2012). Riparian vegetation is also particularly poor, with limited abundance of plants, as well as limited diversity and limited presence of native species (Davies et al., 2012).

Despite degradation in the Campaspe River, including altered flow regimes, grazing and weeds, many values and important assets exist throughout the waterway. Upstream of Kyneton, the North Central Catchment Management Authority (NCCMA) has identified the Campaspe River to have notable assets with high community value (NCCMA 2013). Downstream of Kyneton, the NCCMA has identified the Campaspe River to have priority catchment assets (NCCMA 2013). There are a number of initiatives throughout the Campaspe Catchment to improve the ecological health of the river and to protect assets (NCCMA 2013).

An overview of the Campaspe River catchment above Lake Eppalock is presented in Figure 1 and shows key features such as:

- Waterways (Campaspe River, Five Mile Creek, Snipes Creek, Pipers Creek and Jews Harp Creek).
- Kyneton and Woodend townships.
- Streamflow gauging stations (Redesdale, Kyneton and Ashbourne).
- Kyneton WRP discharge point and Woodend RWP discharge point (this asset is managed by Greater Western Water), and
- Barfold Gorge and Turpin Falls.

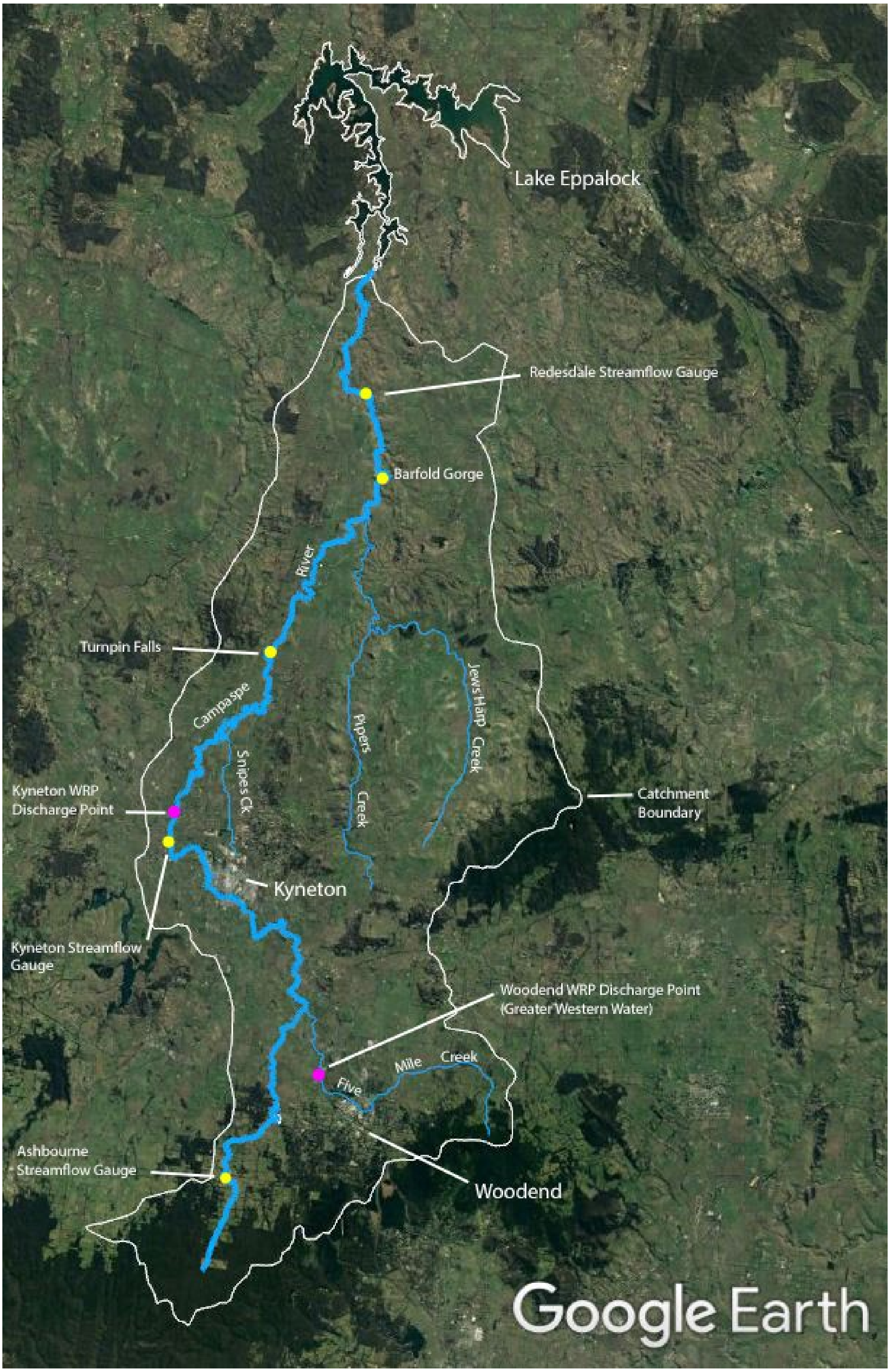

Figure 1 Campaspe River catchment above Lake Eppalock

2.2 Existing threats and sources of pollution

Existing threats and sources of pollution within the Campaspe River catchment are linked to land use and the management practices applied to that land. Land use within the Campaspe River catchment includes agricultural land, rural residential, urban areas, industrial zones (in particular around Kyneton) and natural / forested lands. For agricultural and rural residential areas, the application of fertilizers for pasture is a common land management practice, and applied fertiliser may be transported to waterways via rainfall runoff events. Once in the watercourse, increased nutrients contained within the fertiliser may enhance the growth of weeds and algae (DEPI 2013). Nutrient concentrations in Campaspe River upstream of the WRP discharge point suggests that nutrient rich runoff from agriculture (and potentially urban areas too) occurs within the catchment (see a summary of water quality data including nutrients in Section 4 of this report).

Often associated with grazing is land clearing, poorly vegetated or managed riparian zones and un-fenced stock access to the waterway. A properly maintained riparian zone can provide a number of benefits to a waterway, including filtering rainfall runoff, provision of shade and temperature control of the waterway, provision of instream habitat through over-hanging vegetation and debris, and may also offer connectivity and habitat for terrestrial and arboreal fauna. Stock access to waterways can impact bank stability, adding to sediments, nutrients and pathogens to a waterway. As such, land clearing, an absence of properly managed riparian zones and direct cattle access to waterways are seen as existing threats and sources of pollution in the upper Campaspe River catchment.

2.3 Environmental Values of the Campaspe River

As outlined in the Victorian State Government's Environmental Reference Standard (ERS 2021), discharges to surfaces waters are to be managed to protect environmental values. Environmental values are to be protected, except in circumstances where the background condition does not provide protection, or in the case of artificial waterbodies, such as artificial, or constructed, irrigation channels, stormwater drains, private dams etc. An 'environmental value' is defined in the ERS (2021) to be the same as that under the *Environmental Protection Act 2017*, i.e. a use, an attribute or a function of the environment.

The environmental values for each segment of the water environment are marked in Table 1 by a tick and the relevant segment for this assessment has been highlighted. The Campaspe River is classified under the Cleared Hills and Coastal Plains - uplands of Moorabool, Werribee, Maribyrnong, Campaspe, Loddon, Wimmera and Hopkins catchments bioregion in ERS (2021).

Table 1 Environmental values of inland waters (ERS (2021))

Environmental Values		Aquatic Reserves	Rivers and Streams						Wet-lands
	Segment →	Aquatic Reserves	Highlands	Uplands A	Uplands B	Central Foothills and Coastal Plains	Urban	Murray and Western Plains	Lakes and Swamps
Water dependent ecosystems and species that are:	Largely unmodified	✓	✓	✓	✓				
	Slightly to moderately modified					✓		✓	✓
	Highly modified						✓		
Human consumption after appropriate treatment		✓ if water is sourced for supply – • in a special water supply catchment area set out in Schedule 5 of the *Catchment and Land Protection Act 1994*; or • in accordance with the *Safe Drinking Water Act 2003*.							
Agriculture and irrigation			✓	✓	✓	✓	✓	✓	✓
Human consumption of aquatic foods		✓	✓	✓	✓	✓	✓	✓	✓
Aquaculture		✓ if the environmental quality is suitable and an aquaculture licence has been approved in accordance with the *Fisheries Act 1995*							
Industrial and commercial				✓	✓	✓	✓	✓	
Water based recreation (primary contact)		✓	✓	✓	✓	✓	✓	✓	✓
Water-based recreation (secondary contact)		✓	✓	✓	✓	✓	✓	✓	✓
Water-based recreation (aesthetic enjoyment)		✓	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values		✓	✓	✓	✓	✓	✓	✓	✓
Navigation and shipping									

For the purpose of this risk assessment, the environmental values have been reviewed in the context of available desktop information, including stakeholder input from GHD (2013). This information has been used to determine which environmental values need to be directly considered within the risk assessment. Table 2 provides the justification for the environmental uses and associated values which will be included within the risk assessment.

Table 2 Applicable beneficial uses for the Campaspe River

Environmental Value	Direct Risk Evaluation	Indirect Risk Evaluation	Assumptions	Important values as part of this beneficial use
Aquatic ecosystem	✓	×	The Campaspe River is slightly to moderately modified	Habitat - Instream habitat for fauna - The riffles upstream of Lake Eppalock become shallow during summer and could prevent golden perch and Murray cod moving upstream from the lake and colonising this section of the river. - The North Central CMA and local landcare groups (Langley Landcare and Baynton Sidonia Landcare) run a range of landcare projects that help to improve the aesthetics and enjoyment of the river. Works completed by landcare groups include; fencing, weed control, willow control and revegetation. These works aim to create habitat links to the Campaspe River from the Cobaw Range, to the south east, in order to develop a regional network for habitat in the area. Aquatic Fauna - The state-wide aquatic fauna database managed by the DSE (now DELWP) reported 22 species of fish within the Campaspe River including; 7 exotic and 15 native fish species. - EPBC listed species golden perch, Macquarie perch and Murray cod with , six other species listed on the DSE advisory list, and six listed under the Victorian *Flora and Fauna Guarantee Act 2007*. - Macquarie perch grown at the Snobs Creek Hatchery near Eildon are being released into the Campaspe River downstream of Kyneton in an attempt to restore species numbers within the river. - Incidental capture of both Mountain Galaxias and Southern Pygmy Perch during RBA sampling
Primary contact recreation	✓	×	Primary contact recreation such as swimming is known to occur in the Campaspe River.	Turpin Falls and Barfold Gorge located to the north and downstream of Kyneton on the Campaspe River is used for recreation. Lake Eppalock, located downstream of Kyneton, is used for swimming, boating and skiing.
Secondary contact recreation	✓	×	Secondary contact recreation such as canoeing is known to occur in the Campaspe River.	The Campaspe River and Lake Eppalock, located downstream of Kyneton, is used for secondary recreation as there are some fishing spots, picnic areas and sites where people can canoe (GHD, 2013 stakeholder meeting minutes).
Aesthetic enjoyment and residential amenity	×	✓	Aesthetic values are indirectly protected if aquatic ecosystems are protected and the integrity of the place remains	Aesthetics includes water free from scum, foams, odours and oils.
Indigenous cultural and spiritual values	×	✓	Indigenous and non-indigenous cultural and spiritual values are indirectly protected if aquatic ecosystems are protected and the integrity of the place remains	Under the *Aboriginal Heritage Act 2006* (Vic), a waterway or land within 200 metres of a watercourse is an area of cultural heritage sensitivity. Dja Dja Wurrung Aboriginal people occupied most of the Loddon and Campaspe catchments. Plant species such as Cumbungi, Myrrnong and Nardoo were a stable of the Dja Dja Wurrung. Additional stakeholder engagement for indigenous values is likely to add additional values for consideration in this risk assessment.
Agriculture and irrigation	✓	×	This region has an agricultural and irrigation area with water that is likely	Agriculture and non-potable uses (stock watering) and irrigation There are stock and domestic licences along the Campaspe River, but stakeholders from Goulburn Murray Water were unsure about irrigation licences. Suspension from irrigation occurs when flows in the Campaspe drop below 3 ML/day.

Environmental Value	Direct Risk Evaluation	Indirect Risk Evaluation	Assumptions	Important values as part of this beneficial use
			to be diverted to farm dams for these purposes.	Stock access along the waterway is available for stock watering.
Aquaculture	×	✓	Insufficient information to understand the risk.	N/A
Industrial and commercial use	×	✓	No industrial facilities are in the vicinity of the river	N/A
Human consumption after appropriate treatment	×	✓	Unlikely to be used as a drinking water supply	The Campaspe River is unlikely to be used for drinking water, although there is a more likely possibility of use in home gardens. However, Lake Eppalock is a drinking water offtake for Bendigo, Goornong and Rochester (and has appropriate treatment prior to distribution).
Fish, crustacea & mollusc for human consumption	×	✓	Indirectly protected if aquatic ecosystems are protected and the integrity of the place remains.	The Campaspe River is valued for its recreational fishing value. The river around the WRP is small and shallow yet carried a small population of brown trout and rainbow trout, some river blackfish, redfin and tench. Some brown trout are caught downstream of Kyneton and rainbow trout are taken near Kyneton Falls from self-sustaining populations. Although anglers reported in 2002 a few small brown trout and rainbow trout present, a survey conducted by DSE in 2004 over a river length of 1.7 km near Kyneton took no trout.

2.3.1 Monitored endpoints relate to environmental values

Monitoring of the receiving waters of the Campaspe River, both upstream and downstream of the discharge point, has been undertaken to allow for an assessment of any impacts that the discharge may have on the identified environmental values. The monitoring is summarised below in section 2.4 with regards to ecological condition and monitoring of the Campaspe River, and in section 4, which summarises water quality data and compares the data to guidelines. The monitoring allows the temporal and spatial extent of the discharge to be established, i.e. for some of the environmental values listed (e.g. primary recreation at identified sites such as Turpins Falls) may be located downstream of the extent of influence of the discharge or that swimming typically takes place during non-discharge periods of the year.

2.4 Ecological condition of the study reach

The ecological condition of the Campaspe River near Kyneton forms a key part of understanding the risks associated with the WRP discharge to the river. This is because the ecology of the waterway is really the ‘measurement endpoint’ with which to establish effects of the discharge to the waterway.

Ecological monitoring has been undertaken (and continues) for the Campaspe River within the vicinity of the Kyneton WRP discharge point. Results from GHD (2013),Biosis (2015) and Biosis (2021)are presented below along with a summary of current monitoring by AQUEST (2019 and 2020). A study into platypus habitat in the upper Campaspe River was undertaken by Cesar Australia in 2021. An assessment of the condition of the Campaspe River is presented within the Index of Stream Condition is also presented below.

A description of the Campaspe River near to Kyneton WRP discharge point is as follows (as per GHD 2013):

- The waterway flows through steep to moderately sloping farmland
- Riparian vegetation is dominated by exotic willows that encroach upon the stream and, in some places, completely cover the river bed
- High levels of shading by large overstorey species
- Exotic trees and exotic grasses dominant, rather than shrub species
- Direct stock access on both banks of waterway in some sections

- Channel widths 8 to 12 metres and stream widths 6 to 12 metres
- Substrate is a mix of a high coverage of clay and silt, with a small amount of gravel and sand noted at one location
- Instream features, such as willow roots, with a small amount of algae and some in-stream woody debris.

Further downstream at Redesdale, the river is 7 to 8 m wide, and instream features include deep pools and glides separated by shallow riffles choked with cumbungi (GHD 2013). River substrate is bedrock and sand. River red gum, grass species, gorse and cumbungi also make up the riparian vegetation which can restrict river access at some locations (GHD 2013).

2.4.1 Rapid Bio-assessment

Rapid bio-assessment (RBA) examines the overall health of an aquatic ecosystem, based on macroinvertebrate communities present in the waterway. Results from the RBA for the Kyneton discharge for a number of years were summarized in GHD (2013), comparing wetter and dryer periods as follows:

- Generally, the data for Observed / Expected (O/E) score, Banding, SIGNAL-2 and O/E SIGNAL indices suggest river health was somewhat diminished in dry years, compared to wet years – suggestive of potential water quality and/or habitat degradation.
- Higher median SIGNAL and Number of Families were recorded in dry years, compared to wet years.
- In wet years, median O/E score and Number of Families was higher during low-flow periods, while SIGNAL was marginally higher in high-flow periods. The minimum Banding during high-flow periods was lower than in low-flow periods during wet years.
- In dry years, O/E score and SIGNAL were consistently higher than in low-flow periods, compared to high-flow; median Banding was also higher during low-flow periods, compared to high. Correspondingly SIGNAL-2, Number of Families O/E SIGNAL and Number of EPT Taxa indices were all higher in high-flow periods, compared to low-flow periods in dry years.

Rapid bio-assessment results for the Campaspe River (Biosis 2015):

- Greatest diversity of taxa was recorded at downstream sites, between 1.2 and 2.9 km downstream of the discharge.
- EPA objectives for the Number of Families was not attained for any site.
- SIGNAL scores indicate mild to moderate impairment of water quality at both reference and impact sites.
- ERS (2021) AUSRIVAS objectives for impact sites were attained. Significantly, sites upstream of the discharge recorded O/E 50 0.69 and 0.53, respectively, indicating the macroinvertebrate assemblage was substantially poorer than the AUSRIVAS reference condition impacts within the upper catchment, not related to the discharge.
- Macroinvertebrate indices indicate that stream health has deteriorated at all sites (reference and impact), with a decline in SIGNAL scores and AUSRIVAS bands since 2012 monitoring.

Results from the Biological Stream Health Monitoring report undertaken by Biosis (2020):

- ‘Taxa richness within the Campaspe River was found to be typically consistent between control and impact sites as well as with previous years of monitoring. Consistent with previous iterations of the monitoring program, SIGNAL2 results for the 2020 monitoring period indicate that macroinvertebrate communities were severely impoverished and water quality was generally poor. Poor SIGNAL2 scores were recorded at control and impact sites, continuing to indicate that the poor stream health conditions are reflective of the highly modified and heavily managed nature of landscapes within the region rather than WRP operations.’
- ‘Despite the continuation of poor stream health conditions, it is noted that several control and impact sites increased in band score from ‘B’ to ‘A’ during the 2020 monitoring period when compared with previous iterations of monitoring. This indicates that the sample of macroinvertebrates collected at these monitoring sites meet the representation of what macroinvertebrate communities would be expected to occur, if the site was is in a ‘reference’ or undisturbed condition for the locality. Increases in band scores, HABSCOREs and Taxa richness at both control and impact sites may be largely attributed to an increase in catchment rainfall improving the availability and diversity of habitat for a greater diversity of inhabiting taxa throughout the 2020 monitoring period.’

– ‘When taken as a whole, the monitoring results do not indicate any impacts to stream health occurring as a result of WRP operations generally.’

2.4.2 AQUEST Monitoring 2019 - 2020

The North Central Catchment Management Authority (NCCMA) are undertaking an ecological improvement program for the upper Campaspe River, as documented in a stream frontage management plan (SFMP). The intention of the management plan is to improve the water quality and ecology of the Campaspe River by removing weeds such as willows, revegetation of riparian areas and preventing cattle access to the waterway with fencing at a number of key sites, upstream of the Kyneton WRP discharge point.

Coliban Water is a key contributor and funder of the project, and has taken an interest in the reduction of nutrient and pathogen loads to the Campaspe River as an offset towards future Kyneton WRP discharges to the river. A monitoring program was established for the project to understand any ecological benefits and to potentially quantify any offsets available. The program is being undertaken by the Aquatic Environmental Stress (AQUEST) Research Group, part of RMIT University. The five year monitoring program commenced in 2018-19 and included parameters such as water quality, aquatic ecology, algae monitoring, sediment sampling, ecotoxicology tests. There were eight sites along the Campaspe River, from Carlsruhe to Redesdale and on two tributaries: Post Office Creek and Snipes Creek (see Figure 2).

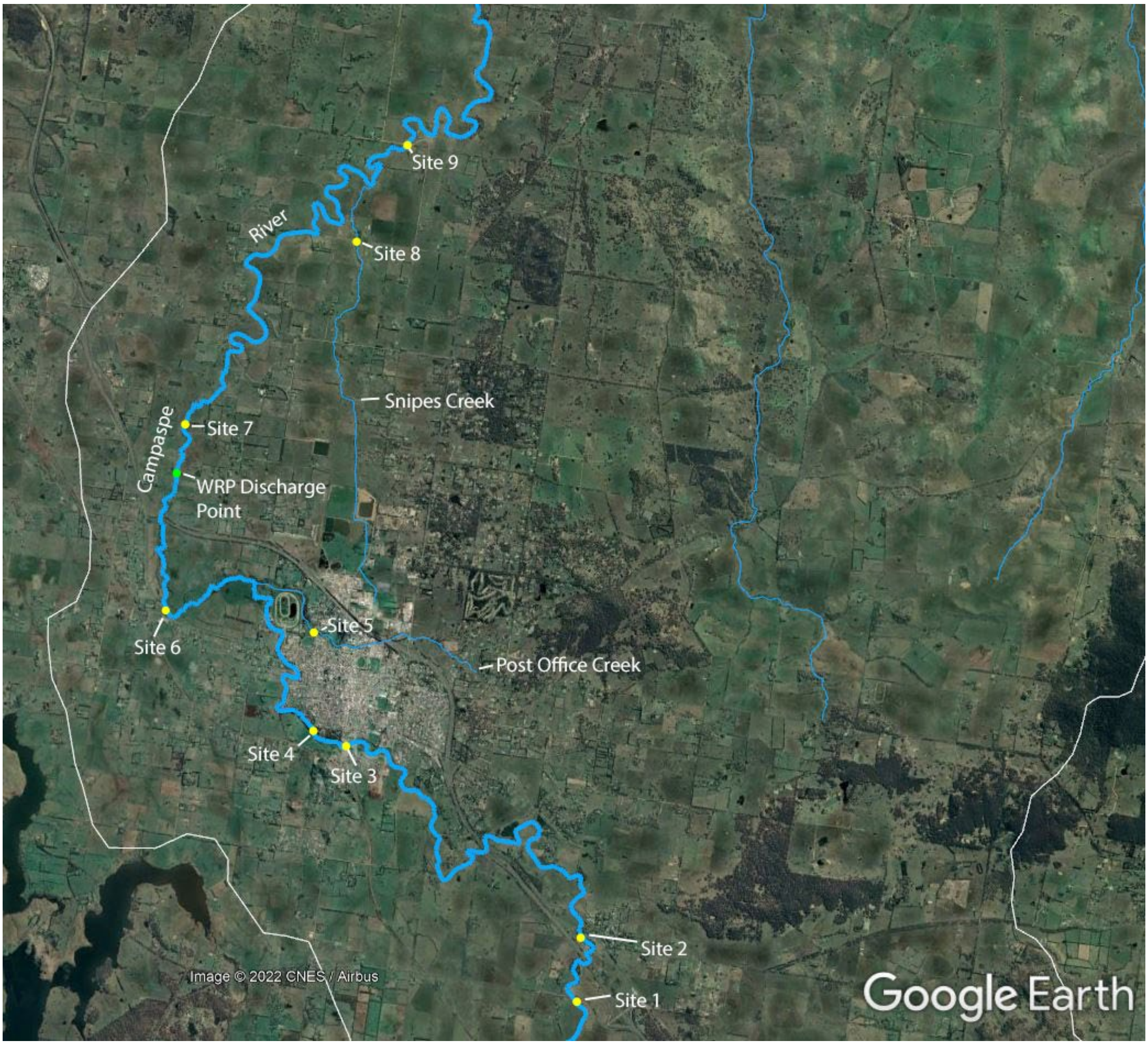

Figure 2 ***Aquest sampling sites 1 – 9 (site 10 at Redesdale is not shown on this map).***

Two reports were available from AQUEST: a summary of the first year's results 2018-19, Myers et al (2019), and second year's results 2019, Myers et al (2020). A summary of the reports is presented below:

Year 1 summary (Myers et al 2019).

- Macroinvertebrate diversity (surveyed in October 2018) was considered good across most sites, given that the Campaspe River and tributaries in the study area are ephemeral. Some of the sites with willow growth and/or the occurrence of contaminants had lower diversity (e.g. Site 8 at Snipes Creek).
- Ecotoxicology results, using snails to determine if there was any ecological impairment, indicated that in-stream waters were generally not impacting invertebrate health, except for Post Office Creek (Site 5) and the Campaspe River at Old Station Rd (Site 7 – downstream of the WRP discharge point).
- Across all sites water quality results showed an enrichment of nutrients and this often led to excessive algal and macrophyte growth.
- The sites in the poorest condition were Snipes Creek (Site 8), Post Office Creek (Site 5) and the Campaspe River at Old Station Rd (Site 7). Contributing to the impact on these waterways were urban and industrial runoff from Kyneton, agricultural runoff, treated discharges from the Kyneton Water Reclamation Plant and potentially septic tank systems from unsewered areas.

Year 2 summary (Myers et al 2020).

- The second year of monitoring is influenced by the commencement of a range of management actions (e.g. weed control, riparian revegetation, fencing and off stream watering for livestock) at four sites.
- As per the first year's monitoring, the 10 sample sites were monitored for water quality, aquatic ecology, nutrient bioavailability and ecotoxicology, during the August to December period of 2019.
- Sites 3, 4 and 6 which are located along the Campaspe River are generally of good quality and show signs of reducing nutrient inputs.
- Sites 1 and 2 in the upper reaches around Carlsruhe, and downstream of Site 7, showed impacts including elevated nutrients and faecal contamination and the presence of pharmaceuticals, herbicides and insecticides. The source of these contaminants is likely to be from wastewater (treated discharges and septic tanks), agricultural and urban runoff, poor habitat condition and unrestricted stock access.
- Similar to the first years monitoring, Post Office Creek (Site 5), Snipes Creek (Site 8), and the Campaspe River at Old Station Road (Site 7), were in poorest condition.

2.4.3 Platypus habitat suitability in the upper Campaspe River

Coliban Water sought to understand the suitability of the upper Campaspe River to support platypus populations (in between Carlsruhe and Redesdale, in which the Kyneton WRP has released treated wastewater). A study was undertaken by Cesar Australia in 2021, to assist in determining potential impacts of the treated water discharges into the upper Campaspe River and the existing abundance of platypuses.

Cesar Australia (2021) noted that platypuses are adaptable to a range of environmental conditions, however, in broad terms, there are three key components that are required for their presence:

- reliable water availability,
- abundant macroinvertebrates,
- and stable earthen banks to construct burrows.

The occurrence of platypuses in the upper Campaspe River was investigated using environmental DNA (eDNA) at 13 sites. Results from the study shows that platypus populations are relatively sparse in the upper Campaspe River and that habitat quality was assessed as poor due to a lack of riparian vegetation, low in-stream complexity, and poor flow regimes, particularly regular cease-to-flow events. There was no evidence of negative impacts from the treated water discharges on platypus populations, and the low numbers are likely a reflection of overall poor habitat condition of the Campaspe River upstream and downstream of the discharge point, and due to the heavily modified catchment areas and seasonal cease-to-flow events.

2.4.4 Stream condition assessment of the Campaspe River

The third Index of Stream Condition report (ISC) (2013) provides a snapshot of the ecological condition of waterways across Victoria. The condition report scores against five criteria where data is available – hydrology, physical form, streamside zone, water quality and aquatic life. Results for the upper Campaspe River (above Lake Eppalock) are presented in Table 3 and in Figure 3 and show that the Campaspe River (Reach 6) and Jews Harp Creek are 'very poor', Pipers Creek is 'poor', and the Campaspe River (Reach 7) and Five Mile Creek are 'moderate'.

Table 3 Index of Stream Condition Assessment scores for waterways in upper Campaspe Catchment

Waterway	Hydrology	Physical form	Streamside Zone	Water Quality	Aquatic Life	Condition
Campaspe River (Reach 6)	2	6	5	4	5	Very Poor
Campaspe River (Reach 7)	8	6	5	-	5	Moderate
Pipers Creek (Reach 23)	4	7	5	-	4	Poor
Five Mile Creek (Reach 24)	6	7	7	-	4	Moderate
Jews Harp Creek (Reach 25)	4	5	3	-	5	Very Poor

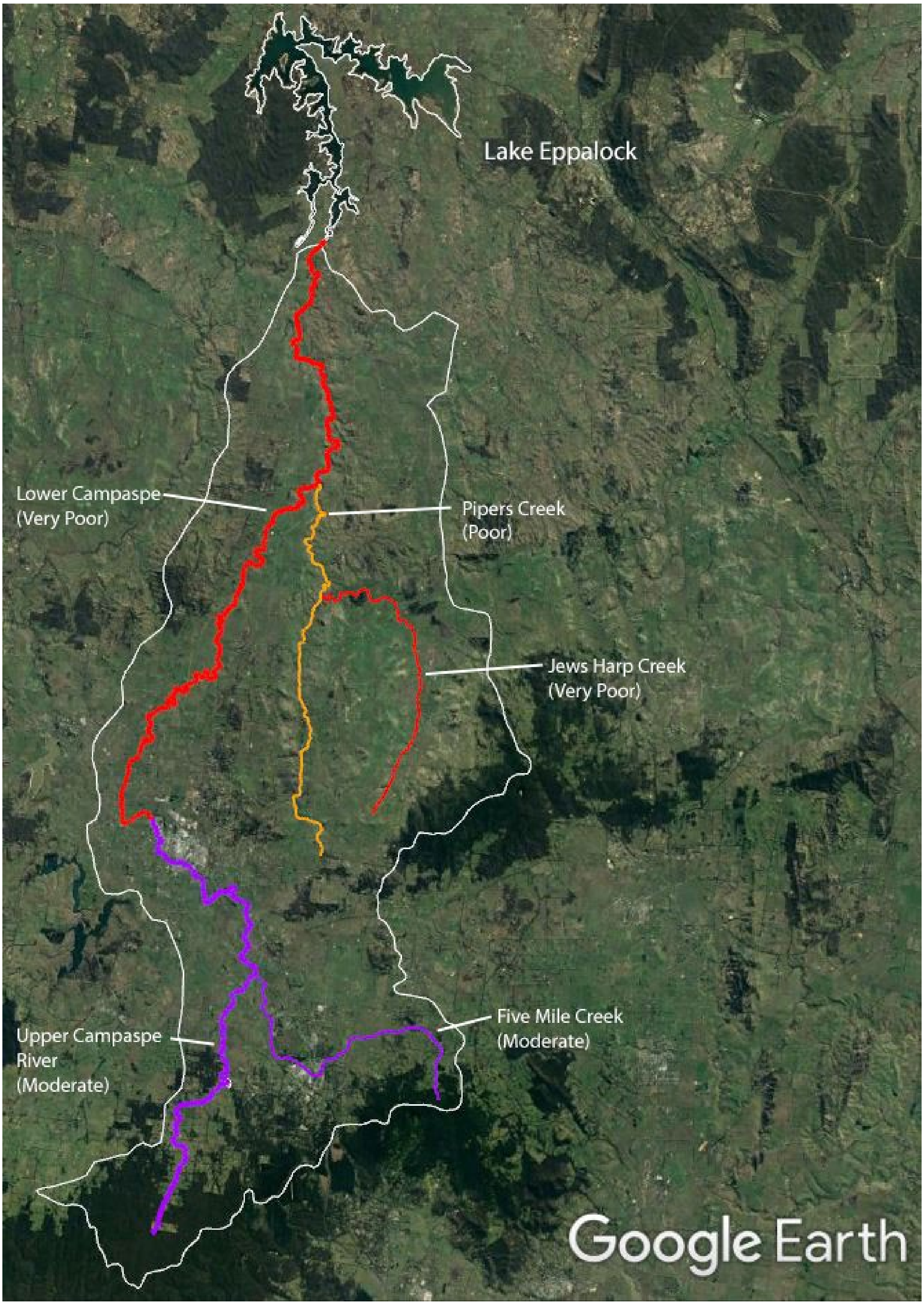

Figure 3 ***Index of Stream Condition 2010 waterway assessment scores***

3. Water Quantity

Volumetric data is presented in this section – both streamflow and Kyneton WRP discharge volume data.

3.1 Streamflow for the Campaspe River

A relatively new streamflow gauging station has been installed on the Campaspe River at Kyneton, upstream of the Kyneton WRP discharge point since December 2019. A rainfall runoff model was developed in order to extend the existing record over a longer period (see GHD 2022a). A summary of observed and modelled streamflow from that report is presented in Figure 4 (normal y axis) and in Figure 5 (log y axis) and a comparison of the flow duration curve for observed and modelled streamflows is presented in Figure 6. Whilst there may not always be an exact match on any given day between observed and modelled streamflow, the flow duration curves show that the modelled data is statistically similar to the observed data.

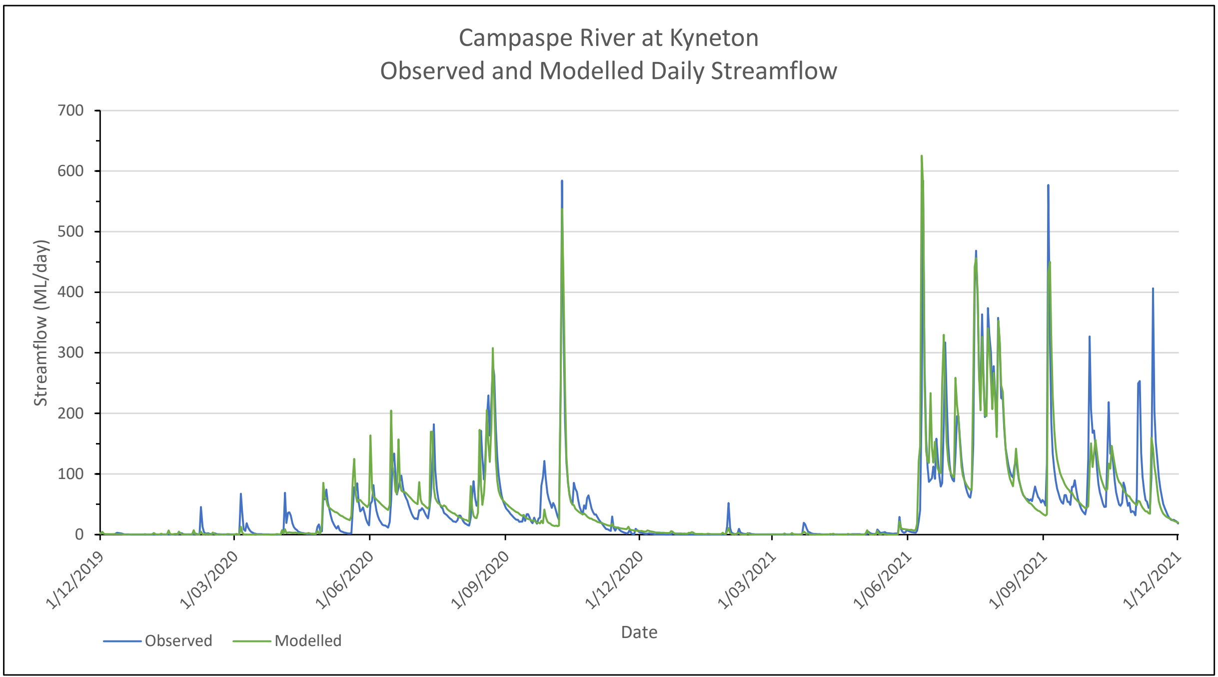

Figure 4 ***Observed and modelled streamflow for Campaspe River at Kyneton (normal y scale)***

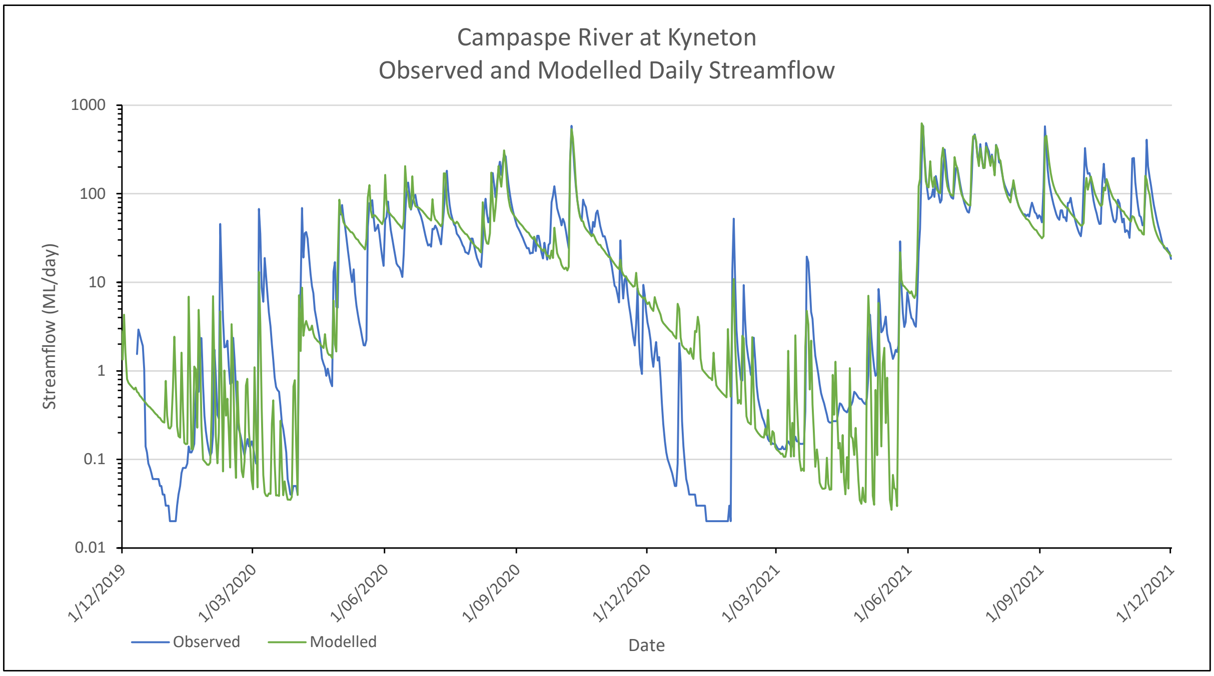

Figure 5 ***Observed and modelled streamflow for Campaspe River at Kyneton (log y scale)***

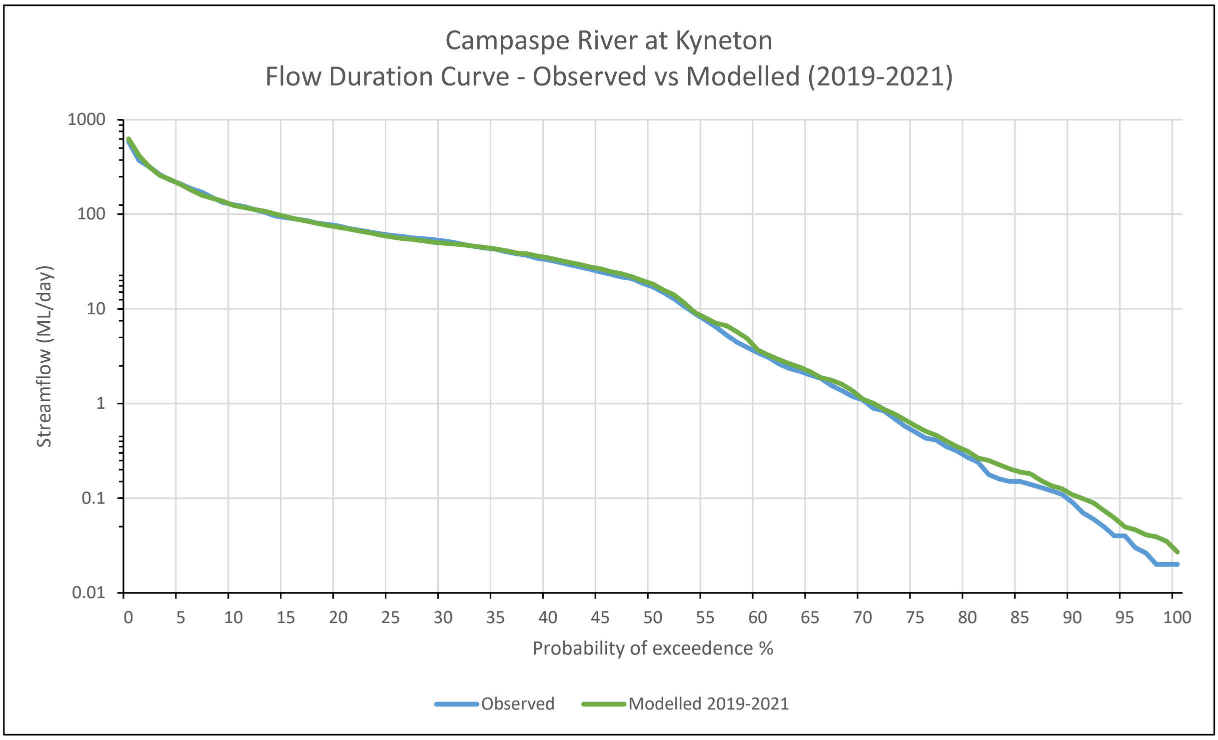

Figure 6 ***Flow duration curve - observed and modelled streamflow for Campaspe River at Kyneton***

Modelled annual streamflow volume for the Campaspe River at Kyneton from 1950 to 2021 is shown in Figure 7. The median streamflow volume for the 1950-1996 period was 18,046 ML/year and this median has reduced to 8,159 ML/year from 1997 – 2021. This 'step change' in streamflow, is similar to a step change noted for the Ashbourne streamflow gauge (GHD 2022).

Statistics on daily streamflow, grouped by month, for the Campaspe River at Kyneton (1997-2021) are presented in Figure 8 and Table 4 and show summer and autumn flows are lower compared to winter and spring. August has the highest median streamflow with 63 ML/day and March has the lowest median streamflow with 0.128 ML/day.

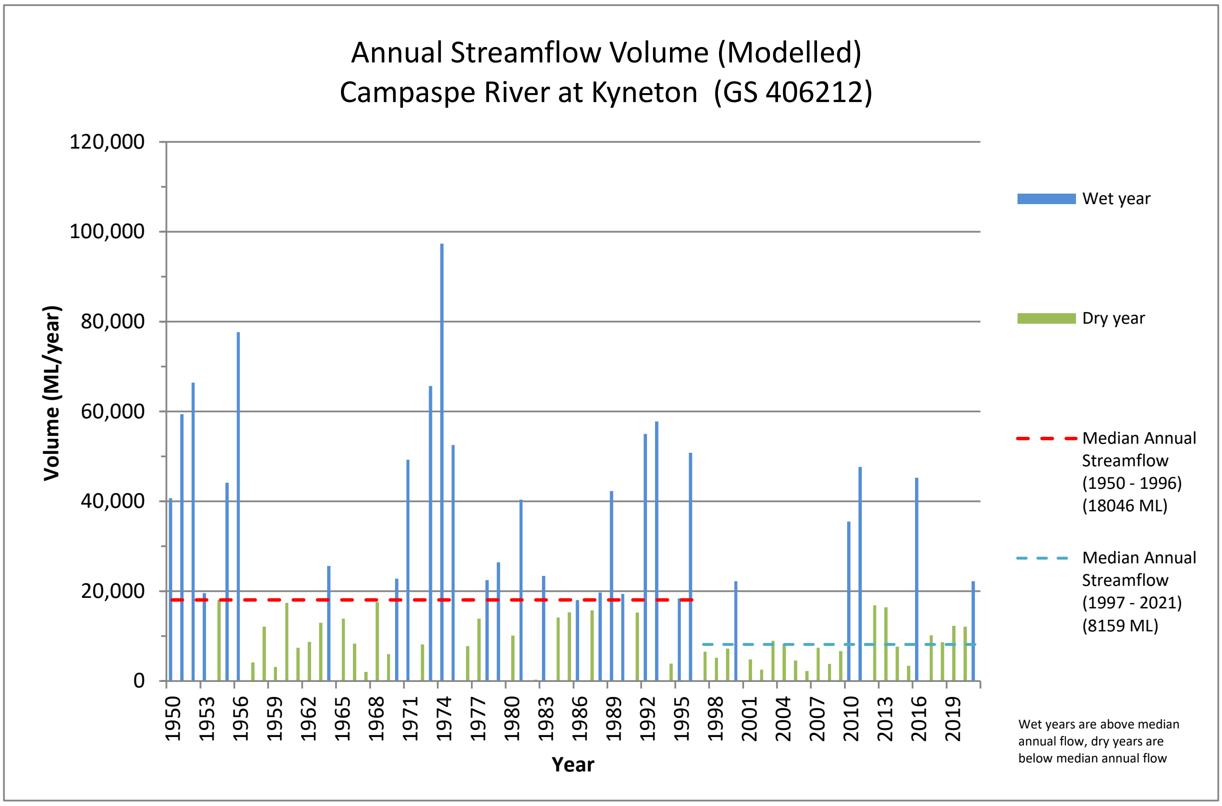

Figure 7 Annual streamflow volume (modelled) for the Campaspe River at Kyneton (1950 – 2021)

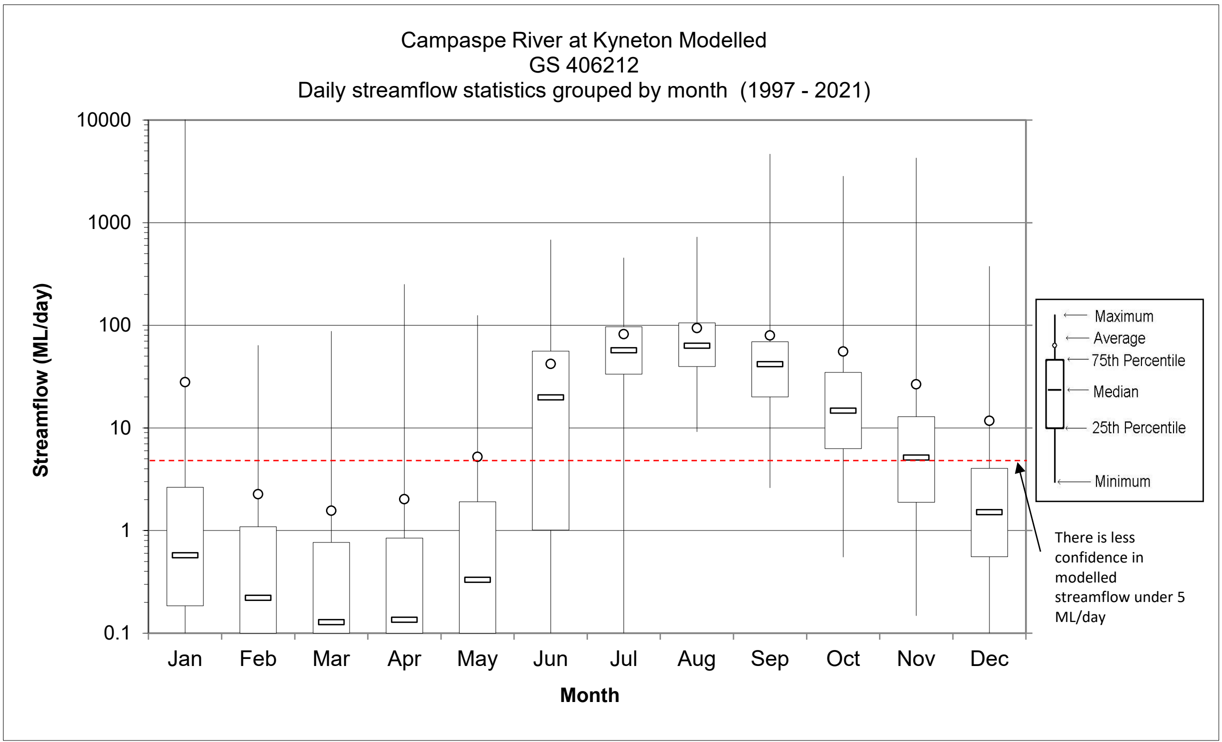

Figure 8 Daily streamflow statistics grouped by month for the Campaspe River at Kyneton (1997 – 2021)

Table 4 ***Daily streamflow statistics grouped by month for the Campaspe River at Kyneton (1997 – 2021)***

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	ML/day											
Maximum	13551	63.8	87.7	251.5	125.0	682.4	456.4	727.1	4680.1	2850.1	4274.3	376.3
90th percentile	9.4	4.3	4.1	3.2	18.6	99.6	187.3	212.4	136.3	107.8	49.0	17.4
75th percentile	2.6	1.1	0.8	0.8	1.9	56.1	96.7	105.7	69.0	34.8	12.8	4.0
Median	0.6	0.2	0.128	0.13	0.3	19.8	56.9	63.0	41.7	14.7	5.1	1.5
25th percentile	0.2	0.1	0.0	0.0	0.1	1.0	33.4	39.6	20.1	6.3	1.9	0.6
10th percentile	0.1	0.0	0.0	0.0	0.0	0.1	22.3	25.6	11.4	3.0	0.9	0.2
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	2.6	0.6	0.1	0.0
Average	27.9	2.3	1.6	2.0	5.2	42.0	81.8	93.8	79.5	55.4	26.6	11.7
Number	775	706	775	750	775	750	775	775	750	775	750	745

Statistics on daily streamflow, grouped by six month period for the Campaspe River at Kyneton (1997-2021) are presented in Figure 9 and Table 5 and show the June-November period has a median streamflow of 33.4 ML/day compared to the December – May period with a median streamflow of 0.4 ML/day.

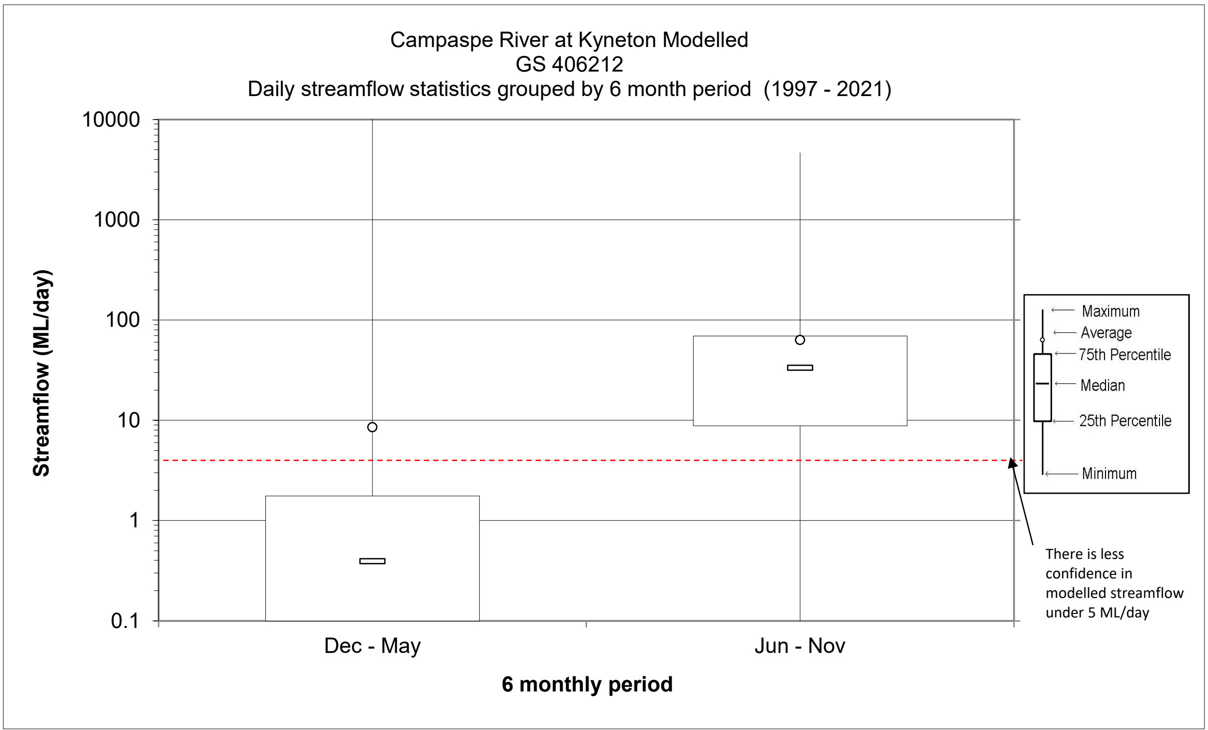

Figure 9 ***Daily streamflow statistics grouped by six-month period for the Campaspe River at Kyneton (1997 – 2021)***

Table 5 Daily streamflow statistics grouped by six-month period for the Campaspe River at Kyneton (1997 – 2021)

	Dec - May	Jun - Nov
	ML/day	
Maximum	13551	4680.1
90th percentile	7.2	139.0
75th percentile	1.8	69.5
Median	0.4	33.4
25th percentile	0.1	8.8
10th percentile	0.0	2.0
Minimum	0.0	0.0
Average	8.6	63.4
Number	4526	4575

3.2 Historical discharge from Kyneton WRP to the Campaspe River

Discharge data from July 2017 to June 2020 was available to establish an 'actual' discharge volume (used later in this report for the establishment of a baseline of discharge for comparison of other discharge options). Daily discharge volumes are presented in Figure 10 and monthly values in Figure 11.

Over the three-year period, from July 2017 to June 2020 (a total of 1096 days and 36 months), discharge to the Campaspe River occurred on 572 days (52.2% of days) and 26 months (72% of months). The daily non-zero median discharge volume was 2.5 ML/day, and the monthly non-zero median discharge was 45.3 ML/month.

Annual discharges from the Kyneton WRP are presented in Table 6 for 2017-18 to 2019-20. The total discharge volume was 1456.2 ML over the three-year period.

Table 6 Annual discharge from Kyneton WRP to Campaspe River

Water Year	Discharge
	ML/year
2017-18	496.3
2018-19	435.6
2019-20	524.2
Total	**1456.2**

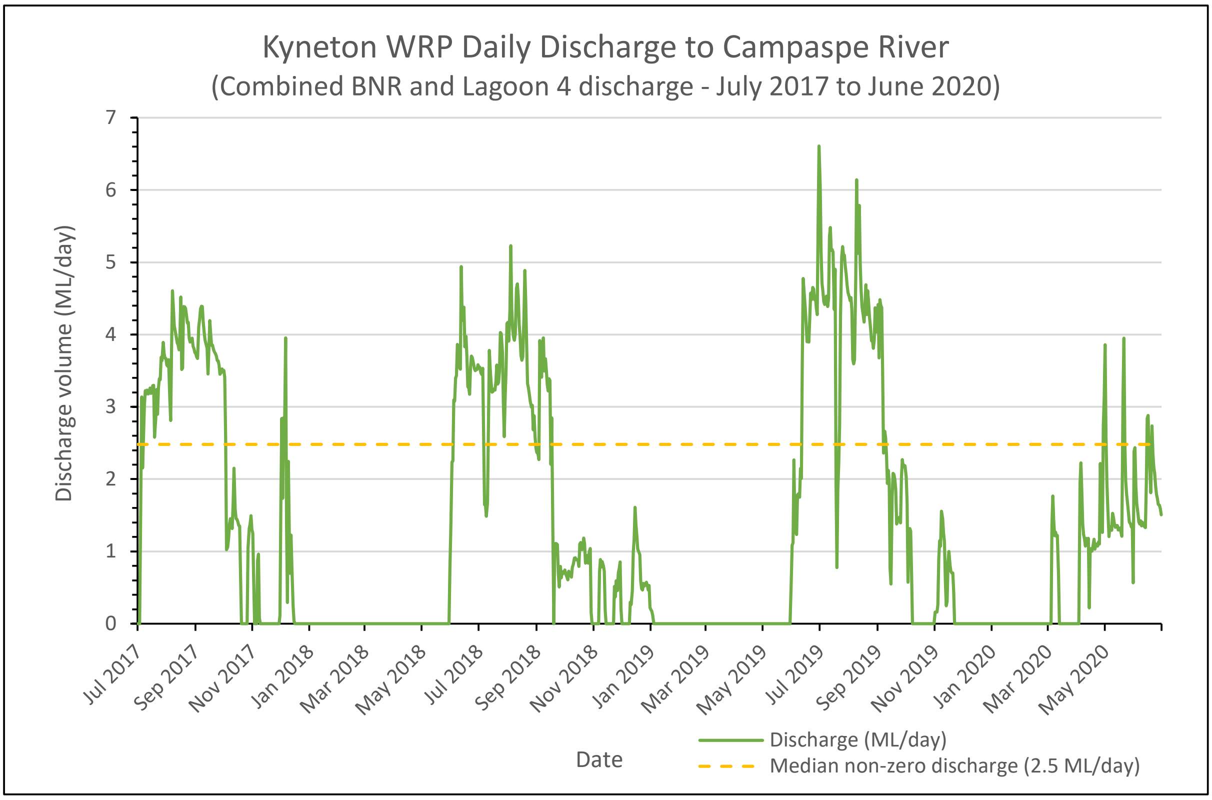

Figure 10 ***Daily discharge volume data for Kyneton WRP (2017-2020)***

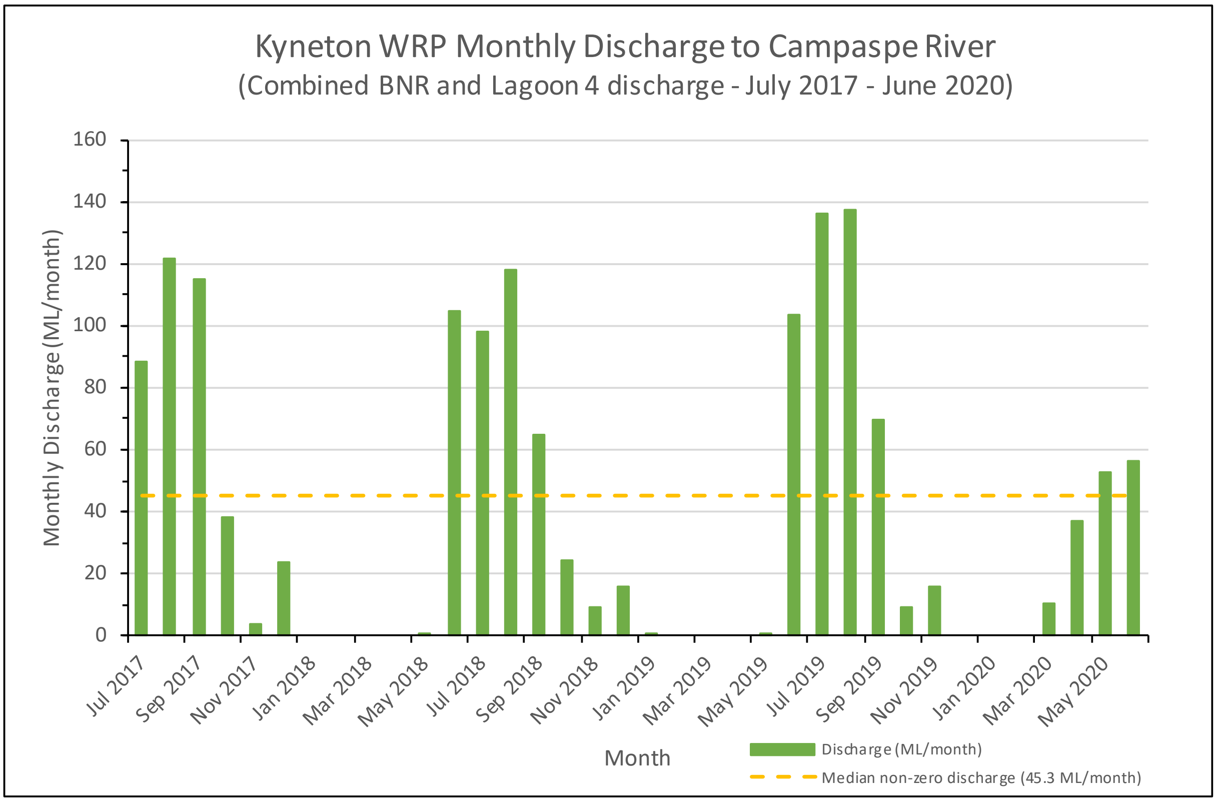

Figure 11 ***Monthly discharge volume data for Kyneton WRP (2017-2020)***

Statistics on daily discharge to the Campaspe River from July 2017 to June 2020 are presented in Figure 12 and in Table 7, grouped by month. Result show the month with the highest median discharge to be August with 4.031 ML/day and period of November to May with the lowest median daily discharge of 0 ML/day.

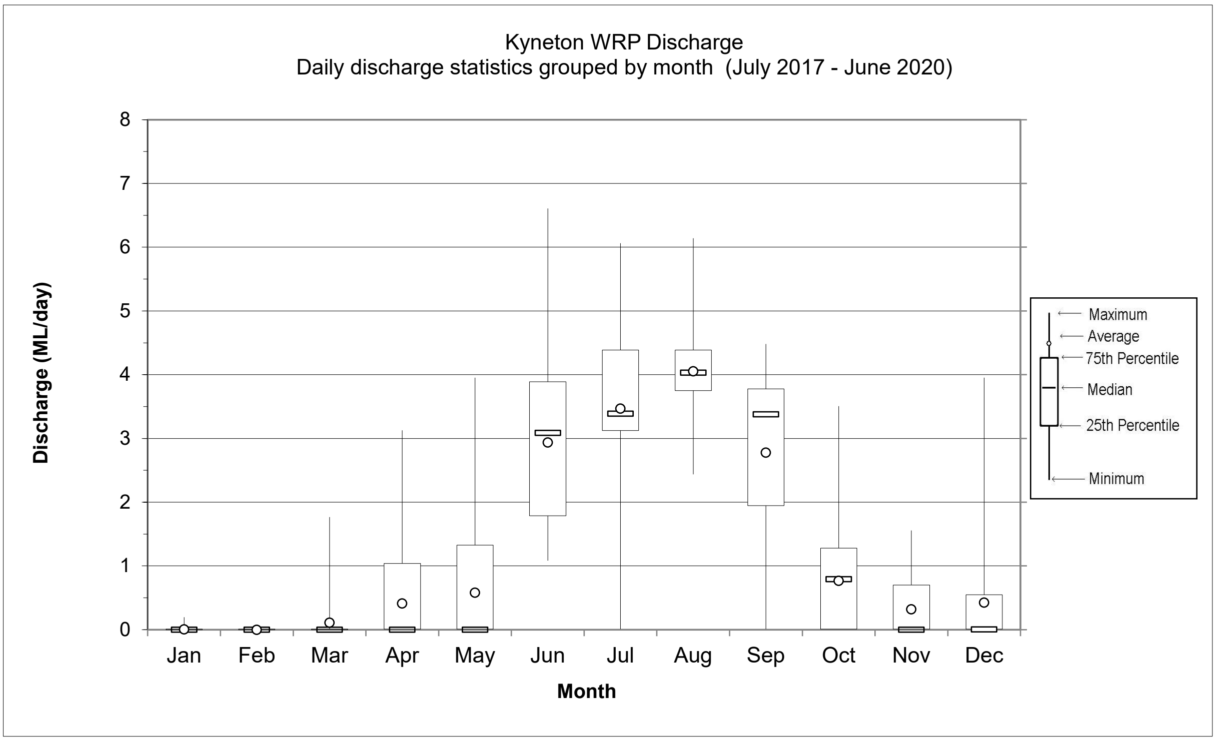

Figure 12 Statistics on daily discharge volume data grouped by month for Kyneton WRP (July 2017 – June 2020)

Table 7 Statistics on daily discharge volume data grouped by month for Kyneton WRP (July 2017 – June 2020)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	ML/day											
Maximum	0.195	0.000	1.767	3.127	3.952	6.608	6.062	6.141	4.483	3.506	1.557	3.954
90th percentile	0.000	0.000	0.000	1.236	1.590	4.490	5.094	4.682	4.176	1.453	0.906	1.358
75th percentile	0.000	0.000	0.000	1.038	1.325	3.888	4.388	4.385	3.778	1.280	0.701	0.546
Median	0.000	0.000	0.000	0.000	0.000	3.088	3.387	4.031	3.379	0.793	0.000	0.000
25th percentile	0.000	0.000	0.000	0.000	0.000	1.786	3.125	3.751	1.945	0.000	0.000	0.000
10th percentile	0.000	0.000	0.000	0.000	0.000	1.379	1.875	3.193	0.788	0.000	0.000	0.000
Minimum	0.000	0.000	0.000	0.000	0.000	1.084	0.000	2.437	0.000	0.000	0.000	0.000
Average	0.005	0.000	0.109	0.414	0.581	2.937	3.469	4.055	2.780	0.767	0.322	0.427
Number	93	85	93	90	93	90	93	93	90	93	90	93

Statistics on daily discharge to the Campaspe River from July 2017 to June 2020 are presented in Figure 13 and in Table 8, grouped by six monthly period. Result show the Jun-November period has the highest median discharge with 2.574 ML/day and period of December to May with the lowest median daily discharge of 0 ML/day.

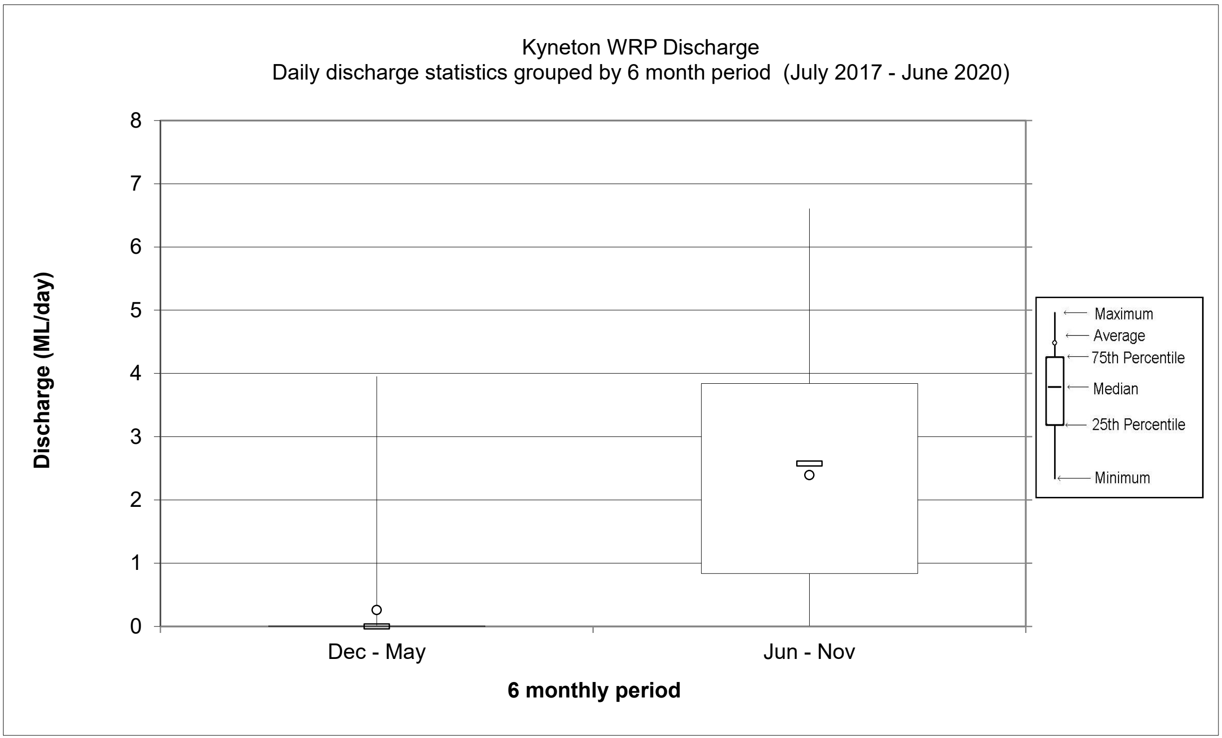

Figure 13 ***Statistics on daily discharge volume data for Kyneton WRP grouped by six month period (July 2017 – June 2020)***

Table 8 ***Statistics on daily discharge volume data grouped by month for Kyneton WRP (July 2017 – June 2020***

	Dec - May	Jun - Nov
	ML/day	
Maximum	3.954	6.608
90th percentile	1.221	4.424
75th percentile	0.000	3.841
Median	0.000	2.574
25th percentile	0.000	0.836
10th percentile	0.000	0.000
Minimum	0.000	0.000
Average	0.259	2.394
Number	547	549

3.2.1 Historical discharge as a proportion of streamflow

Discharge to the Campaspe River from the Kyneton WRP has been governed by streamflow measured at the Redesdale gauging station (and it is proposed to use the streamflow gauge at Kyneton for future releases). Discharge volumes and streamflow for the Campaspe River are presented in Figure 14 for daily data and in Figure 16 for monthly data. The streamflow to discharge ratio for the 2017-2020 period is presented in Figure 15 and shows a median value of 14.5 (i.e. 14.5 ML/day of streamflow to 1 ML/day of discharge). On a daily discharge basis, the total streamflow measured at Redesdale over the 2017-18 to 2019-20 three-year period was 63,890 ML, and estimated at Kyneton (using modelled and observed data) to be 31,600 ML. Discharge from Kyneton WRP to the Campaspe River over the same period was 1,452 ML (see Table 6). The discharge volume, as a proportion of streamflow measured at Redesdale over the three-year period, was 2.3% (1,452 / 63,890), and for streamflow estimated at Kyneton over the same period the proportion was 4.6% (1,452 / 31,600).

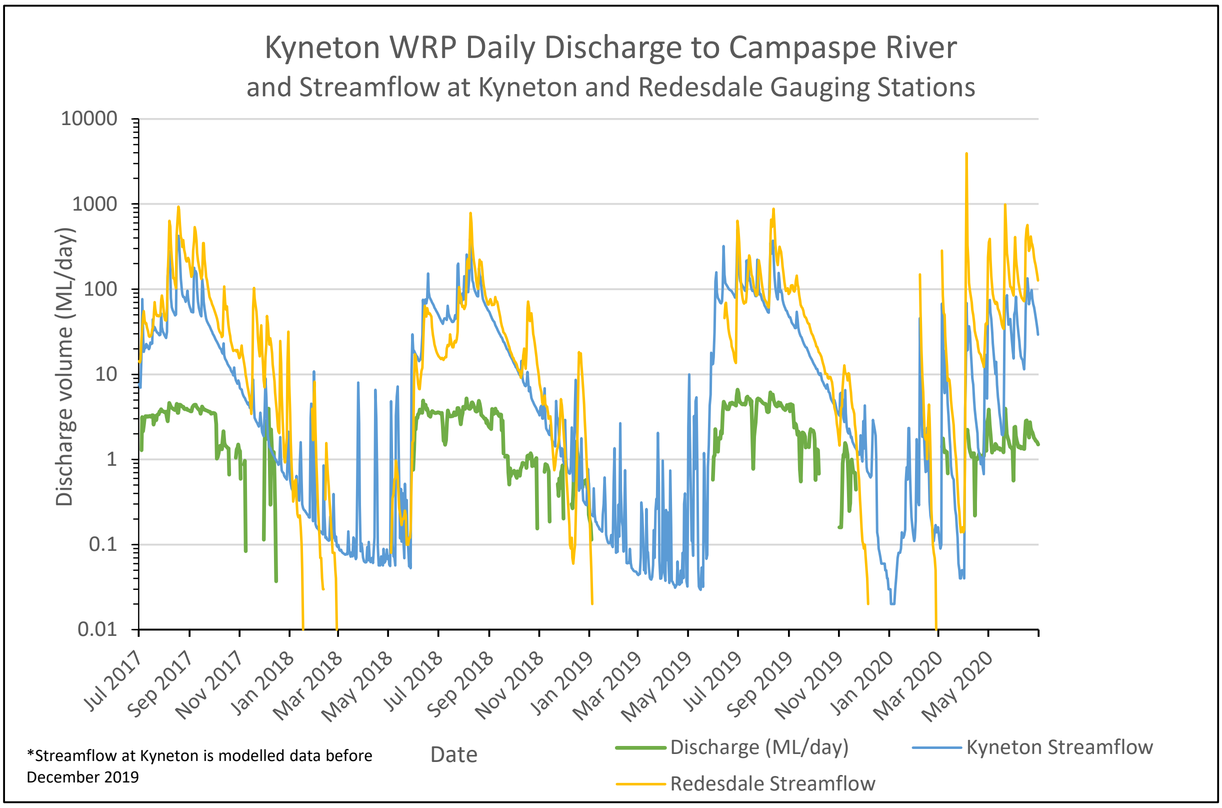

Figure 14 ***Daily discharge for Kyneton WRP and daily streamflow volume for Kyneton and Redesdale gauges (July 2017 – June 2020)***

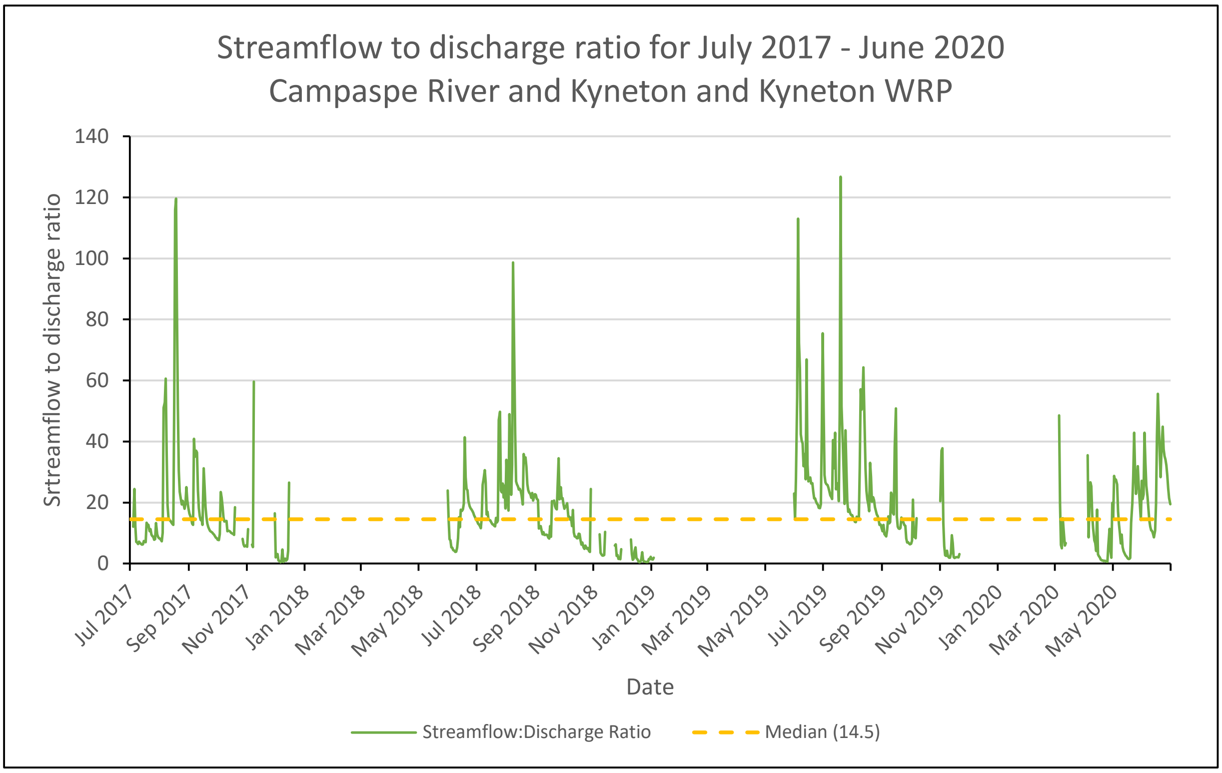

Figure 15 ***Streamflow to discharge ratio for Campaspe River at Kyneton and Kyneton WRP (July 2017 – June 2020)***

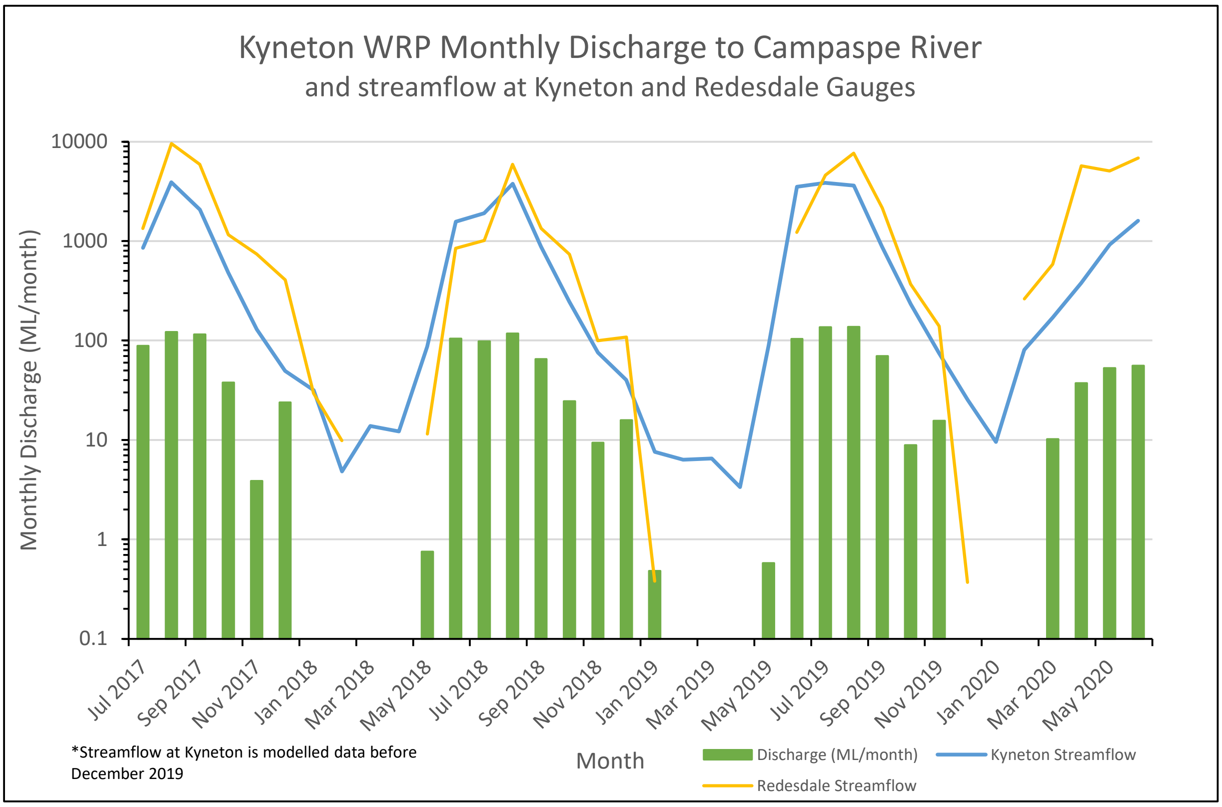

Figure 16 ***Monthly discharge for Kyneton WRP and monthly streamflow volume for Kyneton and Redesdale gauges (July 2017 – June 2020)***

3.3 Current and future Kyneton WRP discharges to the Campaspe River

Whilst historical discharges to the Campaspe River from the Kyneton WRP have at times been a combination of treated domestic and lagoon discharge, future discharge volumes to the Campaspe River are intended to be domestic (BNR) only. The discharge volume to the river will be dependent on a number of factors: the available streamflow, domestic and tradewaste inflow into the WRP, volume of storage within the Kyneton WRP's lagoons, irrigation area and irrigation demand. These factors have been taken into account within a water balance model that has recently been developed (GHD 2022a).

3.3.1 Current Kyneton WRP inflows 2019-2021

Domestic and tradewaste inflow data for 2019 – 2021 for the Kyneton WRP are presented in Figure 17. For this period, the average annual domestic inflow was 1.97 ML/day and 0.8 ML/day for tradewaste. A key consideration for inflow volumes at Kyneton WRP is the infiltration of stormwater. Whilst 2019 was a 10th percentile rainfall year, both 2020 and 2021 were higher than the median rainfall (annual statistics are defined for 1997 to 2021) – see Figure 18. As such, inflow into Kyneton WRP during wetter periods like 2020 and 2021 are likely to be higher than drier years.

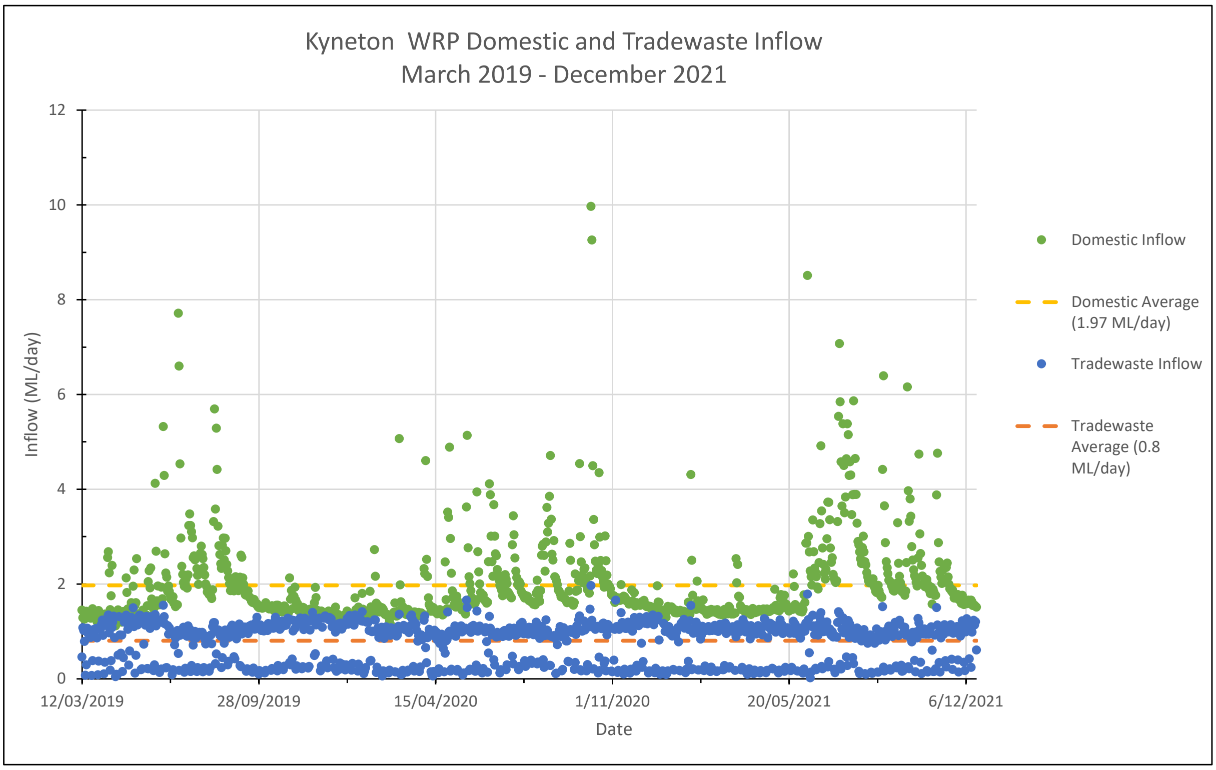

Figure 17 Daily inflows into Kyneton WRP March 2019 - December 2021 (approximately. 2.8 years of data)

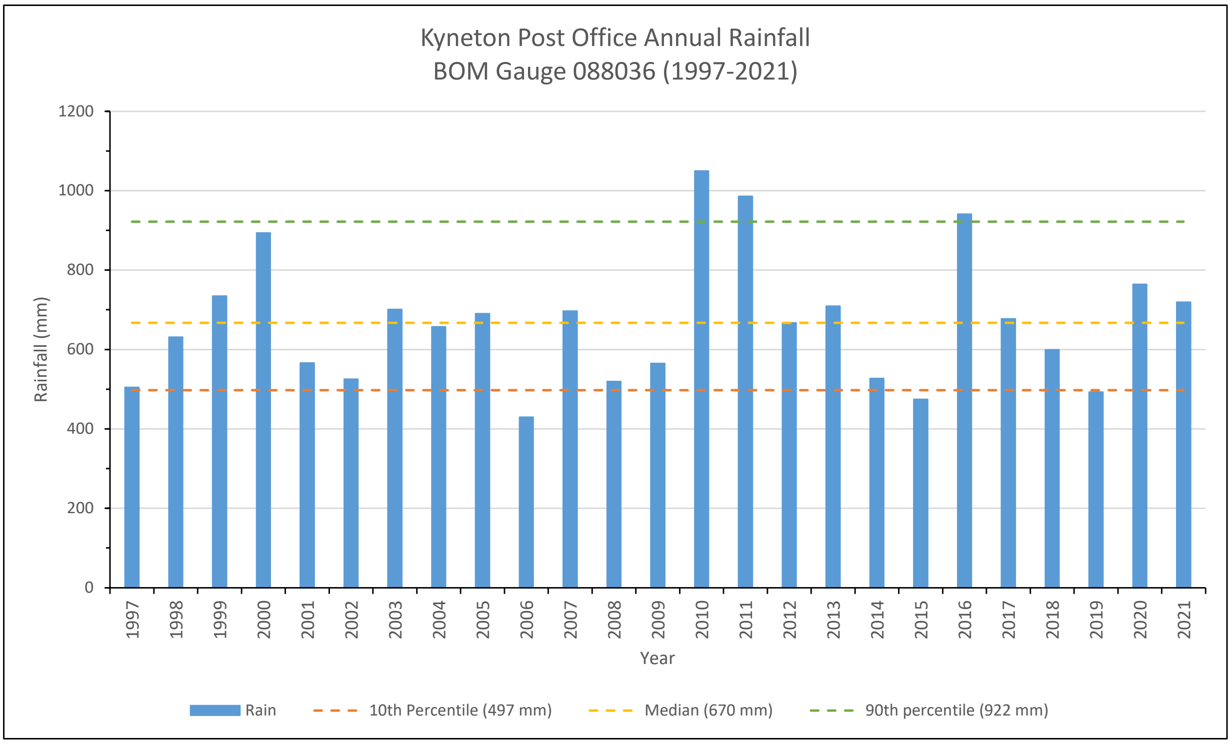

Figure 18 ***Annual rainfall data for Kyneton 1997 to 2021***

3.3.2 Predicted WRP discharge to river during 2022 and 2036 scenarios

In order to determine the risks associated with Kyneton WRP discharges to the Campaspe River, two scenarios have been investigated – a 2022 and 2036 scenario. These scenarios align with data available on population growth and corresponding inflows into the Kyneton WRP, shown in the Kyneton Town Vision (GHD 2021)

Inflows into the Kyneton WRP for these scenarios were then processed through the water balance for Kyneton WRP (GHD 2022a). The inflows for 2022 were 1.6 ML/day domestic and 1.1 ML/day tradewaste. and for 2036, 2.4 ML/day domestic inflow and 1.1 ML/day tradewaste.

The outputs from the water balance model to the Campaspe River (using a streamflow-to-discharge ratio of 1:2) are shown as daily values in Figure 18, as monthly values in Figure 19 and as annual values in Figure 20. More water was discharged to the Campaspe River under the 2036 scenario (an average over the 3 years of 368 ML/year) compared to the 2022 scenario (average annual volume of 255 ML/year). For the daily and monthly discharges, it was typical that the 2036 scenario discharged more water than the 2022 scenario but this was not always the case.

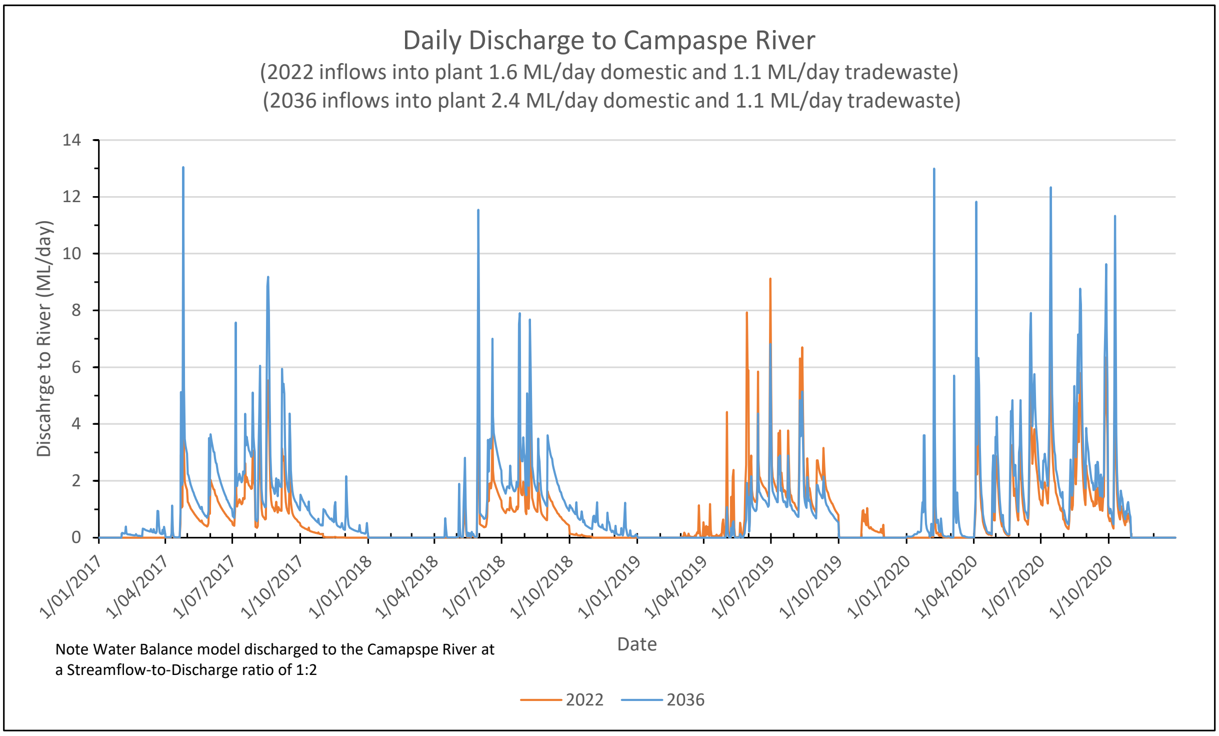

Figure 19 Daily discharge to Campaspe River under 2022 and 2036 scenarios

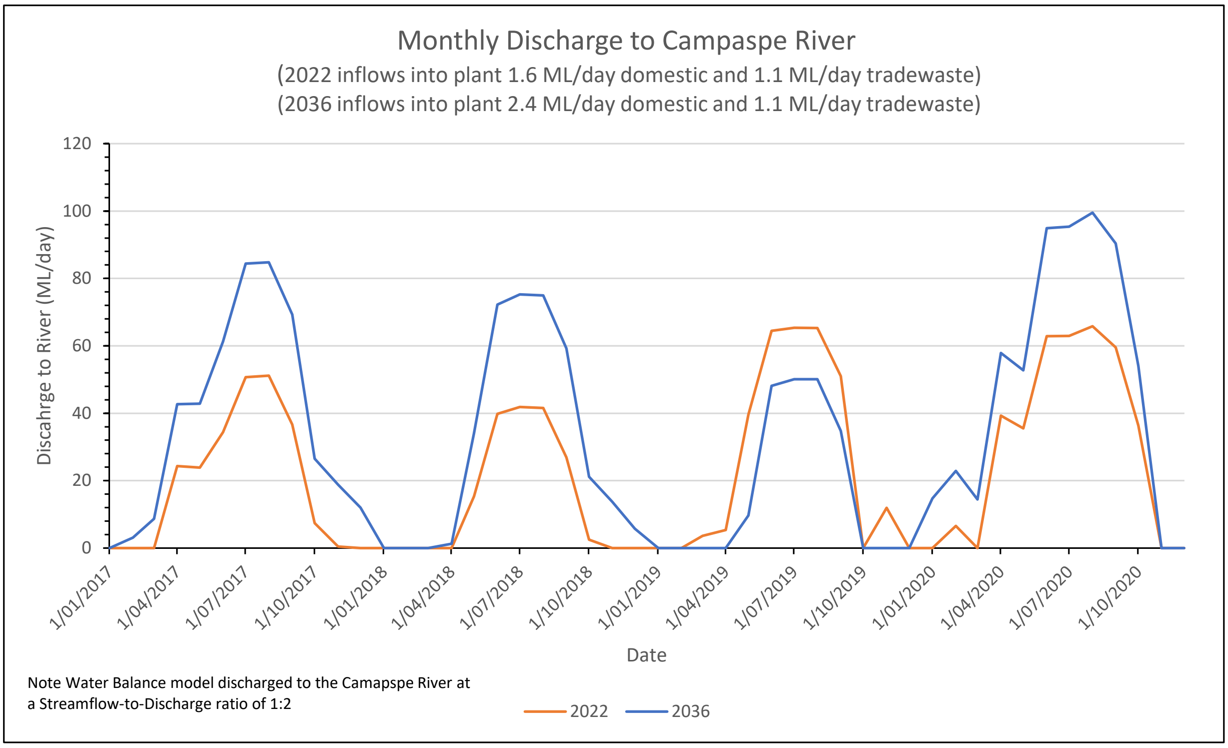

Figure 20 ***Monthly discharge to Campaspe River under 2022 and 2036 scenarios***

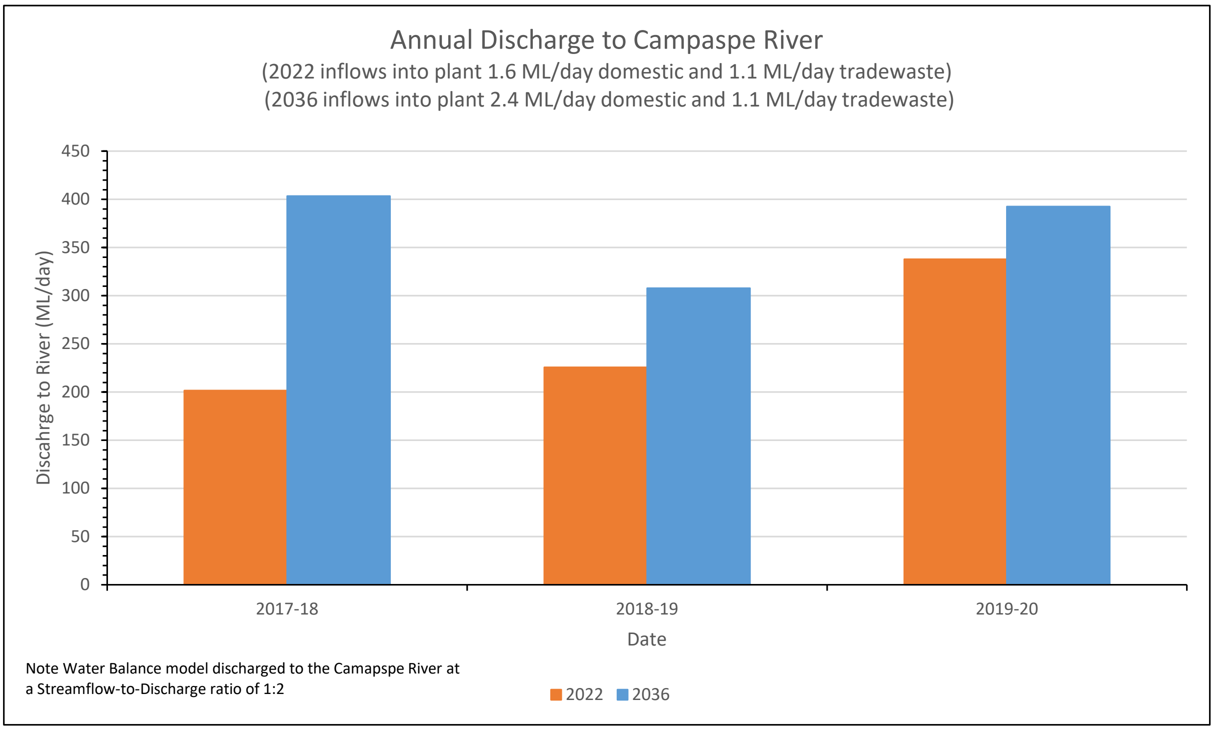

Figure 21 ***Annual discharge to Campaspe River under 2022 and 2036 inflow conditions***

4. Water Quality

A broad range of water quality data was available for this project – a total of over 20,296 data points over the 2015-2021 period, covering parameter groups such as general physico-chemical, metals, nutrients, microbiology and cations/ionic salts. Data was available for the Campaspe River upstream and downstream of the discharge point, as well as for WRP influent and treated discharge for the BNR plant, Lagoon 4 and a combined discharge of the two treatment systems. An overview of water quality sites and the Kyneton WRP discharge point on the Campaspe River is presented in Figure 22. Detailed presentation for all water quality data in this project is available in GHD (2022c).

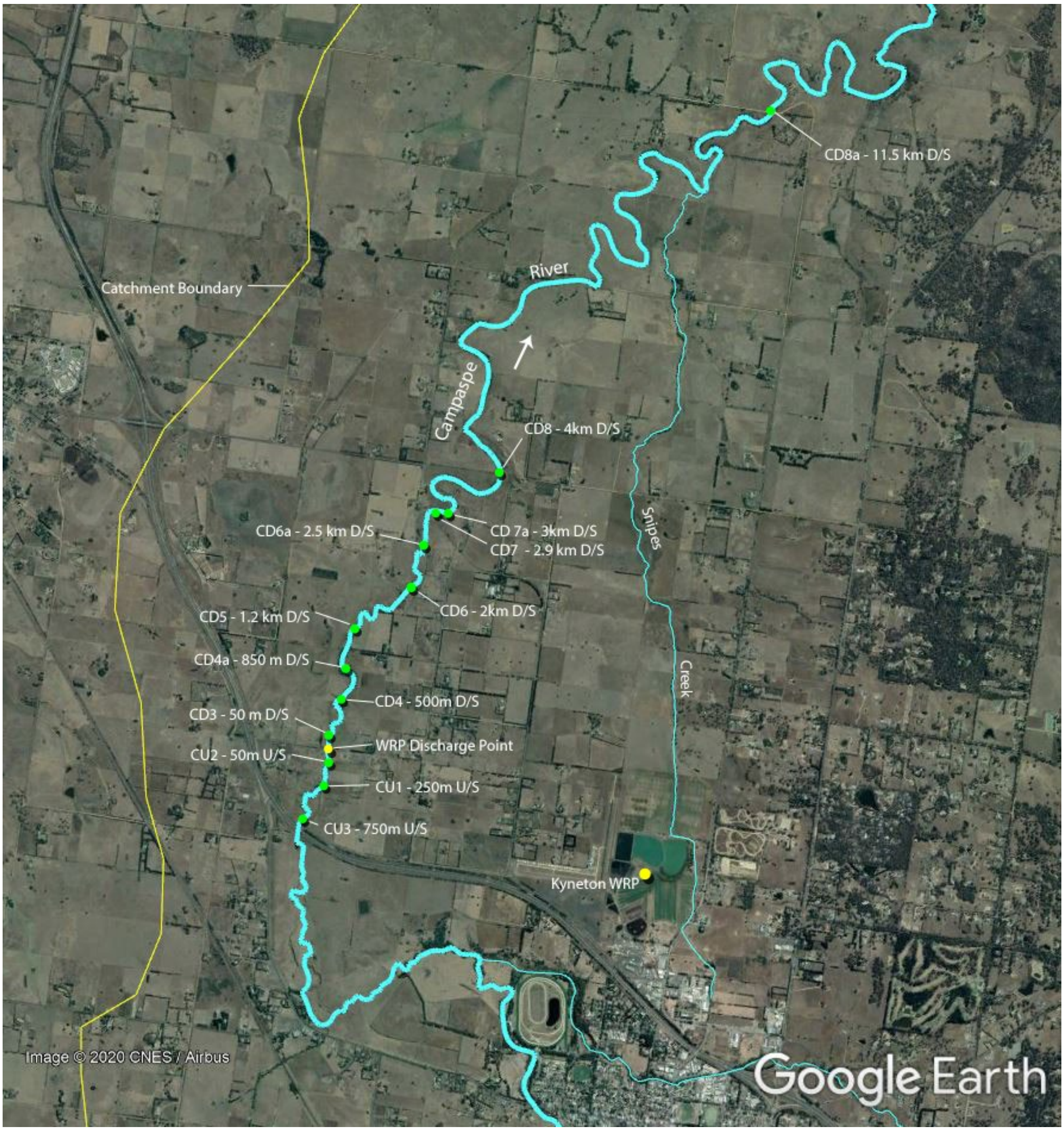

Figure 22 Water quality sampling sites and Kyneton WRP discharge point on the Campaspe River

4.1 Water quality guidelines

The Campaspe River falls under the Central Foothills and Coastal Plains (Uplands of the Campaspe River) in the ERS (2021). The environmental quality indicators and objectives for the river are summarised in Table 9

Table 9 Physical environmental quality indicators and objectives from ERS (2021) for Central Foothills and Coastal Plains (Uplands of the Campaspe River)

Indicator	Unit	Objective statistic / range	Objective value
Dissolved oxygen	% saturation	25th Percentile - Maximum	>=70 - 130
Electrical Conductivity	µS/cm	75th percentile	<2000
pH	pH units	25th Percentile – 75th Percentile	6.8 – 8.0
Total nitrogen	mg/L	75th percentile	<1.05
Total phosphorus	mg/L	75th percentile	<0.055
Toxicants			95% Protection
Turbidity	NTU	75th percentile	<15

For other parameters for which data is available for this project, but there are no guideline values for them in ERS (2021), ANZG (2018) (which is based on ANZECC (2000)) provides guidance and these are presented in Table 10.

Table 10 Physical environmental quality trigger values ANZG (2018)

Indicator	Unit	Objective statistic / range	Objective value
Arsenic	mg/L	Toxicant trigger value - 95% species level of protection	0.0024
Cadmium	mg/L	Toxicant trigger value - 95% species level of protection	0.0002
Chromium	mg/L	Toxicant trigger value - 95% species level of protection	0.001
Copper	mg/L	Toxicant trigger value - 95% species level of protection	0.0014
Lead	mg/L	Toxicant trigger value - 95% species level of protection	0.0034
Mercury	mg/L	Toxicant trigger value - 95% species level of protection	0.0006
Nickel	mg/L	Toxicant trigger value - 95% species level of protection	0.011
Nitrogen (Ammonia) as N	mg/L	Toxicant trigger value - 95% species level of protection at pH of 8	0.9
Nitrogen (Total Oxidised) as N	mg/L	Default trigger value for moderately disturbed ecosystems	0.015
Nitrogen – Nitrate#	mg/L	95% Level of species protection. ('NIWA' guidelines)	2.4
Zinc	mg/L	Toxicant trigger value - 95% species level of protection	0.008

Primary and secondary contact guidelines are presented in Table 11.

Table 11 Primary and Secondary Contact / Recreation trigger values ERS (2018), ANZG (2018) and NHMRC (2008)

Indicator	Unit	Objective statistic / range	Objective value
Ammonia NH_3-N	mg/L	Guidelines for Managing Risks in Recreational Water – NHMRC (2008) – Table 9.3 (values in this table relate to ingestion of water and the limits are based on drinking water guideline limits which is 0.5 mg/L for ammonia).	0.5
Dissolved Oxygen	%	NHMRC (2008) The minimum value is specified as > 80% saturation.	80%
E. coli (primary contact)	orgs/100 mL	For freshwater, using ERS (2021), 95th percentile (using Hazen Method) of < 260 E. coli / 100 mL. with a minimum of 60 samples. The Guidelines for Managing Risks in Recreational Water (NHMRC 2008), table 5.7, gives a basis for human health outcomes, but is based on enterococci concentrations to derive the probable human health outcomes (no data is available for enterococci for Campaspe River). Intestinal enterococci are considered the most suitable indicators for recreational use in water.	< 260 (95th percentile)
E. coli (secondary contact)	orgs/100 mL	For freshwater, using ERS (2021), 95th percentile (using Hazen Method) of < 5,500 *E. coli* / 100 mL. with a minimum of 60 samples.	< 5,500 (95th percentile)
Nitrate – N (NO_3-N)	mg/L	NHMRC (2008) – Table 9.3 (values in this table relate to ingestion of water and the limits are based on drinking water guideline limits which is 50 mg/L for Nitrate – which calculates to be 50 / 4.42 = 11.3 mg/L for Nitrate-N).	11.3
Nitrite – N (NO_2-N)	mg/L	NHMRC (2008) – Table 9.3 (values in this table relate to ingestion of water and the limits are based on drinking water guideline limits which is 3 mg/L for Nitrite – which calculates to be 3 / 3.28 = 0.91 mg/L for Nitrite-N).	0.91
pH	pH units	NHMRC (2008). The pH of recreational water should be within the range 5–9, assuming that the buffering capacity of the water is low near the extremes of the pH limits.	5 – 9 (Min – Max)
Suspended solids	mg/L	ANZG (2018) Section 5.2.3.3. To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter black disc (Secchi disc) should exceed 1.6 m. A substitute for Sechii disk depth is suspended solids and a value of 15 mg/L is adopted until a better value can be found.	15
Temperature	deg. C	ANZG (2018) Section 5.2.3.3, Table 5.2.3. Water cooler than 15°C is extremely stressful to swimmers not wearing appropriate protective clothing. Extended periods of continuous immersion at these temperatures may cause death. Thermal stress can be induced by temperatures exceeding the normal skin temperature of 33°C, and there is a risk of injury with prolonged exposure to temperatures above 34–35°C	15 - 33
Total dissolved solids	mg/L	ANZG (2018) Section 5.2.3.3, Table 5.2.3	1000

Irrigation water quality trigger values were obtained from ANZG (2018), section 4.2 and relevant parameters are presented in Table 12.

Table 12 Irrigation trigger values EPA (2003) and ANZG (2018)

Indicator	Unit	Objective statistic / range	Objective value
E. coli	orgs/100 mL	EPA (2003) in the Guidelines for use of reclaimed water set out different ranges of *E. coli* for each class of wastewater (Class A < 10, Class B < 100, Class C < 1000, Class D < 10000 E. coli / 100 mL). Assume Class B is an acceptable level of quality.	100 (median over 12 month period)
Electrical Conductivity	µS/cm	ANZG (2018) Table 4.2.5. The EC limit is highly dependent on soil type and crop types so 950 uS/cm is a guide only.	950
pH	pH units	ANZG (2018) Section 4.2.10.1, To limit corrosion and fouling of pumping, irrigation and stock watering systems, pH should be maintained between 6 and 8.5 for groundwater systems and between 6 and 9 for surface water systems.	6 – 9 (Min – Max)
Total N	mg/L	ANZG (2018) Section 4.2.7, Table 4.2.11. Long term value for irrigation (up to 100 years) is based on maintaining crop yield, preventing bioclogging of irrigation equipment and minimising off-site impacts from runoff or deep drainage. A short term value is also available (up to 20 years of irrigation) and the range provided is 25 – 125 mg/L depending on the individual circumstances of each site.	5
Total P	mg/L	ANZG (2018) Section 4.2.3.3, Table 4.4.2. The 0.05 mg/L limit is a long term value (up to 100 years of irrigation) and is provided to minimise the risk of 'bioclogging' of irrigation equipment (this might be considered of relatively low consequence). Short term values (up to 20 years of irrigation) are also presented for total P – and these are 0.8 – 12 mg/L depending on site specific requirements.	0.05
Nitrite – N (NO_2-N)	mg/L	NHMRC (2008) – Table 9.3 (values in this table relate to ingestion of water and the limits are based on drinking water guideline limits which is 3 mg/L for Nitrite – which calculates to be 3 / 3.28 = 0.91 mg/L for Nitrate-N).	0.91

Stock watering water quality trigger values were obtained from ANZG (2018), section 4.3 and relevant parameters are presented in Table 13.

Table 13 Stock watering trigger values EPA (2003) and ANZECC (2018)

Indicator	Unit	Objective statistic / range	Objective value
E. coli	orgs/100 ml	EPA (2003) in the Guidelines for use of reclaimed water set out different ranges of *E. coli* for each class of wastewater (Class A < 10, Class B < 100, Class C < 1000, Class D < 10000 E. coli / 100 mL). Cattle can drink Class A and B (although pigs may not drink the water).	100 (median over 12 month period)
Nitrate – N (NO_3-N)	mg/L	ANZG (2018) Section 4.3.3.3. Nitrate concentrations less than 400 mg/L in livestock drinking water should not be harmful to animal health. Stock may tolerate higher nitrate concentrations in drinking water, provided nitrate concentrations in feed are not high. Water containing more than 1500 mg/L nitrate is likely to be toxic to animals and should be avoided.	400
Nitrite – N (NO_2-N)	mg/L	ANZG Section 4.3.3.3. Concentrations of nitrite exceeding 30 mg/L may be hazardous to animal health.	30
Total Dissolved Solids	mg/L	ANZG Section 4.3.3.5. Table 4.3.1. Actual limit depends on the stock but poultry and cattle are the least tolerant. Sheep are tolerant to much higher concentrations.	2500

4.2 Campaspe River - upstream of discharge point

An overview of statistics of key water quality parameters for the Campaspe River upstream of the discharge point (combined data from sites CU1, CU2 and CU3 upstream of the discharge point, during the period 2015-2021 inclusively) is presented in Figure 23 and in Table 14. Results show there are non-compliances with some parameters including nutrients (total N and total P), ammonia, and for primary contact (i.e. swimming), with regards to *E. coli* concentration.

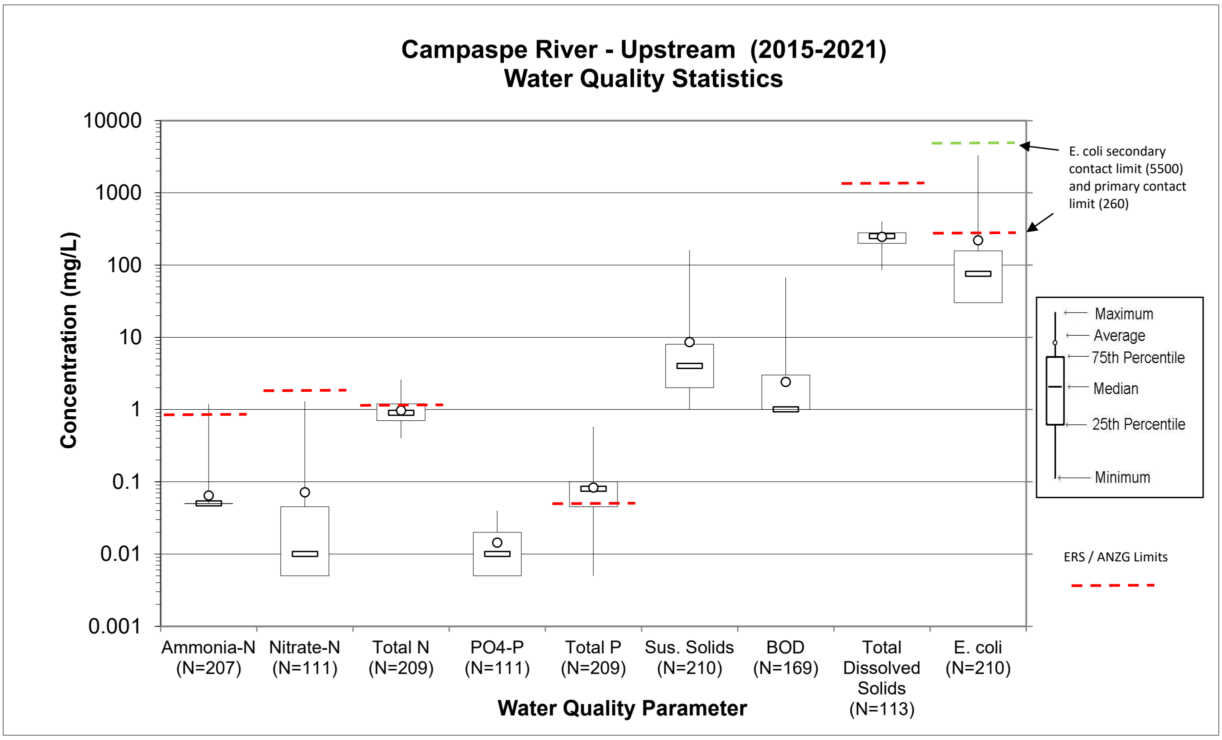

Figure 23 ***Statistics of water quality data for the Campaspe River – upstream (data from 2015-2021)***

Table 14 ***Statistics of water quality data Campaspe River – Upstream (data from 2015-2021)***

	Ammonia-N	Nitrate-N	Total N	PO_4-P	Total P	Sus. Solids	BOD	Total Diss. Solids	*E. coli*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	orgs/100mL
Maximum	1.2	1.3	2.6	0.040	0.580	160	67	400	3300
90th percentile	0.050	0.13	1.5	0.030	0.140	13	4	320	377
75th percentile	0.050	0.05	1.2	0.020	0.100	8	3	280	157.5
Median	0.050	0.01	0.9	0.010	0.080	4	1	250	75.5
25th percentile	0.050	0.01	0.7	0.005	0.045	2	1	200	30
10th percentile	0.050	0.01	0.60	0.005	0.025	1	1	170	15
Minimum	0.05	0.005	0.400	0.005	0.005	1	1	86	0
Average	0.064	0.071	0.969	0.014	0.083	9	2.4	246	220
Number	207	111	209	111	209	210	169	113	210
Guideline	0.9 at pH 8	2.4	1.05 75th %ile	-	0.055 75th %ile	-	-	1340 75% ile	260 / 5500 95th %ile^

^ ERS primary contact limit is 260 orgs/100 mL, as a 95th percentile and secondary contact limit of 5,500 orgs/mL, as a 95th percentile.

Metals data for the Campaspe River upstream of the discharge point is presented in Figure 24 and Figure 25.

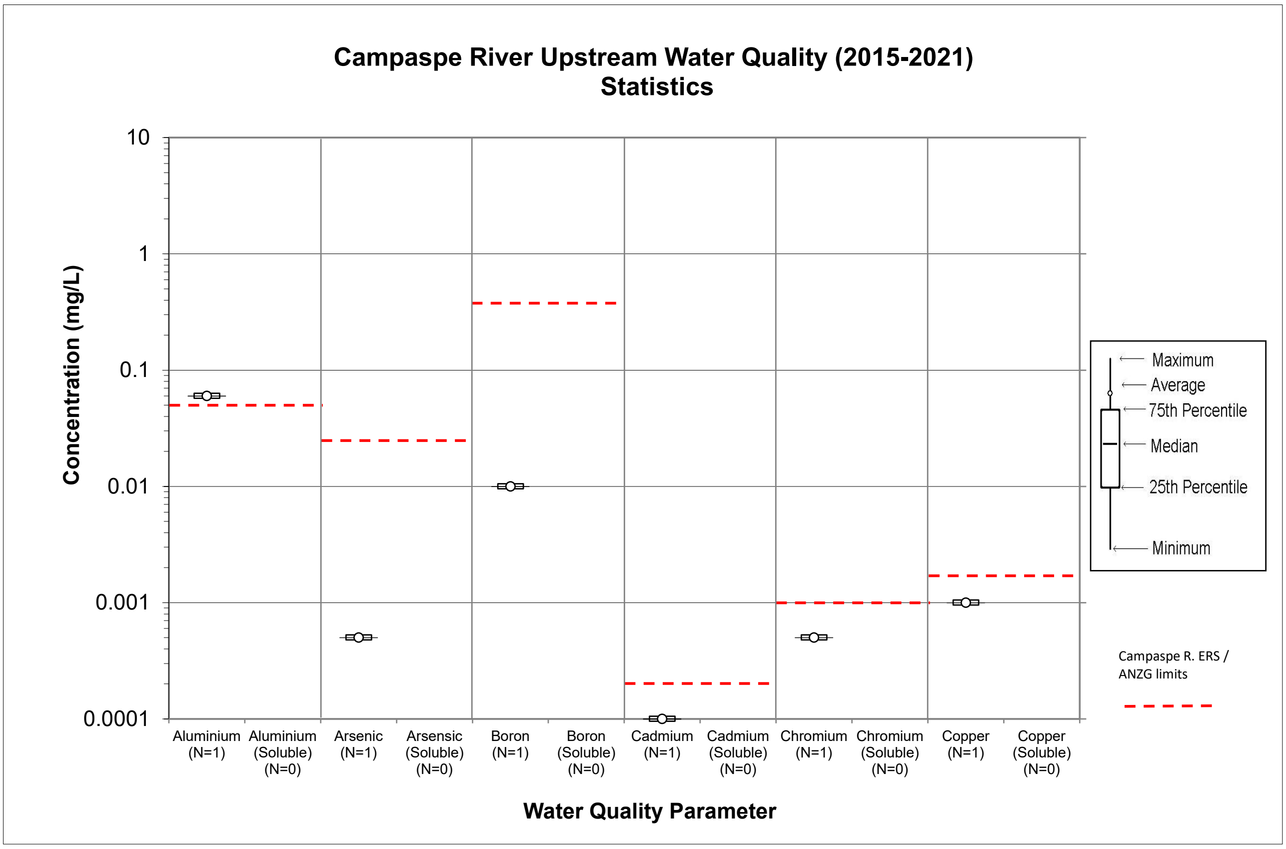

Figure 24 Statistics of metals (aluminium to copper) data for the Campaspe River – upstream (data from 2015-2021)

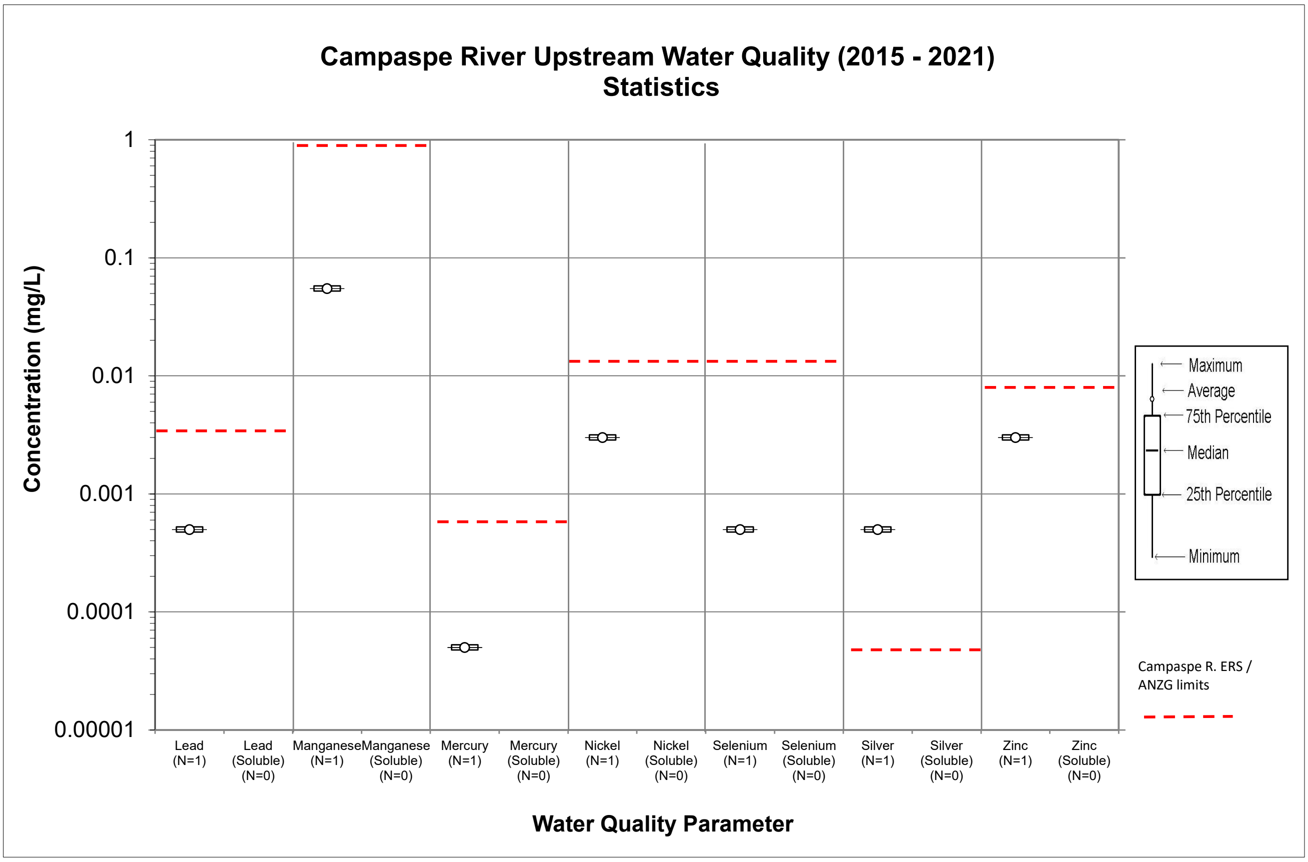

Figure 25 Statistics of metals (lead to zinc) data for the Campaspe River – upstream (data from 2015-2021)

4.3 Kyneton WRP Discharge

An overview of statistics of key water quality parameters for the Kyneton WRP discharge (combined BNR and Lagoon 4) to the Campaspe River for the 2015-2020 period is presented in Figure 26 and in Table 15. This data is presented here as it is representative of the Kyneton WRP discharge during the risk assessment analysis period of 2017-2020 used later in this report.

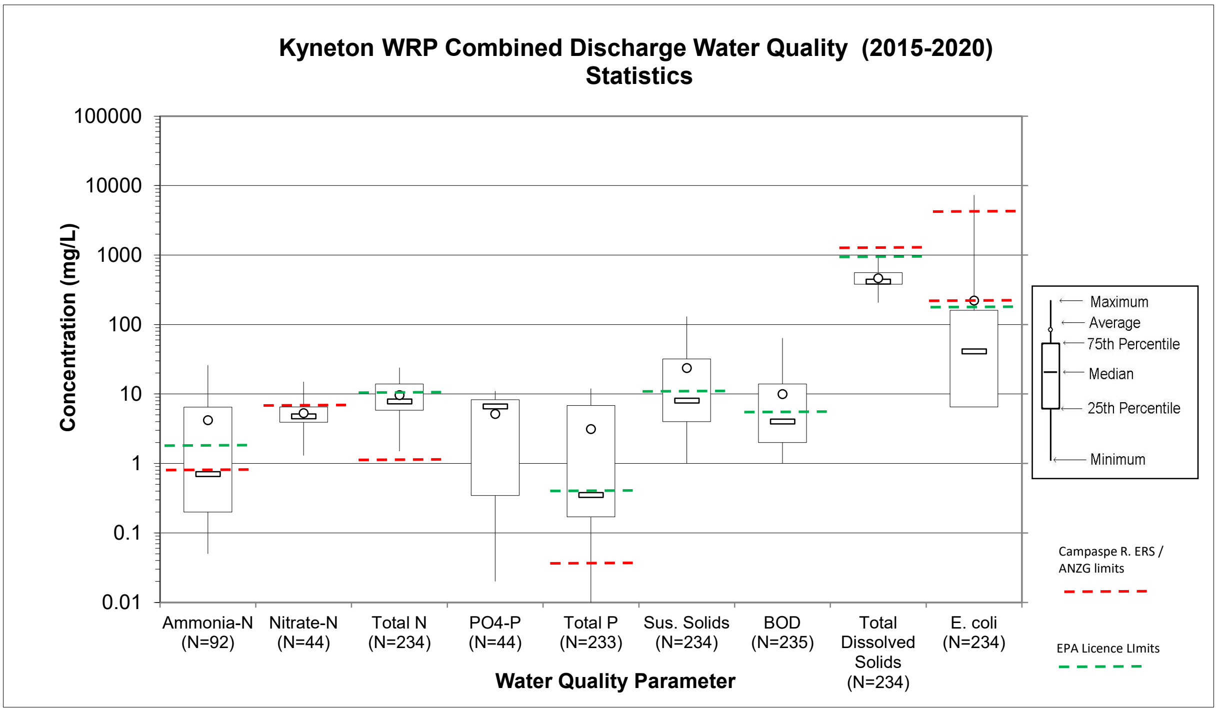

Figure 26 Statistics of water quality data – Kyneton WRP combined BNR and Lagoon 4 historical discharge to Campaspe River

Table 15 Statistics of water quality data – Kyneton WRP combined BNR and Lagoon 4 historical discharge to Campaspe River

	Ammonia-N	**Nitrate-N**	**Total N**	**PO_4-P**	**Total P**	**Sus. Solids**	**BOD**	**Total Diss. Solids**	***E. coli***
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	orgs/100mL
Maximum	26.00	15.00	24.0	11.000	12.000	130	64	1005	7300
90th percentile	13.90	7.78	17.0	9.270	9.462	70	26	646	392
75th percentile	6.48	6.53	13.9	8.300	6.827	32	14	558	160
Median	0.70	4.75	7.8	6.600	0.350	8	4	413	41
25th percentile	0.20	3.93	5.8	0.345	0.170	4	2	380	7
10th percentile	0.05	3.20	4.1	0.066	0.103	2	1	360	0
Minimum	0.05	1.30	1.5	0.020	0.010	1	1	206	0
Average	4.20	5.30	9.6	5.152	3.128	24	10	464	221
Number	92	44	234	44	233	234	235	234	234
EPA Licence (median)	2	-	10	-	0.5	10	5	1000	200

An overview of statistics of key water quality parameters for the Kyneton WRP discharge (BNR only) is presented in Figure 27 and in Table 16. Results show that BNR discharge is of considerably better quality than the combined BNR / Lagoon 4 discharge. Also to note is that *E. coli* data is considerably lower after March 2021, than the statistics presented here, after the installation of a new ultra violet treatment system.

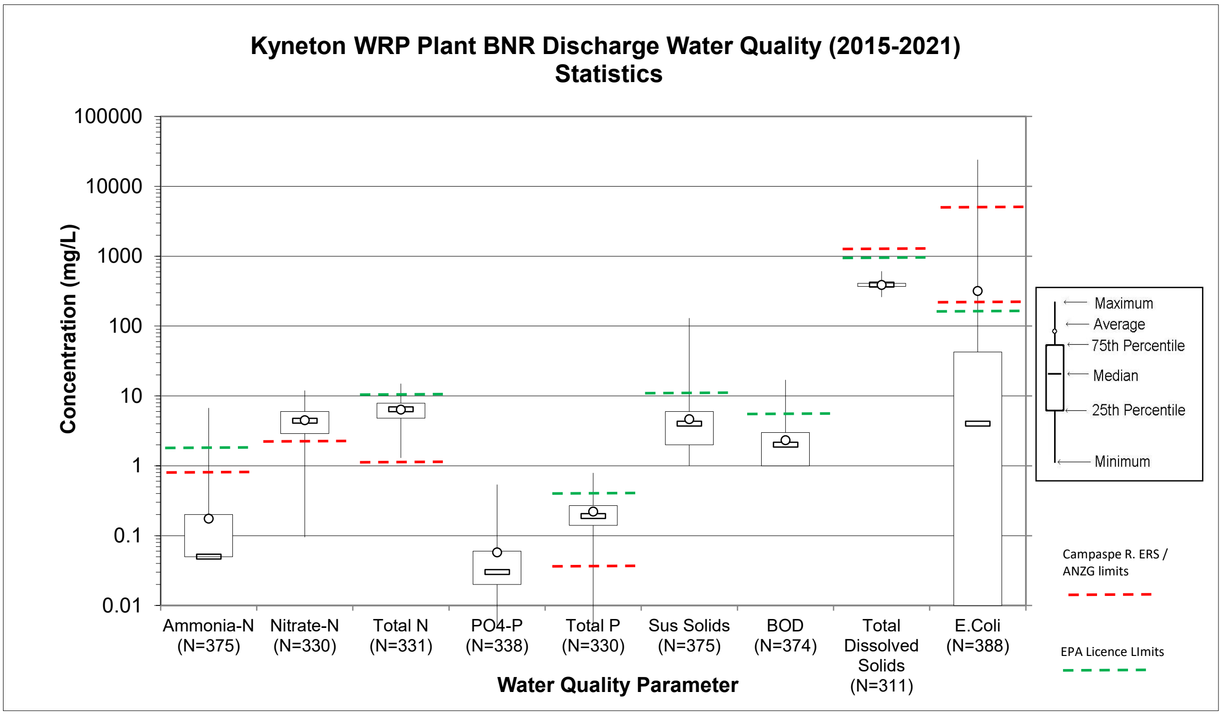

Figure 27 Statistics of water quality data – Kyneton WRP BNR only discharge to Campaspe River (2015-2021)

Table 16 Statistics of water quality data – Kyneton WRP BNR only discharge to Campaspe River (2015-2021)

	Ammonia-N	Nitrate-N	Total N	PO_4-P	Total P	Sus. Solids	BOD	Total Diss. Solids	*E. coli*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	orgs/100mL
Maximum	6.7	12.0	15.0	0.540	0.790	130	17	610	24000
90th percentile	0.400	7.30	9.0	0.140	0.406	8	4	430	405
75th percentile	0.200	5.98	7.85	0.060	0.270	6	3	410	42.5
Median	0.050	4.40	6.4	0.030	0.190	4	2	390	4
25th percentile	0.050	2.90	4.8	0.020	0.140	2	1	370	1
10th percentile	0.050	1.70	3.40	0.005	0.100	1	1	340	0
Minimum	0.05	0.095	1.300	0.005	0.005	1	1	260	0
Average	0.175	4.477	6.359	0.058	0.221	5	2.3	388	316
Number	375	330	331	338	330	375	374	311	388
EPA Licence (median)	2	-	10	-	0.5	10	5	1000	200

Metals data for the Kyneton WRP BNR discharge is presented in Figure 28 and Figure 29.

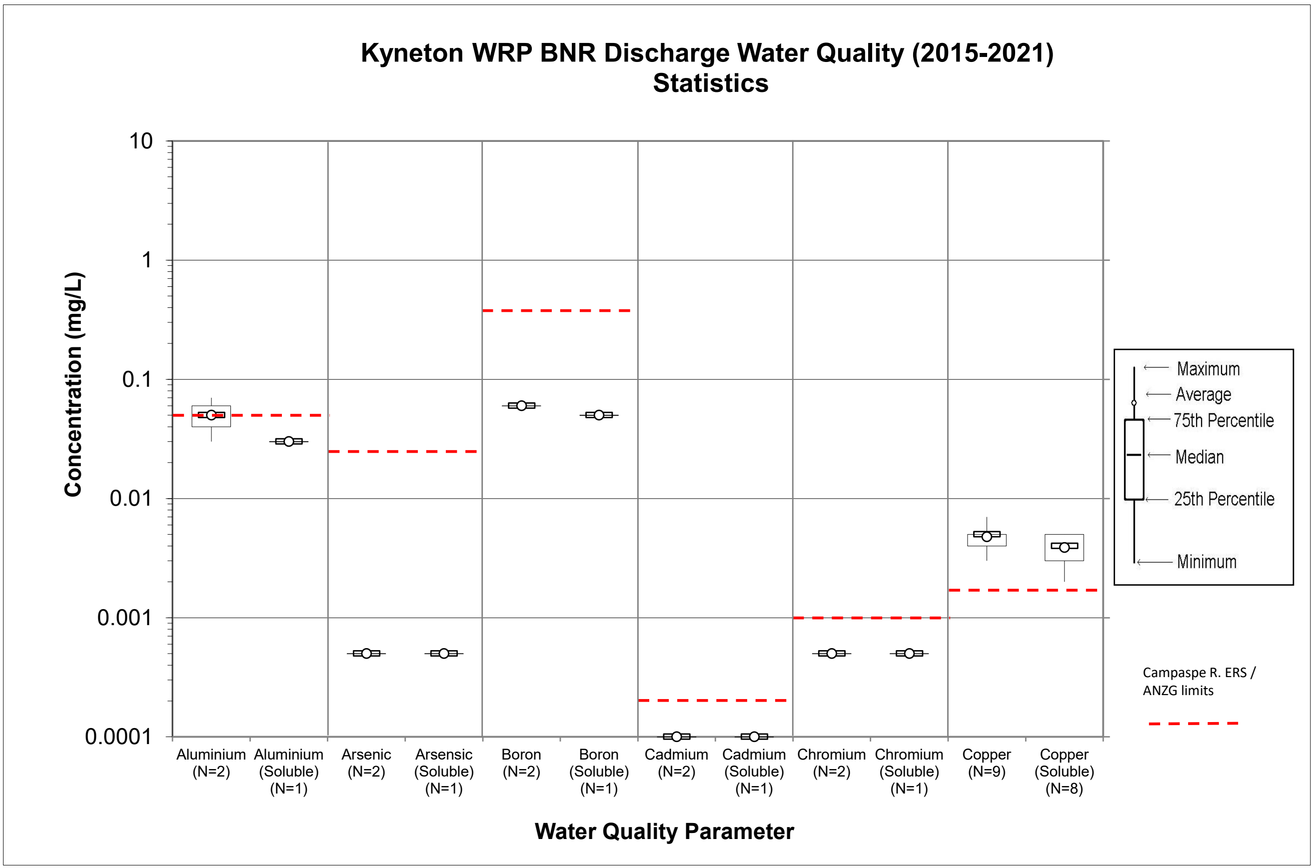

Figure 28 *Statistics of metals (aluminium to copper) data for the Kyneton BNR discharge (data from 2015-2021)*

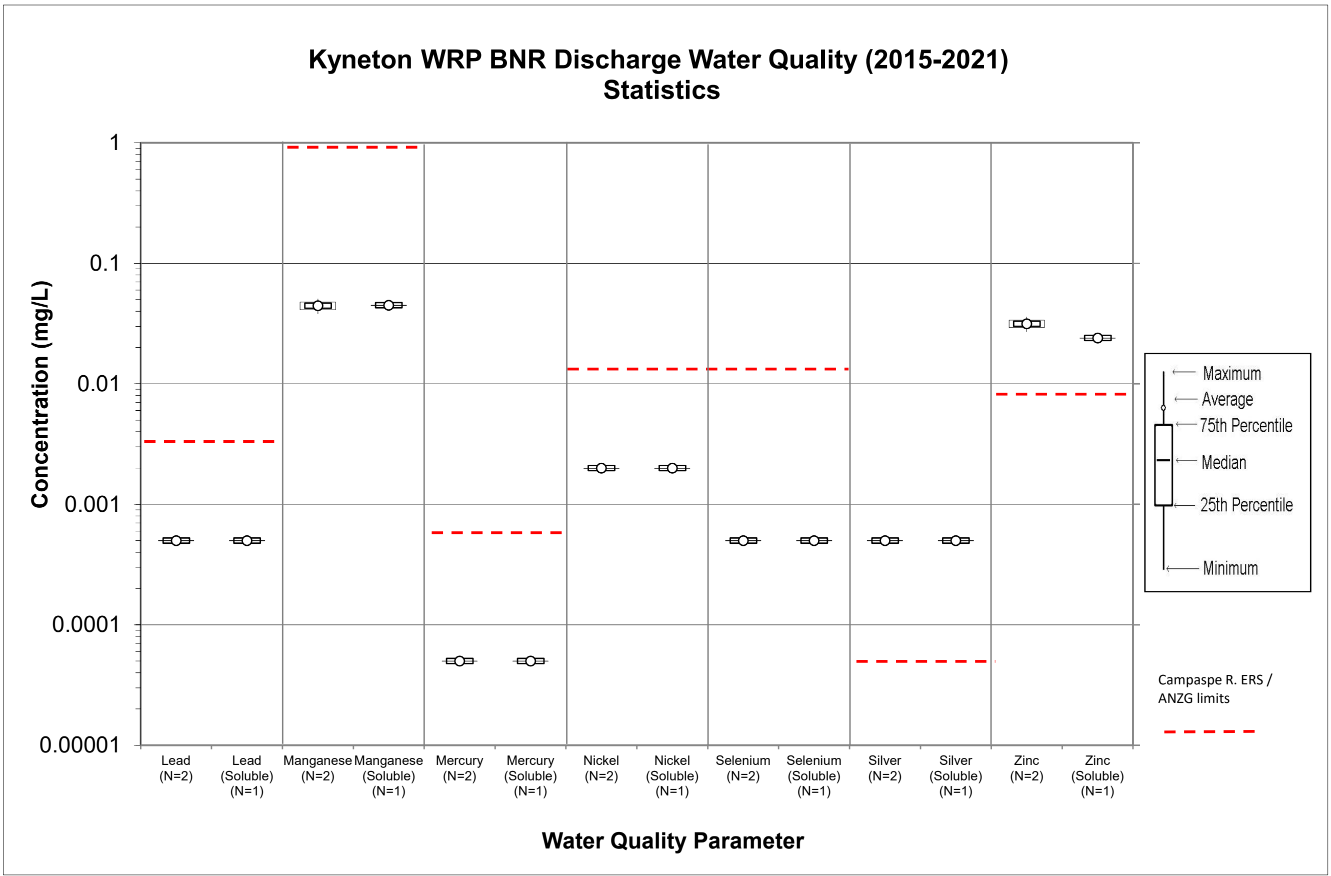

Figure 29 *Statistics of metals (lead to zinc) data for the Kyneton BNR discharge (data from 2015-2021)*

4.4 Campaspe River downstream of the discharge point

Statistics of key water quality parameters for the Campaspe River downstream of the discharge point (all sites combined from CD3 to site CD8a, downstream of the discharge point) is presented in Figure 30 and in Table 17. Data is presented for both discharge and non-discharge periods.

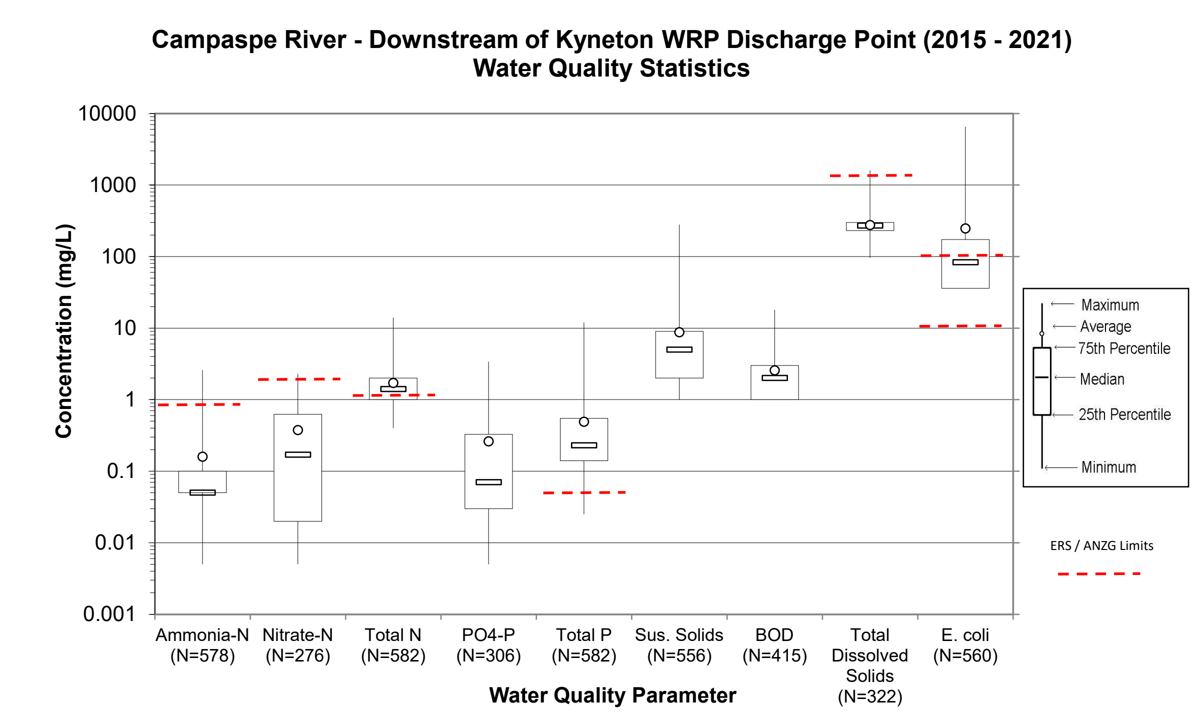

Figure 30 *Statistics of water quality data for the Campaspe River – downstream (all data for both discharge and non-discharge periods from 2015-2021)*

Table 17 *Statistics of water quality data for the Campaspe River – downstream (all data for both discharge and non-discharge periods from 2015-2021)*

	Ammonia-N	Nitrate-N	Total N	PO_4-P	Total P	Sus. Solids	BOD	Total Diss. Solids	*E. coli*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	orgs/100mL
Maximum	2.6	2.3	14.0	3.400	12.000	280	18	1600	6500
90th percentile	0.400	0.94	3.0	0.680	1.100	18	5	350	463
75th percentile	0.100	0.63	2	0.328	0.550	9	3	300	172.5
Median	0.050	0.17	1.4	0.070	0.230	5	2	270	83
25th percentile	0.050	0.02	1	0.030	0.140	2	1	230	36
10th percentile	0.050	0.01	0.80	0.020	0.090	1	1	200	15
Minimum	0.005	0.005	0.400	0.005	0.025	1	1	96	0
Average	0.159	0.376	1.716	0.262	0.490	9	2.6	275	247
Number	578	276	582	306	582	556	415	322	560
Guideline	0.9 at pH 8	2.4	1.05 75th %ile	-	0.055 75th %ile	-	-	1340 75%ile	260 / 5500 95th %ile^

^ ERS primary contact limit is 260 orgs/100 mL, as a 95th percentile and secondary contact limit of 5,500 orgs/mL, as a 95th percentile.

Metals data for the Campaspe River downstream of the discharge point is presented in Figure 31 and Figure 32.

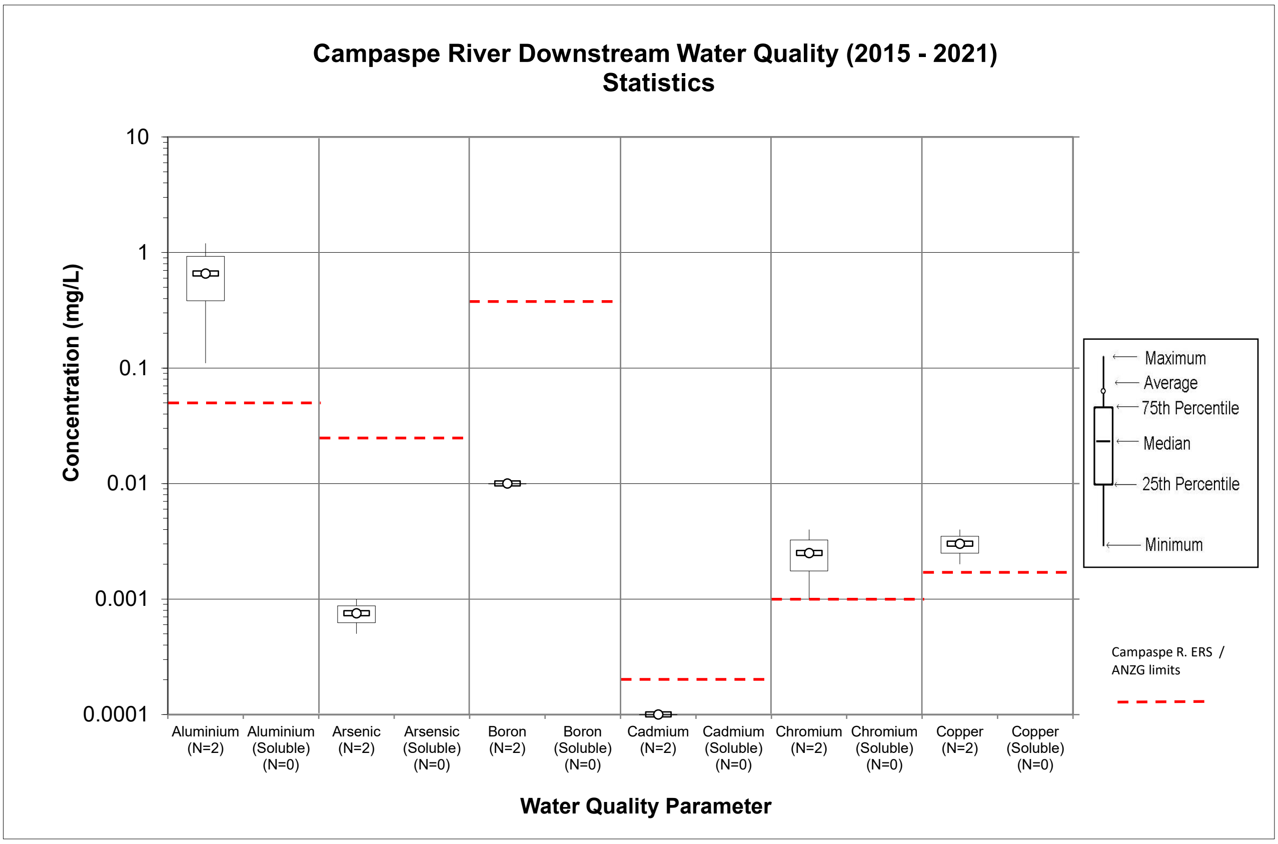

Figure 31 Statistics of metals (aluminium to copper) data for the Campaspe River – downstream (data from 2015-2021)

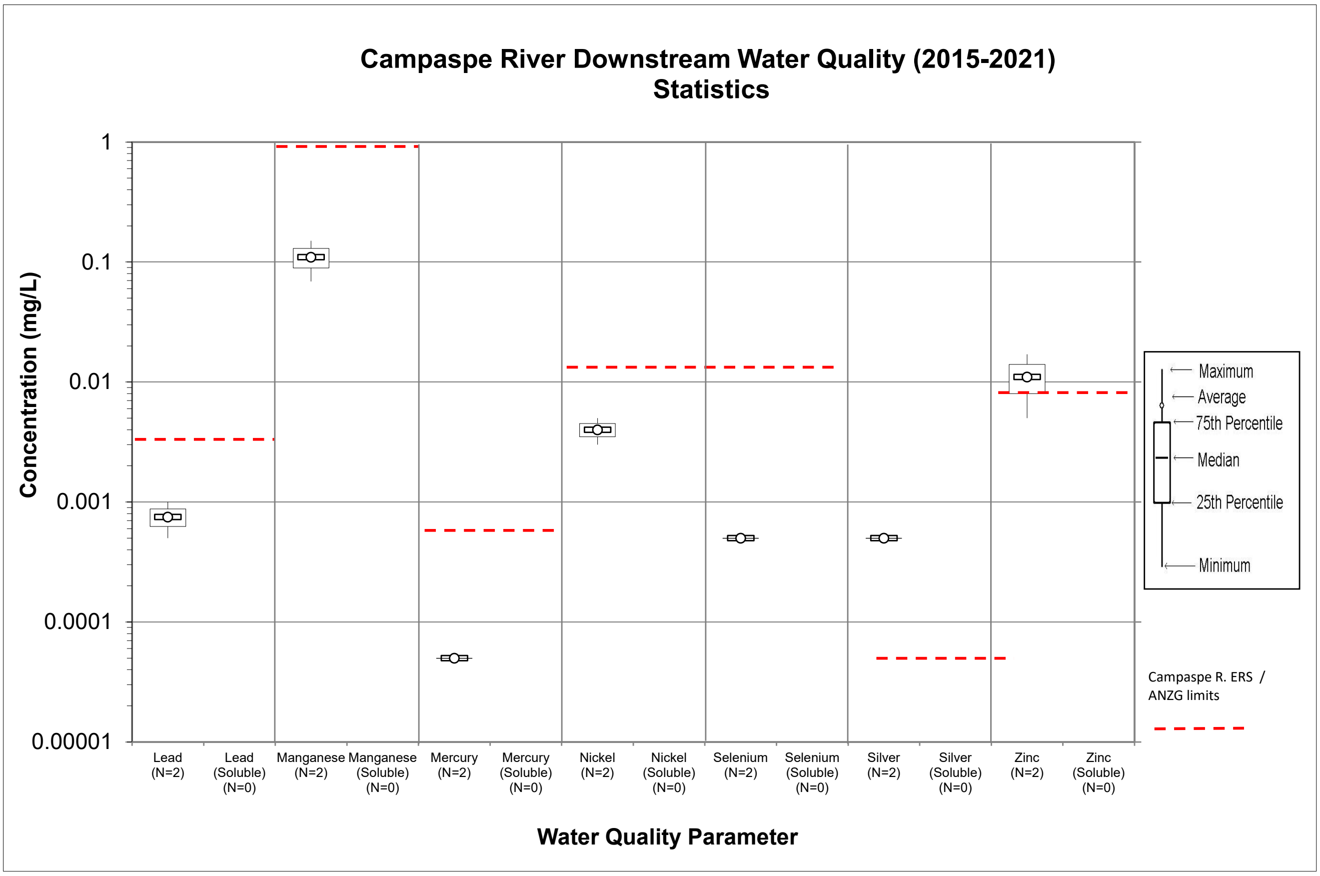

Figure 32 Statistics of metals (lead to zinc) data for the Campaspe River – downstream (data from 2015-2021)

4.4.1 Campaspe River Downstream – non-discharge periods

Water quality statistics for the Campaspe River downstream of the Kyneton WRP discharge point (sites CD3 – CD8a), for non-discharge periods during the July 2017-Dec 2021 are presented in Figure 33 and in Table 18.

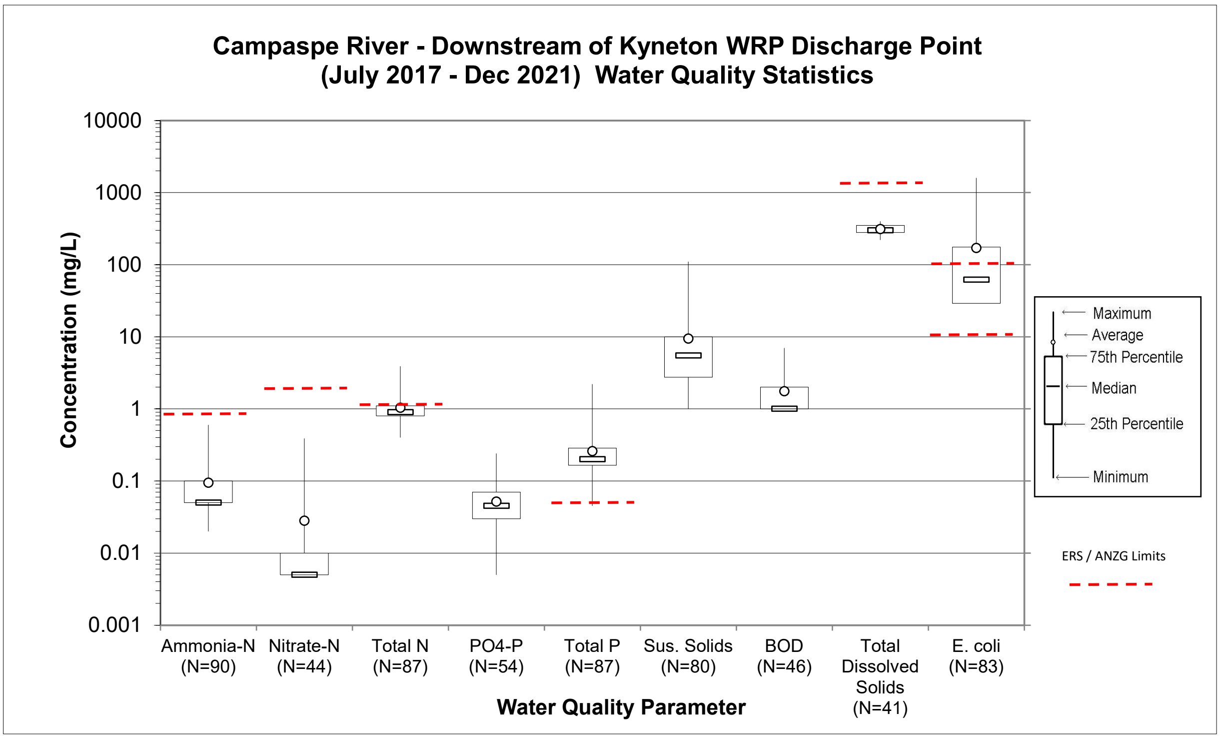

Figure 33 *Statistics of water quality data for the Campaspe River – downstream (non-discharge periods from July 2017 – December 2021)*

Table 18 *Statistics of water quality data for the Campaspe River – downstream (non-discharge periods from July 2017 – December 2021)*

	Ammonia-N	Nitrate-N	Total N	PO_4-P	Total P	Sus. Solids	BOD	Total Diss. Solids	*E. coli*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	orgs/100mL
Maximum	0.6	0.4	3.9	0.240	2.200	110	7	400	1600
90th percentile	0.200	0.06	1.4	0.080	0.390	16	3.5	380	374
75th percentile	0.100	0.01	1.1	0.070	0.285	10	2	350	175
Median	0.050	0.01	0.9	0.045	0.200	6	1	300	62
25th percentile	0.050	0.01	0.8	0.030	0.165	3	1	280	29
10th percentile	0.050	0.01	0.70	0.013	0.130	1	1	270	6.4
Minimum	0.02	0.005	0.400	0.005	0.045	1	1	220	0
Average	0.095	0.028	1.040	0.052	0.260	9	1.8	312	171
Number	90	44	87	54	87	80	46	41	83
Guideline	0.9 at pH 8	2.4	1.05 75th %ile	-	0.055 75th %ile	-	-	1340 75%ile	260 / 5500 95th %ile^

^ ERS primary contact limit is 260 orgs/100 mL, as a 95th percentile and secondary contact limit of 5,500 orgs/mL, as a 95th percentile.

4.4.2 Campaspe River Downstream – discharge periods

Water quality statistics for the Campaspe River downstream of the Kyneton WRP discharge point (sites CD3 – CD8a), for discharge periods during the July 2017 – December 2021 are presented in Figure 34 and in Table 19.

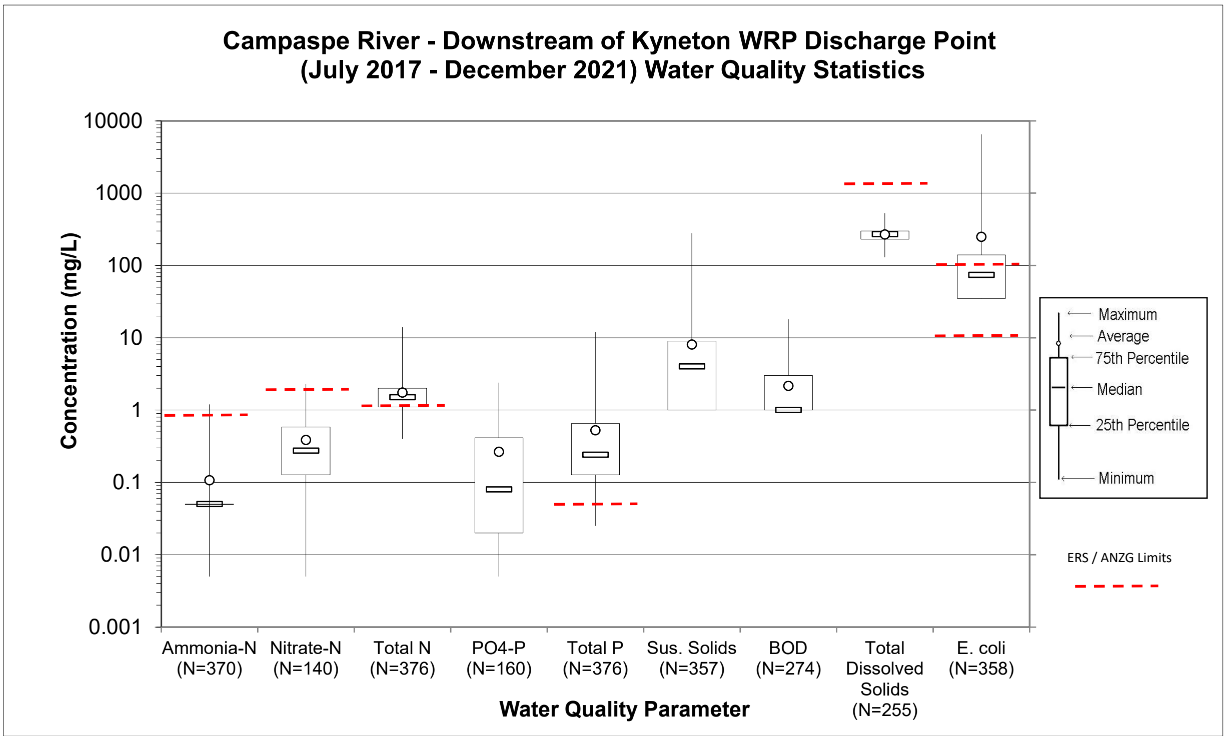

Figure 34 Statistics of water quality data for the Campaspe River – downstream (discharge periods from July 2017 – December 2021)

Table 19 Statistics of water quality data for the Campaspe River – downstream (discharge periods from July 2017 – December 2021)

	Ammonia-N	Nitrate-N	Total N	PO_4-P	Total P	Sus. Solids	BOD	Total Diss. Solids	*E. coli*
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	orgs/100mL
Maximum	1.2	2.3	14.0	2.400	12.000	280	18	530	6500
90th percentile	0.203	0.75	2.7	0.741	1.200	17	4	340	369
75th percentile	0.050	0.58	2	0.413	0.650	9	3	300	140
Median	0.050	0.28	1.5	0.080	0.240	4	1	270	74
25th percentile	0.050	0.13	1.1	0.020	0.128	1	1	230	35
10th percentile	0.050	0.05	0.80	0.019	0.080	1	1	200	14.1
Minimum	0.005	0.005	0.400	0.005	0.025	1	1	130	0
Average	0.107	0.386	1.747	0.265	0.525	8	2.2	268	248
Number	370	140	376	160	376	357	274	255	358
Guideline	0.9 at pH 8	2.4	1.05 75^{th} %ile	-	0.055 75^{th} %ile	-	-	1340 75%ile	260 / 5500 95^{th} %ile^

^ ERS primary contact limit is 260 orgs/100 mL, as a 95th percentile and secondary contact limit of 5,500 orgs/mL, as a 95th percentile.

4.5 Overview of water quality compliance in the Campaspe River

An overview of compliance with guidelines for key water quality parameters is presented in Table 20 for all available water quality data from 2015-2021. Results for Ashbourne gauging station show compliance with all the parameters for which data is available. At the Campaspe River upstream of the discharge point, there is non-compliance for some metals (aluminium and silver), nutrients (ammonia, total N and total P) and for *E. coli* with regards to primary contact (i.e. swimming). Changes from upstream to downstream of the discharge point are noted for ammonia, chromium, copper, zinc, dissolved oxygen and turbidity.

Table 20 Compliance of water quality data Campaspe River – all data from 2015-2021

Parameter	Unit	Guideline value				Campaspe River Sites			
		Maximum	95th %ile	75th %ile	25th %ile	Ashbourne Gauge	All Upstream	All Downstream	Redesdale Gauge
							CU1 – CU3	CD3-CD8a	
Percentage of data not complying with maximum guideline									
Dissolved Oxygen (%)	%	130						0%	0%
Nitrogen – Ammonia - N	mg/L	0.9					0.5%	3%	0%
Nitrogen - Nitrate as N	mg/L	2.4					0%	0%	
Aluminium	mg/L	0.055					100%	100%	0%
Arsenic	mg/L	0.024					0%	0%	0%
Boron	mg/L	0.37					0%	0%	
Cadmium	mg/L	0.0002					0%	0%	0%
Chromium	mg/L	0.001					0%	50%	19%
Copper	mg/L	0.0014					0%	100%	62%
Lead	mg/L	0.0034					0%	0%	0%
Manganese	mg/L	1.9					0%	0%	0%
Mercury	mg/L	0.0006					0%	0%	0%
Nickel	mg/L	0.011					0%	0%	0%
Selenium	mg/L	0.011					0%	0%	0%
Silver	mg/L	0.00005					100%	100%	
Zinc	mg/L	0.008					0%	50%	37%
Parameters meeting guideline with yes/no criteria									
Dissolved Oxygen (%)	%				70		Yes	No	No
Electrical Conductivity	µS/cm			2000		Yes	Yes	Yes	Yes
pH	pH Units				6.8	Yes	Yes	Yes	Yes
pH	pH Units			8		Yes	Yes	Yes	No
Turbidity	NTU			15		Yes	Yes	No	Yes
Nitrogen - Total	mg/L			1.05			No	No	No
Phosphorus - Total	mg/L			0.055		Yes	No	No	No
E. Coli (Primary Contact)	orgs/100mL		260				No	No	
E. Coli (Secondary Contact)	orgs/100mL		5500				Yes	Yes	

However, as can be seen in Table 21 there is a change in compliance for turbidity and total nitrogen in the Campaspe River downstream of the discharge point, compared to the upstream sites even during non-discharge periods. *E. coli* (primary contact) and total phosphorus are non-compliant both upstream and downstream of the discharge point during non-discharge periods. Copper (with 52% of available data non complaint) and zinc (30% of data non-compliant) were also non compliant at Redesdale during non-discharge periods.

Table 21 Compliance of water quality data Campaspe River – non discharge days from June 2017 – December 2021

Parameter	Unit	Guideline value				Campaspe River Sites			
		Maximum	95th %ile	75th %ile	25th %ile	Ashbourne Gauge	All Upstream	All Downstream	Redesdale Gauge
							CU1 – CU3	CD3-CD8a	
Percentage of data not complying with maximum guideline									
Dissolved Oxygen (%)	%	130						0%	0%
Nitrogen – Ammonia -N	mg/L	0.9					0%	0%	0%
Nitrogen - Nitrate as N	mg/L	2.4					0%	0%	
Aluminium	mg/L	0.055							
Arsenic	mg/L	0.024							0%
Boron	mg/L	0.37							
Cadmium	mg/L	0.0002							0%
Chromium	mg/L	0.001							0%
Copper	mg/L	0.0014							52%
Lead	mg/L	0.0034							0%
Manganese	mg/L	1.9							
Mercury	mg/L	0.0006							0%
Nickel	mg/L	0.011							0%
Selenium	mg/L	0.011							
Silver	mg/L	0.00005							
Zinc	mg/L	0.008							30%
Parameters meeting guideline with yes/no criteria									
Dissolved Oxygen (%)	%				70			No	No
Electrical Conductivity	µS/cm			2000		Yes	Yes	Yes	Yes
pH	pH Units				6.8	Yes	Yes	Yes	Yes
pH	pH Units			8		Yes	Yes	Yes	No
Turbidity	NTU			15		Yes	Yes	No	Yes
Nitrogen - Total	mg/L			1.05			Yes	No	No
Phosphorus - Total	mg/L			0.055		Yes	No	No	No
E. Coli (Primary Contact)	orgs/100mL		260				No	No	
E. Coli (Secondary Contact)	orgs/100mL		5500				Yes	Yes	

Compliance with key water quality parameters during discharge periods (see Table 22), shows a similar pattern of compliance to Table 20: the Campaspe River upstream of the discharge point shows non-compliance for some metals (aluminium and silver), nutrients (ammonia, total N and total P) and for *E. coli* with regards to primary contact (i.e. swimming).

Changes from upstream to downstream of the discharge point are noted for chromium, copper, zinc, dissolved oxygen, and non-compliance for total N, total P and *E. coli* (primary contact) both upstream and downstream of the discharge point.

The available metals data for the Campaspe River upstream and downstream of the discharge point is relatively low (typically, n= 0 or 2 for most metals parameters), and as such may not provide an accurate comparison to guidelines. It is noted that for some parameters (e.g. silver) the limit of detection is considerably higher than the ANZG guideline, meaning that all data appears 'non-compliant' when in fact the assessment may be more accurately stated as 'indeterminate'. Elevated chromium, copper and zinc downstream of the discharge point, compared to upstream, on discharge-only days, may be attributable to Kyneton WRP discharge on some occasions, however because the number of data is low particularly within the Campaspe River, it is difficult to make accurate conclusions in this regard. Also, it is likely that these discharges since 2015 have been a blended BNR and lagoon 4 discharge (which is typically higher in concentration for most parameters). Future discharges will be BNR only.

Table 22 Compliance of water quality data Campaspe River –discharge days from June 2017 – December 2021

Parameter	Unit	Guideline value				Campaspe River Sites			
		Maximum	95th %ile	75th %ile	25th %ile	Ashbourne Gauge	All Upstream	All Downstream	Redesdale Gauge
							CU1 – CU3	CD3-CD8a	
Percentage of data not complying with maximum guideline									
Dissolved Oxygen (%)	%	130						0%	0%
Nitrogen – Ammonia -N	mg/L	0.9					1%	1%	0%
Nitrogen - Nitrate as N	mg/L	2.4					0%	0%	
Aluminium	mg/L	0.055					100%	100%	
Arsenic	mg/L	0.024					0%	0%	0%
Boron	mg/L	0.37					0%	0%	
Cadmium	mg/L	0.0002					0%	0%	0%
Chromium	mg/L	0.001					0%	50%	31%
Copper	mg/L	0.0014					0%	100%	72%
Lead	mg/L	0.0034					0%	0%	0%
Manganese	mg/L	1.9					0%	0%	
Mercury	mg/L	0.0006					0%	0%	0%
Nickel	mg/L	0.011					0%	0%	0%
Selenium	mg/L	0.011					0%	0%	
Silver	mg/L	0.00005					100%	100%	
Zinc	mg/L	0.008					0%	50%	52%
Parameters meeting guideline with yes/no criteria									
Dissolved Oxygen (%)	%				70		Yes	No	No
Electrical Conductivity	µS/cm			2000		Yes	Yes	Yes	Yes
pH	pH Units				6.8	Yes	Yes	Yes	Yes
pH	pH Units			8		Yes	Yes	Yes	No
Turbidity	NTU			15		Yes	Yes	Yes	Yes
Nitrogen - Total	mg/L			1.05			No	No	Yes
Phosphorus - Total	mg/L			0.055		Yes	No	No	No
E. Coli (Primary Contact)	orgs/100mL		260				No	No	
E. Coli (Secondary Contact)	orgs/100mL		5500				Yes	Yes	

5. Mixing Zone Assessment

5.1 Mixing zone overview

In Victoria, the approach for designating a mixing zone is specified in the EPA Guidance for the Determination and Assessment of Mixing Zones, Publication 1344 (2010). Primarily, this approach uses the Environmental Reference Standard (ERS 2021) (EPA Victoria 2021) environmental quality objectives as the basis for determining the spatial and temporal extent of a mixing zone (EPA, 2009). The ERS environmental quality objectives, and applicable ANZG (2018) trigger values, describe the levels of environmental quality required to protect the beneficial uses and ecological values of the receiving waterway.

The boundary of the mixing zone is defined in terms of the concentration of indicator parameters in the receiving waterway and is considered to be where the concentration decreases to below ERS (2021) environmental quality objectives or ANZG trigger values, or returns to background condition levels (ANZG 2018). Mixing zones have generally been designated for soluble, non-bioaccumulating toxicants.

For the purpose of this project, the boundary of the mixing zone within the receiving waterway is the downstream distance from the discharge point where the in-stream water quality (at a monitoring site) complies with an applicable water quality objective:

– Environmental Reference Standard – (ERS 2021) - water quality objectives for rivers and streams – Cleared Hills and Coastal Plains (upper Campaspe segment);
– ANZG (2018) Guidelines for Fresh and Marine Water Quality default trigger values for Upland rivers of South-east Australia, if not specified in ERS (2021); or
– Return to background/upstream condition levels.

In all instances, the upstream boundary of the mixing zone has been assumed to be the point at which the discharge enters the receiving waterway.

5.2 Mixing zone estimation for water quality parameters

Using water quality data available for the Campaspe River during the Kyneton WRP discharge periods, mixing zones were determined for each parameter by calculating what distance downstream of the discharge point that concentrations for various parameters either returned to upstream values or met guideline values.

Analysis was undertaken on water quality data, where it was available, at multiple sites downstream of the discharge point to allow a mixing zone to be estimated for a number of different parameters. A summary of the mixing zone distance findings, using a 'median conditions' method, is presented in Table 23. The 'median conditions' method essentially considers the median (or other key metric such as 95th percentile) concentration of each site and the trend of this value with distance downstream of the discharge point. The 'median conditions' assessment is essentially a first pass of the available data to see if a mixing zone may be present or absent for each given parameter.

Results indicate that there are different mixing zones for each of the parameters available within this study, i.e. there are multiple mixing zone boundaries for the Kyneton WRP discharge, depending on the parameter and upstream conditions. The results also show that the mixing zone distance can change from day to day for any given parameter i.e. the mixing zone for each parameter is complex, multifaceted and continuously changing.

A range of parameters showed no apparent mixing zone (or a very short zone) over any of the sample days e.g. *E coli*, ammonia, nitrate, turbidity and pH. On some days, for a range of parameters, WRP discharge concentrations were lower than the Campaspe River concentrations upstream of the discharge point – on these occasions, the mixing zone distance was deemed to be zero. For total N and total P, a mixing zone was noted to be present, using the 'median conditions' assessment, and was shown to be 11.5 km downstream. This is an indicative estimate of the mixing zone distance for these parameters and a more accurate assessment of mixing zones for total N and total P has been undertaken within section 6 of this report, using defined nutrient decay rates for the Campaspe River (decay rates are defined in section 5.3 of this report).

Table 23 Mixing zone estimation using the 'median conditions' assessment

Parameter →	Ammonia-N	Electrical Conductivity	*E. coli*	Nitrate-N	pH	Total N*	Total P*	Turbidity
Site	-	-	-	-	-	CD8a	CD8a	-
Distance downstream	0	0	0	0	0	11.5 km	11.5 km	0

*Note these mixing zones are only present on days of discharge only. Also to note is that a more accurate determination of mixing zone for total N and total P is presented in section 6 of this report.

Key limitations to the accuracy of mixing zone determinations must be taken into account when considering the accuracy of estimating the mixing zone distances:

– Accurate streamflow in the Campaspe River at the discharge point (i.e. most of the water quality data available was sampled prior to the Kyneton streamflow gauge being installed), and this affects the accuracy of determining velocity and mixing zone distance.
– There is not enough, or no, data available for some parameters (e.g. heavy metals).

An overview of each of the parameters and their mixing zone assessments are presented in the sections below.

5.2.1 Ammonia Mixing Zone

Longitudinal data on days of discharge during 2020 and 2021 for ammonia as N are presented in Figure 35. The results show the median concentration for each of the days in which data was available downstream does not exceed the ANZG (2018) limit of 0.9 mg/L. As such, using the median estimation method, there is no mixing zone for ammonia.

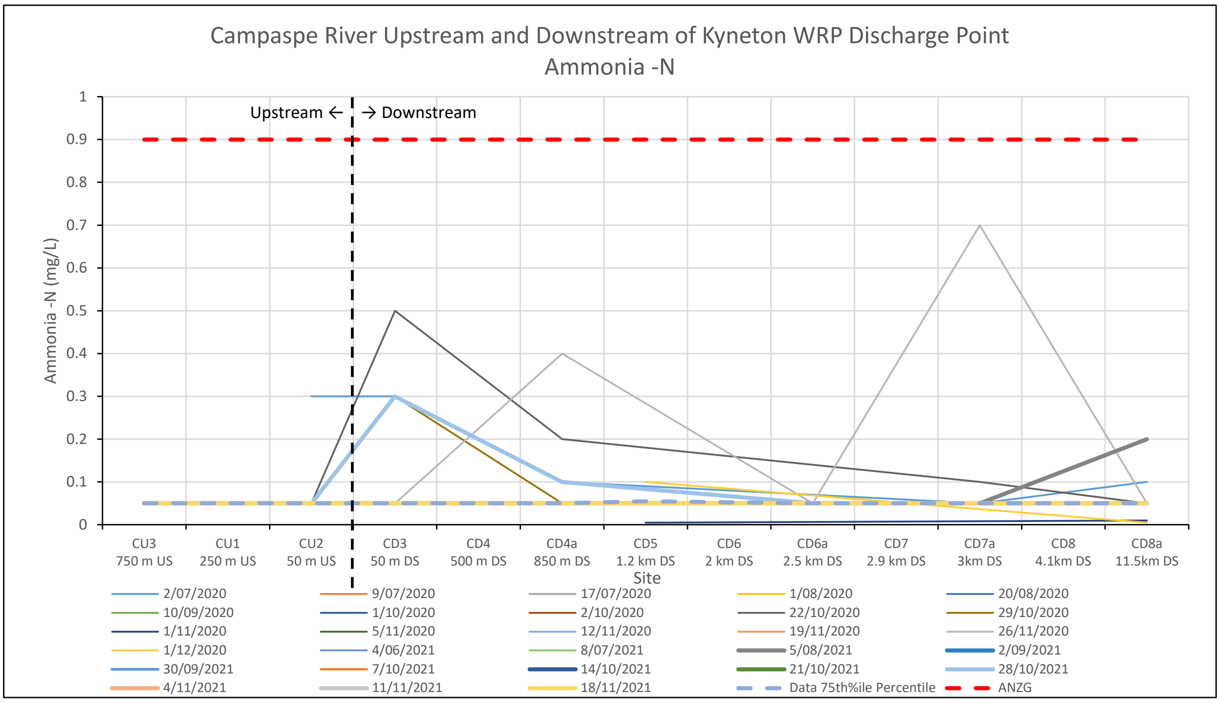

Figure 35 Ammonia longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream

5.2.2 Electrical conductivity mixing zone

Longitudinal data on days of discharge for electrical conductivity for 2020 – 2021 are presented in Figure 36. The results show the median concentration for each of the days in which data was available downstream does not exceed the ERS (2021) 75th percentile value of 2000 µS/cm. As such, using the median estimation method, there is no mixing zone for electrical conductivity.

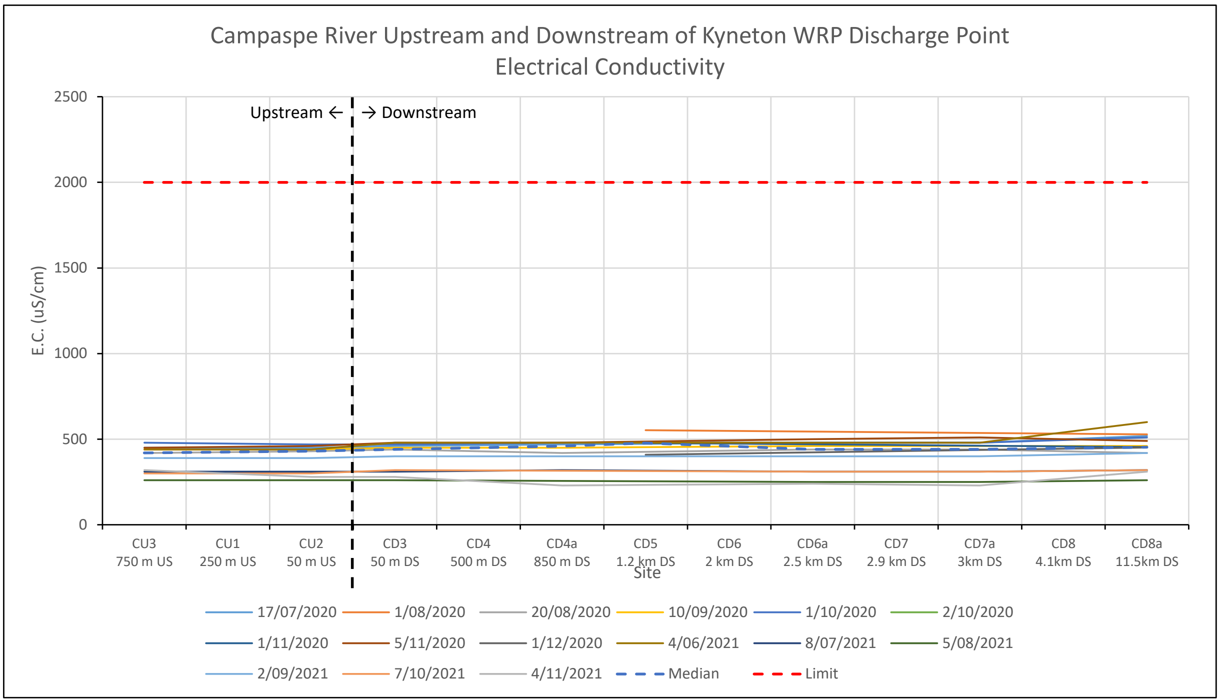

Figure 36 Electrical conductivity longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream

5.2.3 *E. coli* mixing zone

Longitudinal data on days of discharge for *E. coli* are presented in Figure 37. The results show the 95th percentile concentration (for each of the days in which data was available) exceeds the primary contact limit (260 orgs/100mL) i.e. is not suitable for swimming, but is below the secondary contact limit (5,500 orgs/100 mL) upstream of the discharge point. The *E. coli* 95th percentile value does not change much downstream compared to upstream – i.e. the Kyneton WRP discharge does not have much of an effect on *E. coli* concentrations in the Campaspe River (typically the discharge is lower in *E. coli* than the river, and after March 2021 *E. coli* in the discharge is considerably lower than the river after the installation of a new U.V. treatment system). Because of the similarity in concentration upstream and downstream of the discharge point, the mixing zone for *E. coli* is 0 km.

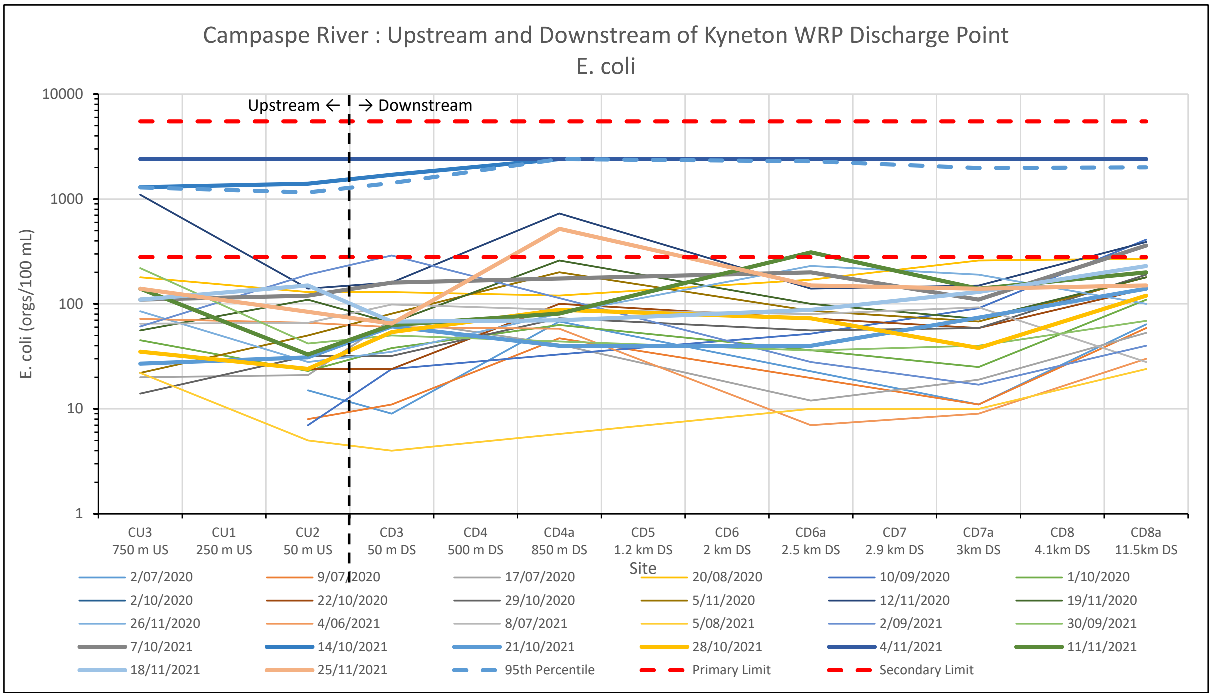

Figure 37 ***E. coli longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream***

5.2.4 Nitrate as N mixing zone

Longitudinal data on days of discharge for nitrate as N are presented in Figure 38. The results show the median concentration for each of the days in which data was available downstream does not exceed the NIWA / ANZG (2018) limit of 2.4 mg/L. As such, using the median estimation method, there is no mixing zone for nitrate as N.

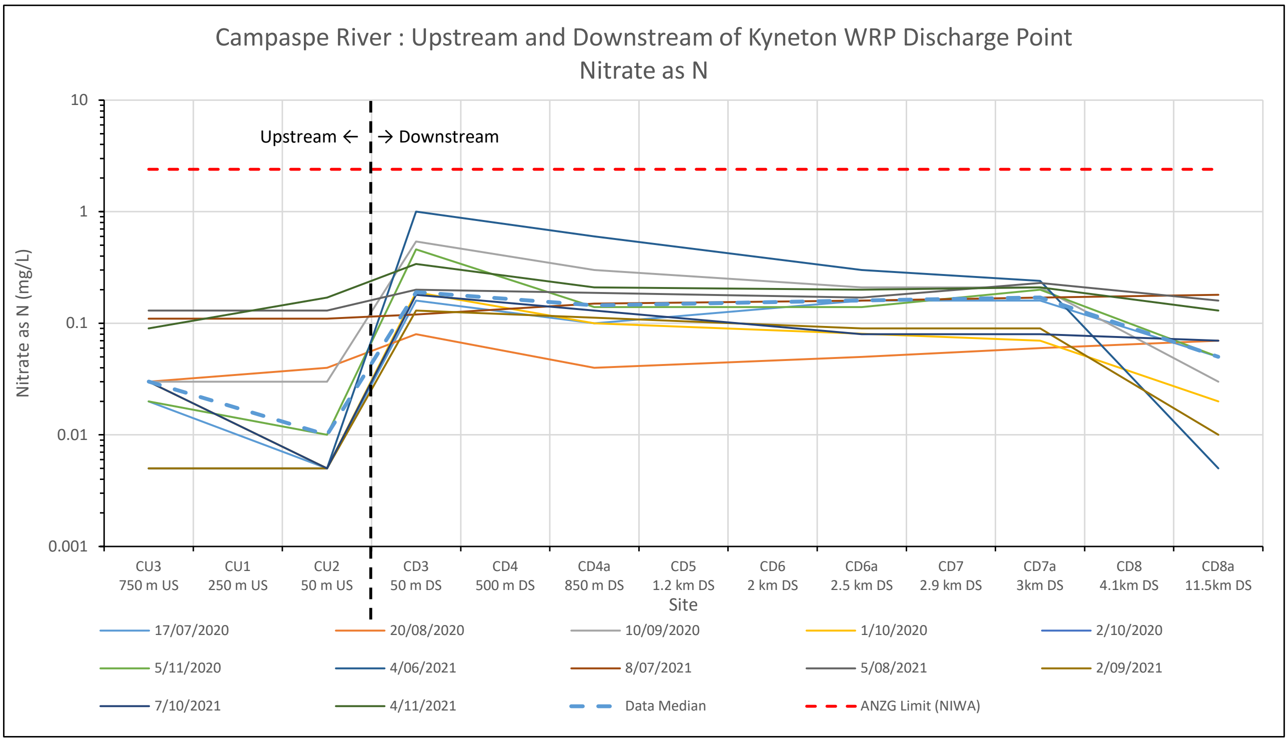

Figure 38 ***Nitrate as N longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream***

5.2.5 pH mixing zone

Longitudinal data on days of discharge for pH are presented in Figure 39. The results show the median value for pH for each of the days in which data was available downstream does not exceed the ERS (2021) 75th percentile of 8, or is lower than the ERS (2021) 25th percentile of 6.8. As such, there is no mixing zone for pH.

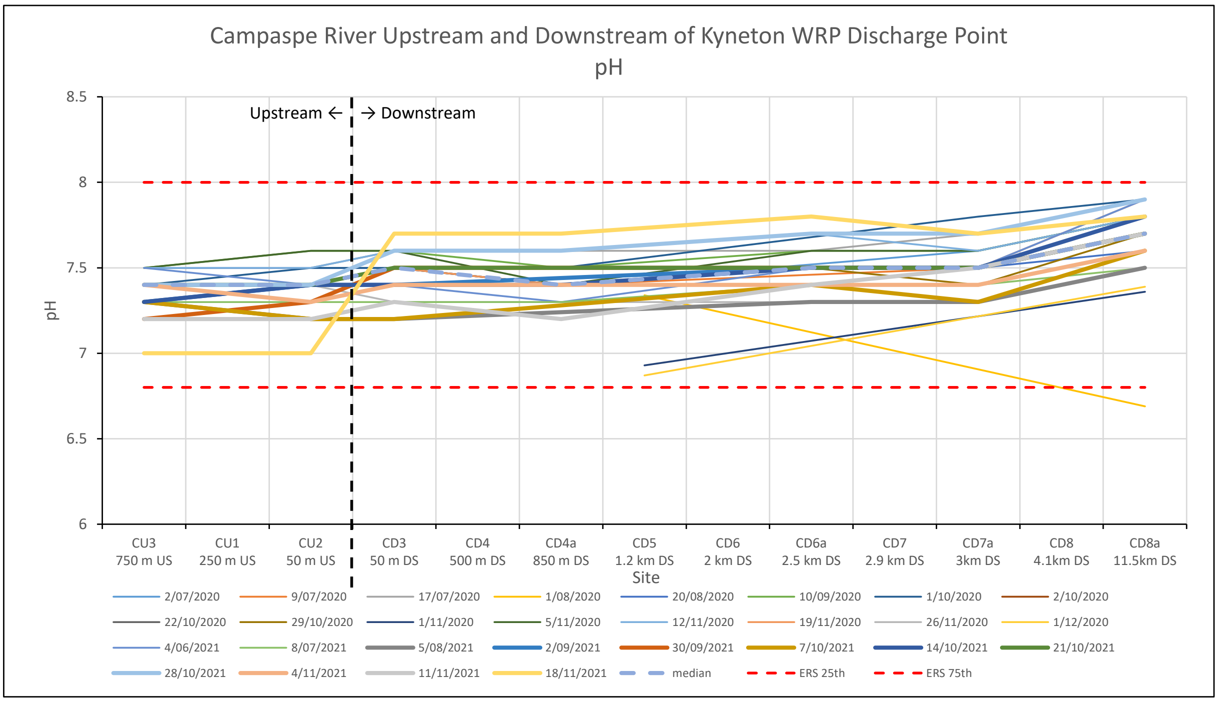

Figure 39 pH longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream

5.2.6 Total N mixing zone

Longitudinal data on days of discharge for total N concentrations within the Campaspe River are presented in Figure 40. The results show an increase in the creek concentrations, due to the WRP discharge, followed by a reduction in concentration with distance downstream. The median value at each site is plotted along with the guideline limit (1.05 mg/L) and shows the median value approaching the guideline value at site CD8a (11.5 km downstream of the WRP discharge point). This mixing zone assessment is for days of discharge only during the July 2020 – December 2021 period).

It should be noted for total N (and total P), a more accurate mixing zone assessment was undertaken and is presented within the discharge risk assessment (section 6 of this report), using decay rates determined from section 5.3 of this report.

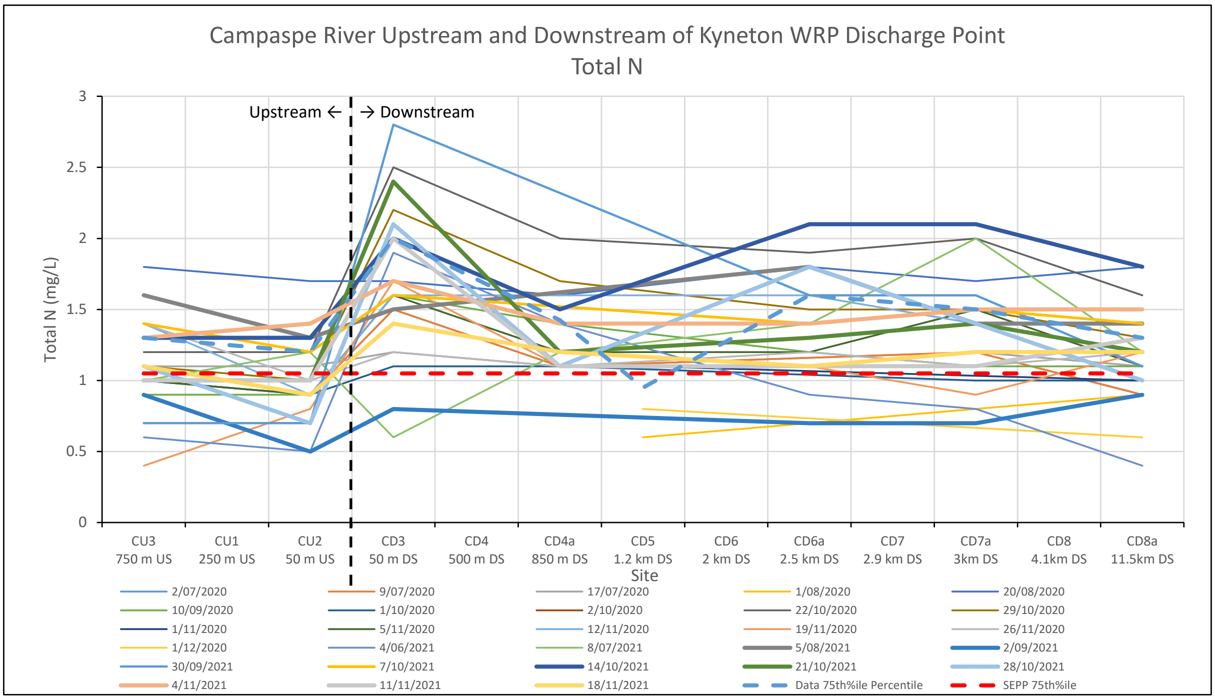

Figure 40 ***Total N longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream***

Statistics of total N concentration data within the Campaspe River on days of discharge are presented in Figure 41. After the initial peak in concentration directly downstream of the discharge point at CD3, results show an approximate downward trend in concentration with distance downstream and that CD8a (11.3 km downstream) has amongst the lowest values when compared to the other downstream sites.

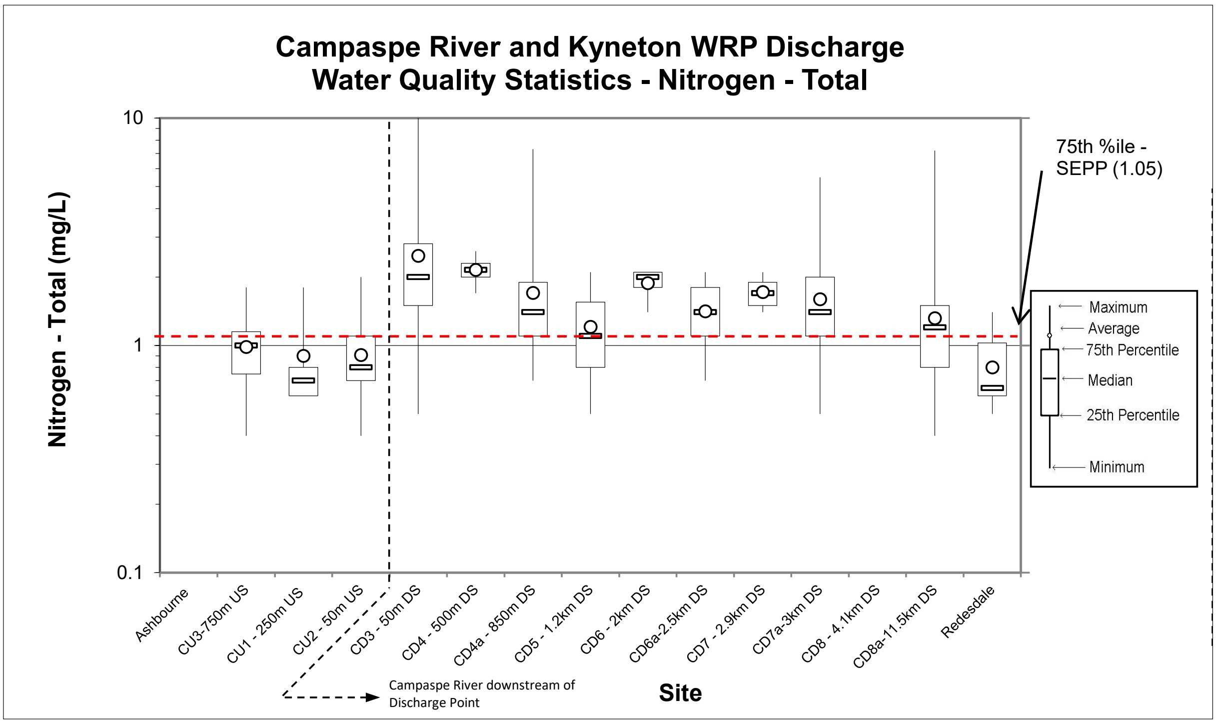

Figure 41 ***Statistics of total nitrogen data (on discharge days only – July 2020 – December 2021) showing changes in concentration with distance downstream***

5.2.7 Total P mixing zone

Longitudinal data on days of discharge for total P concentrations within the Campaspe River are presented in Figure 42. Results show an increase in the creek concentrations, due to the WRP discharge, followed by a general reduction in concentration with distance downstream (although small increases are noted at some sites). The median value at each site is plotted, along with the 75th percentile guideline limit (0.055 mg/L), and shows the median value approaching, but not meeting, the guideline value at site CD8a (11.5 km downstream of the WRP discharge point). The mixing zone for total P is only present on days of discharge during the July 2020 – December 2021 period).

It should be noted for total P, as for total N, a more accurate mixing zone assessment was undertaken and is presented within the discharge risk assessment (section 6 of this report), using decay rates determined within section 5.3 of this report.

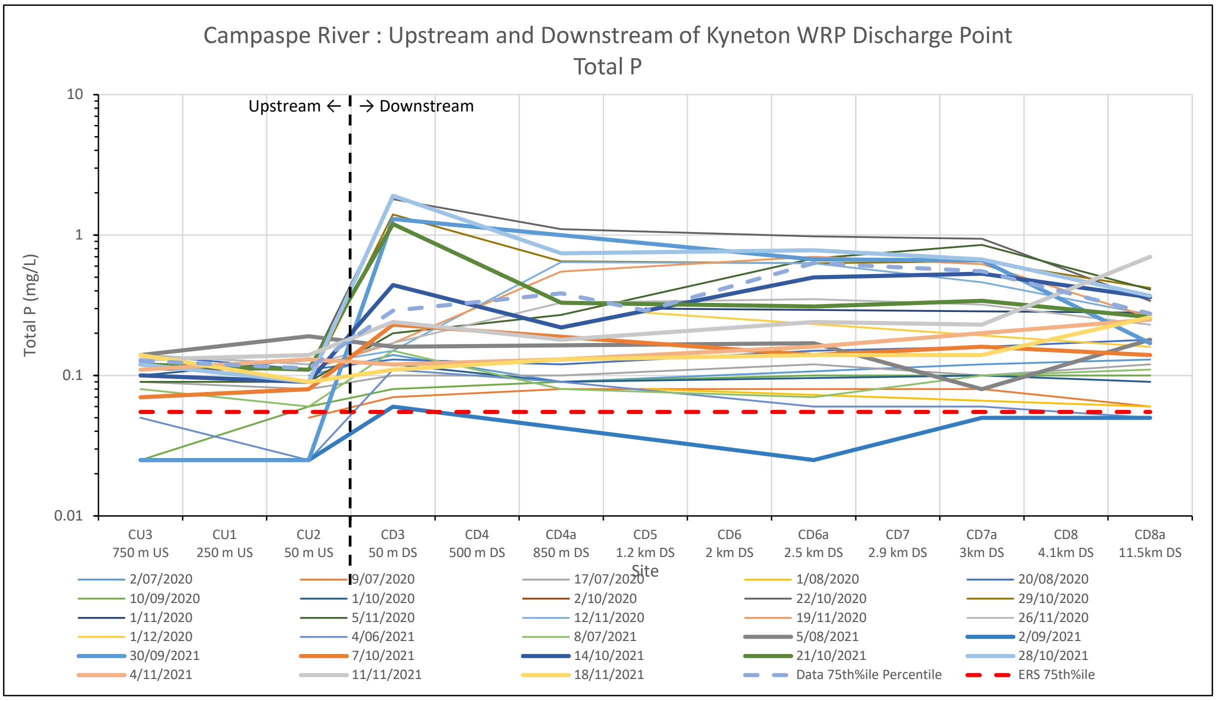

Figure 42 ***Total P longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream***

Statistics of total P concentration data within the Campaspe River on days of discharge are presented in Figure 43. After the initial peak in concentration directly downstream of the discharge point at CD3, results show a downward trend (although there are some small increases in between some sites) in concentration with distance downstream, and that CD8a (11.3 km downstream) has the lowest median values when compared to the other downstream sites. Total P at Redesdale is similar to values upstream of the discharge point.

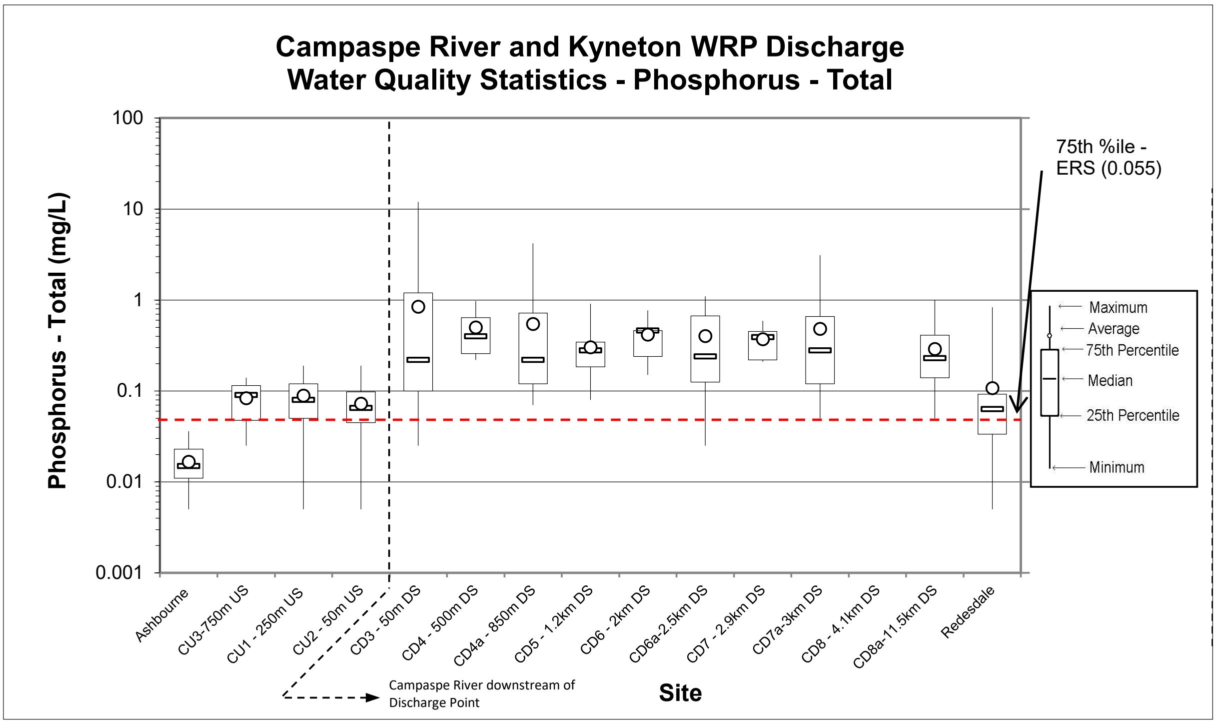

Figure 43 ***Statistics of total phosphorus data (on discharge days only – July 2020 – December 2021) showing changes in concentration with distance downstream***

5.2.8 Turbidity mixing zone

Longitudinal data on days of discharge for turbidity are presented in Figure 44. The results show the median concentration for each of the days for which data was available downstream of the discharge point does not exceed the ERS (2021) guideline of 15 NTU. As such, using the median estimation method, there is no mixing zone for turbidity.

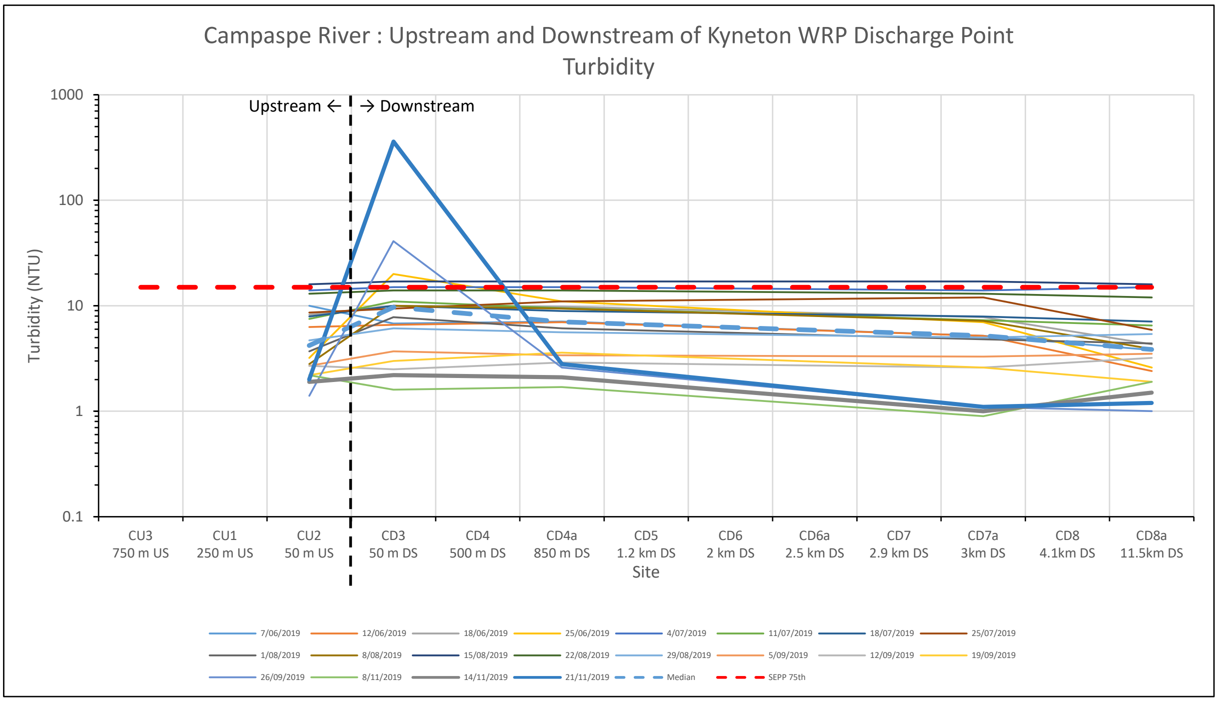

Figure 44 ***Turbidity longitudinal data (on discharge days only, where data was available) showing changes in concentration with distance downstream***

5.3 Nutrient decay rate determination

Nutrient decay rates for total nitrogen and total phosphorus have been determined for the Campaspe River downstream of the Kyneton WRP discharge point. This assessment has used updated streamflow values (i.e. modelled streamflow data from Kyneton gauging station if measured data was not available) and additional water quality data that was available since previous Kyneton WRP discharge assessment reports were developed. The change in streamflow measurement has meant that a ‘recalibration’ of nutrient decay rates is required to match the newer streamflow data.

Longitudinal data for total N and total P is presented in Figure 45 and in Figure 46 for days of discharge on which there was an obvious reduction in concentration with distance downstream. For each of these days in which nutrient decay with distance downstream was apparent, a line of best fit was estimated and the decay rate (k) noted.

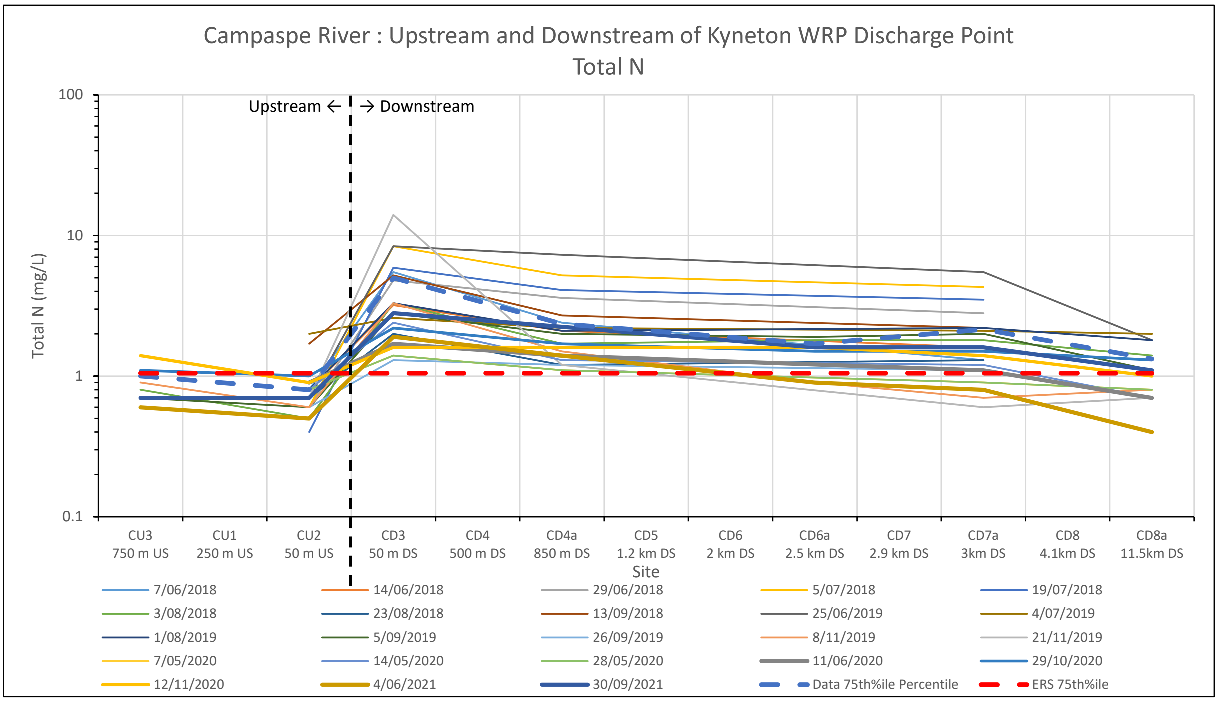

Figure 45 ***Total nitrogen longitudinal data on discharge days where an obvious decay in concentration with distance downstream was apparent***

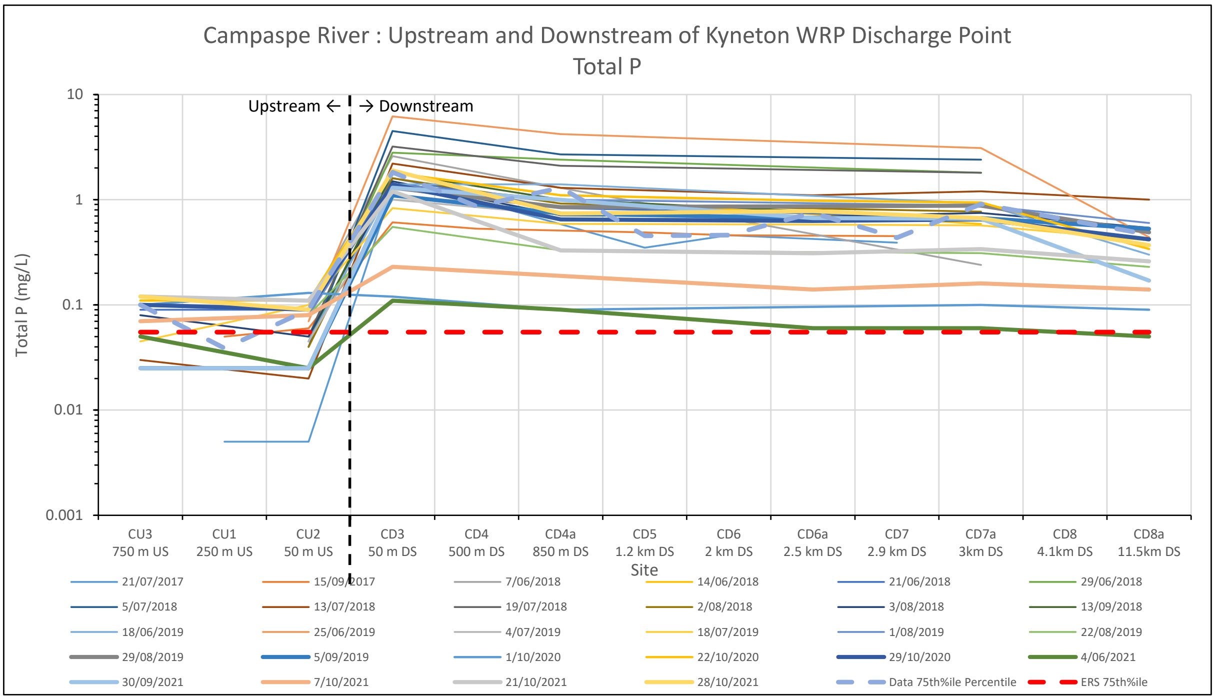

Figure 46 ***Total phosphorus longitudinal data on discharge days where an obvious decay in concentration with distance downstream was apparent***

The decay function is defined by a first order equation $C_t=C_o\ e^{-kt}$, where C_t is the concentration at time t, C_0 is the initial concentration (i.e. at time = 0), k is the decay rate (units of 1/day) and t is time in days. Data on each individual day's line of best fit is presented in Appendix D.

The relationship between streamflow in the Campaspe River and the velocity of that flow was determined in GHD (2015). A line of best fit between streamflow and the velocity of a kinematic wave (water velocity) was determined to be $y=0.0946\ x^{0.2897}$ – where y is velocity (units of m/s) and x is the streamflow (units of ML/day).

Results of updated decay rates for total N and total P in the Campaspe River are presented in Table 24

Table 24 ***Campaspe River decay rates measured for total N and total P***

Total N		**Total P**	
Date	Decay Rate	Date	Decay Rate
10/06/2016	-2.998	10/06/2016	-7.179
11/08/2016	-1.333	14/10/2016	-2.495
23/06/2017	-5.591	23/06/2017	-13.983
7/06/2018	-9.012	21/07/2017	-9.502
14/06/2018	-3.958	15/09/2017	-1.938
29/06/2018	-2.412	7/06/2018	-10.351
5/07/2018	-3.136	14/06/2018	-4.852
19/07/2018	-2.354	21/06/2018	-3.521
3/08/2018	-1.116	29/06/2018	-1.954
23/08/2018	-2.652	5/07/2018	-2.929
13/09/2018	-5.157	13/07/2018	-0.898
25/06/2019	-1.881	19/07/2018	-2.647
4/07/2019	-0.318	2/08/2018	-4.29

Total N		Total P	
1/08/2019	-0.709	3/08/2018	-1.612
5/09/2019	-1.378	13/09/2018	-6.057
26/09/2019	-0.702	18/06/2019	-2.088
8/11/2019	-6.456	25/06/2019	-3.32
21/11/2019	-26.046	4/07/2019	-1.374
12/03/2020	-1.507	18/07/2019	-0.994
7/05/2020	-1.343	1/08/2019	-1.216
14/05/2020	-2.71	22/08/2019	-1.579
28/05/2020	-1.351	29/08/2019	-1.368
11/06/2020	-0.812	5/09/2019	-1.068
29/10/2020	-1.001	31/10/2019	-15.549
12/11/2020	-0.934	1/10/2020	-0.405
4/06/2021	-3.287	22/10/2020	-4.38
30/09/2021	-2.514	29/10/2020	-3.784
		3/12/2020	-0.327
		10/12/2020	-0.378
		11/02/2021	-0.324
		4/06/2021	-1.064
		30/09/2021	-5.768
		7/10/2021	-1.254
		21/10/2021	-19.229
		28/10/2021	-9.229
Maximum	-0.318	Maximum	-0.324
Median	-2.354	Median	-2.495
Minimum	-26.046	Minimum	-19.229

6. Risk Assessment using EPA Framework

6.1 Risk assessment overview and methods

There are multiple approaches available for undertaking discharge risk assessments. A semi-quantitative risk assessment of the Kyneton WRP discharge to the identified environmental values of the Campaspe River is presented in this section in order to meet requirements set out in relevant legislation and to align with the EPA risk assessment framework (EPA Publication 1287). An additional risk assessment of the discharge is also undertaken using a 'Daily Risk Tool' method and is presented in section 7.

The risk assessment has been carried out in three phases to align with the EPA risk assessment framework, including:

- Phase 1 - Problem Formulation;
- Phase 2 - Risk Analysis;
- Phase 3 - Risk Characterisation

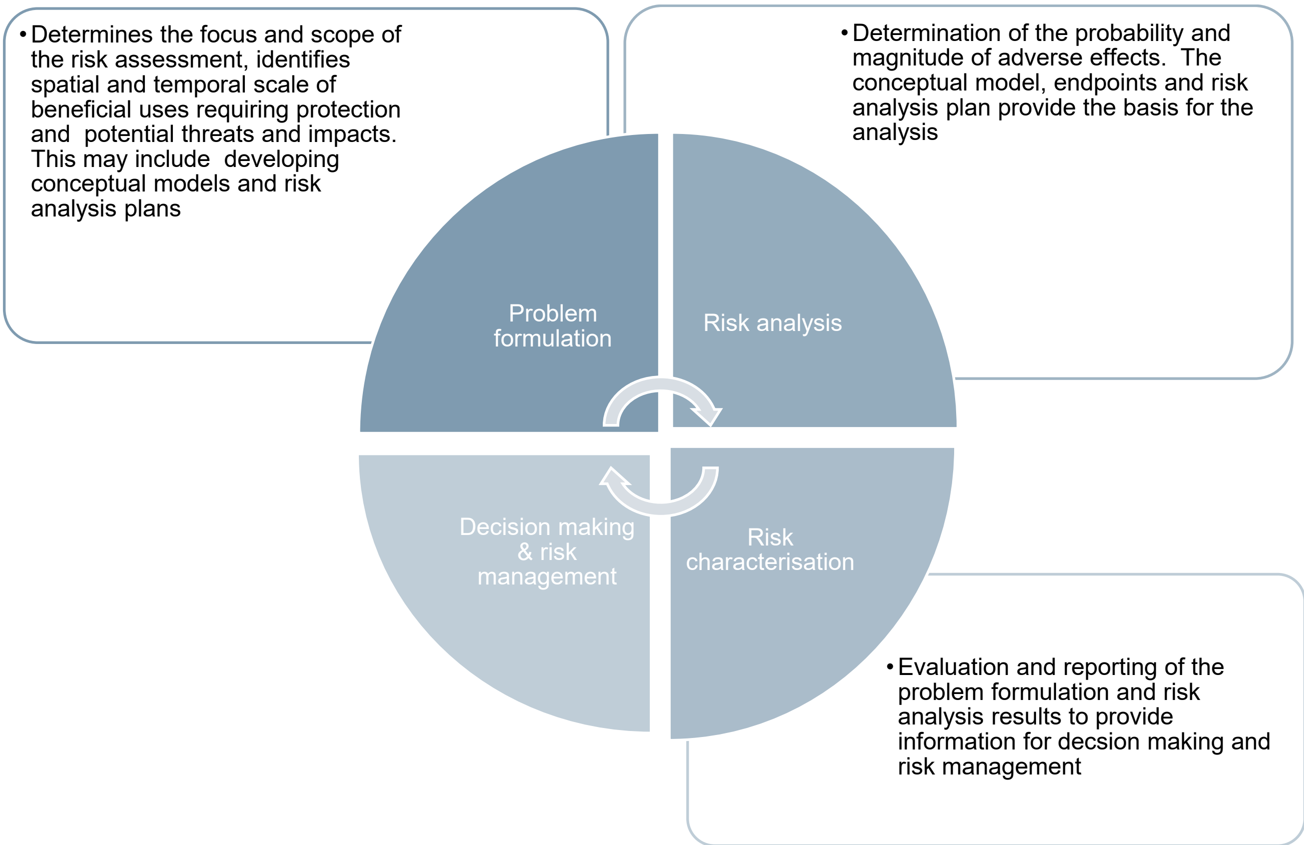

Figure 47 EPA Risk Assessment Framework (Publication 1287)

6.2 Problem Formulation

The focus and scope of the risk assessment is to investigate the potential risks posed by the Kyneton WRP discharges to the environmental values of the Campaspe River. The spatial boundary includes the extent of the mixing zones for the WRP discharges within the Campaspe River under current and potential future discharge scenarios. Coliban Water's key management goals in conducting the risk assessment are to:

- Understand any risks to the receiving environment and to appropriately manage or eliminate these risks
- Determine the spatial extent of risk i.e. determine mixing zones distance and level of impact to environmental values for the Kyneton WRP on the Campaspe River
- Protect environmental values outside the mixing zones
- Continue to monitor the receiving environment and to adapt as appropriate
- Support decision-making on where to invest resources for the most desirable environmental, economic and social outcomes
- Ensure continuous improvement in management of the Kyneton WRP.

6.2.1 Risk methods used in assessment

In assessing the risk of discharge from the Kyneton WRP to the environmental values of the Campaspe River, and following the EPA Framework, two different but aligned approaches have been used. The first is a method that assesses high concentration (within the WRP discharge) but low frequency risks (i.e. an assessment of the risk of toxicity at the discharge point under unusually high concentrations of known toxicants), whilst the second method applied assesses lower to medium range concentrations within the WRP discharge with higher frequency (more typical of expected longer term discharges to the Campaspe River).

The two approaches are used because the first method is suited to traditional likelihood/consequence risk method as set out in the EPA Framework, whereas the second method utilises a methodology developed within a document known as AVIRA (Aquatic Value Identification and Risk Assessment – Riverness (2013)) which has been used for the development of the Regional Waterway Strategies across Victoria and to assess risks to waterways.

6.2.1.1 Risk assessment approach for high concentration / low frequency risks

The assessment of high concentration but low frequency risks is discussed in this section. Risk analysis is essentially an assessment of the probability and magnitude of an adverse effect with specific consequences to environmental values within a certain period (Hart et al., 2005).

In the risk analysis phase, the endpoints, conceptual model and risk analysis plan developed in problem formulation are used to analyse risk to the environmental values of the waterbody.

For each identified hazard, the following steps are taken to analyse risk:

- Determine the likelihood of the hazard causing an adverse effect
- Assess the consequence (impact) on the environmental value/s identified
- Calculate the severity of the risk based on the likelihood and magnitude of the impact.

The severity of the risk then guides the management action – higher risks should be managed or eliminated whereas lower risks may be accepted or tolerated. The assessment of risk is undertaken on the ‘pre-control risk’ (inherent risk) which is the magnitude or degree of harm if no controls were in place and also the ‘post-control risk’ (residual risk): which is the magnitude or degree of harm with controls in place. This helps determine the importance of existing or proposed controls and if new or improved controls are required.

6.2.1.2 Risk assessment approach for low to medium range concentrations but longer term risks

This approach is used to assess the ongoing / longer term risks of WRP discharge on the receiving waterway. GHD have developed a risk assessment approach based upon our experience with risk assessments associated with discharges to rivers. The approach is based on the Aquatic Value Identification and Risk Assessment (AVIRA) process (Riverness 2014) and is compliant with the AS/NZS ISO 31000:2009 risk assessment framework.

The method identifies the association of threats to values, and recognises that not all stressors or enhancers have an equal impact on all environmental values. There is less of a focus on likelihood of risk, as the discharge is considered permanent or very frequent, so the focus then turns to ‘values, threats and association’.

The approach considered:

- ***Environmental Values within the Campaspe River*** – based upon a review of the environmental values outlined within the state's ERS (2021), relevant databases, and a review of waterway strategies. Values, as they align with the beneficial uses of the waterway, are reviewed and assessed to determine whether they are likely to be present within the Campaspe River.
- ***Threats*** – the components of the discharge which could impact on the environmental values of the Campaspe River. This requires:
  - An assessment of the quality of the discharge;
  - Review of the existing quality both upstream and downstream of the discharge point on the Campaspe River
- ***Association*** – determines whether there is a relationship between a particular contaminant associated with the discharge and the beneficial uses, or environmental values, of the river.

The risk analysis phase requires a risk assessment to be undertaken for those value and threat pairings which have been identified as plausible. This was determined by the values identified in the river and the association of values to the threats within the discharge.

A risk assessment of all threat and value pairings was not undertaken – just for relevant parameters /stressors for which there was adequate information to make an assessment with. It is acknowledged that there may be other threats / parameters for which there is not enough data currently available.

6.2.2 Environmental values and stressors

The first step in the risk assessment process is to identify and define the relationships and interactions between potential stressors, hazards and threats associated with Kyneton WRP treated wastewater discharge and the environmental values of the receiving waterway – the Campaspe River.

Based on the environmental values identified for the Campaspe River (see Table 2), the key values in which risk were assessed are:

- Largely Modified Aquatic Ecosystems.
- Primary and Secondary Recreation.
- Agriculture / Irrigation / Stock Watering.
- Aesthetic enjoyment.

Table 25 presents a high level conceptual model in the form or a threats / values interaction matrix for a range of key stressors. For each stressor and its associated hazard, a brief description of the specific threatening process is provided. Note that a range of other potential stressors could have been included, except that there is either no data or very little data available for these for the Campaspe River and Kyneton WRP (e.g. heavy metals).

The risk prioritisation process has been completed only for direct threats to the environmental values of the receiving waterway. The complexity of interaction effects between stressors and environmental factors has been accounted for in the rationale provided for individual risk ratings.

Table 25 Potential impacts to values and beneficial uses of the Campaspe River resulting from Kyneton WRP discharge

	Stressor →	**Suspended Solids**	**BOD**	***E. coli***	**NH3 -N**	**NOx -N**	**Total N**	**Total P**	**Total Dissolved Solids**	**pH**
Value ↓	Hazard →	High solids load	Increased concentration	Microbiological contamination	Increased concentration; Introduction of toxicant	Increased concentration; Introduction of toxicant	Increased concentration	Increased concentration	Increased concentration	Unnatural variation
Water Quality	Primary and Secondary contact recreation	**Increased turbidity**		**Potential human health issues**	**Toxicity**		*Eutrophication*	*Eutrophication*	Toxicity	Toxicity
	Aesthetic enjoyment and residential amenity	**Increased turbidity**			*Visual amenity impacted*		*Visual amenity impacted*	*Visual amenity impacted*		
	Agricultural (stock)			**Potential livestock health issues**		**Toxicity**	*Eutrophication*	*Eutrophication*	**Exceed tolerances**	
	Irrigation (crops)	*Clogging of equipment*		**Potential human health issues**			**Decreased crop yields and off-site impacts**	**Bio-clogging of equipment and off-site impacts**	**Exceed tolerances**	**Unsuitable for general use**
	Fish for human consumption			**Potential human health issues**			*Eutrophication*	*Eutrophication*		Toxicity
Aquatic biota	Native Species	**Impaired physiological function**	*Impaired physiological function*		**Toxicity**	**Toxicity**	*Altered habitat*	*Altered habitat*	**Exceed tolerances**	**Exceed tolerances**
	Threatened aquatic fauna	**Impaired physiological function**	*Impaired physiological function*		**Toxicity**	**Toxicity**	*Altered habitat*	*Altered habitat*	**Exceed tolerances**	**Exceed tolerances**
Aquatic Ecosystems	Habitat values	**Smothering of benthic habitats**			*Altered habitat*	*Altered habitat*	*Altered habitat*	*Altered habitat*		
	Ecosystem functions	*Loss of productivity*	*Loss of productivity*				*Eutrophication*	*Eutrophication*		
Vegetation	Aquatic plants	**Smothering**			*Proliferation of nuisance species*	*Proliferation of nuisance species*	**Proliferation of nuisance species**	**Proliferation of nuisance species**	**Exceed tolerances**	**Exceed tolerances**
	Riparian vegetation						**Altered composition**	**Altered composition**	**Exceed tolerances**	

Bold text - direct threat to the value. *Grey text* - indirect interaction affect

A threat score table (Table 26) has been developed to identify plausible impacts to environmental values as a result of the activities associated with the discharge. The threat score table forms the basis of the risk assessment. Threat scores provide an indication of the potential for an analyte to impact a beneficial use or value, i.e. the higher the score, the greater the likelihood of an impact.

Table 26 Threat Score Ranking for discharge

Score	Stressor Score Ranking*
5	>5 x ERS objective
4	>2 x ERS objective to 5 x ERS objective
3	> ERS objective to 2 x ERS objective
2	>0.5 x ERS objective
1	≤0.5 x ERS objective

6.2.3 Likelihood Descriptors

Likelihood is based on what is known, or should be known, about the hazard, and the factors influencing the likelihood of risk occurring. A likelihood description score table is presented in Table 27.

Table 27 Likelihood descriptors

Likelihood Title	Description	Estimated time boundaries
Certain	Expected to happen regularly under normal circumstances	Weekly - Monthly
Likely	Expected to happen at some stage	Monthly – Yearly
Possible	May happened at some stage	Yearly – 10 years
Unlikely	Not likely to happen in normal circumstances	10 – 100 years
Rare	Could happen but probably never will	100 + years

6.2.4 Consequence Descriptors

A risk assessment consequence is the potential impact of a threat on a value, and can provide a measure of possible change to communities and species. Consequence descriptions have been applied to both environmental aspects and risk to aquatic ecosystems, but also to social aspects, as the local community are likely to derive benefits from a healthy ecosystem.

Consequence descriptors have been provided on a scale of 1 to 5, where 1 represents little or no impact, and 5 represents an extreme impact. The consequence descriptors used to assess the potential impact for each possible risk are shown in Table 28.

The consequence descriptor provides an indication of the specific impact at the study site, taking into consideration existing upstream conditions (in contrast with the threat scores, which are intended to be able to be applied more broadly to other risks or other values outside this project). Application of the consequence descriptors is guided by the water quality and mixing zone analysis, and additional information reviewed, to provide guidance on the condition, values and uses of the Campaspe River.

Table 28 Consequence descriptors / scores

		Negligible	Minor	Moderate	Major	Extreme
Consequence Level		Minimal, if any impact for some communities. Potentially some impact for a small number (<10) of individuals.	Low level impact for some communities, or high impact for a small number (<10) of individuals.	High level of impact for some communities, or moderate impact for communities area-wide.	High level of impact for communities area-wide.	High level of impact.
		Very localised scale	Zone of influence is tens of metres or more than one habitat	Zone of influence is several kilometres or multiple habitats	Zone of influence is several kilometres and more than one habitat	Zone of influence is several kilometres and more than one habitat
		1	2	3	4	5
Environmental	Habitat, communities and / or assemblages	Alteration or disturbance to habitat within natural variability. Less than 5% of the area of habitat affected or removed.	5-10% of the area of habitat affected in a major way or removed	10 to 30% of the area of habitat affected in a major way or removed.	30 to 70% of the area of habitat affected in a major way or removed.	Greater than 70% of the area of habitat affected in a major way or removed.
	Species and / or groups of species (including protected species)	Less than 5% impact on abundance No detectable change in abundance	5-10% impact on abundance Detectable change in abundance but no effect on viability	10-30% impact on abundance Obvious change in abundance and detectable change in viability	30-70% impact on abundance Obvious change in abundance and in viability	>70% impact on abundance Major change in abundance and in viability
Social	Amenity - Sensory / Perception (visual, noise, odour).	Short term impacts that alter perception of area as a high amenity place to live / visit. Region still seen as attractive place to live and visit.	Short term (months) localised impacts that alter perception of area as a high amenity place to live / visit. Region not locally seen as attractive place to live and visit.	Medium term (1-2 years) regional impacts that alter perception of area as a high amenity place to live / visit. Region not widely seen as attractive place to live. Some people may make complaints. Creek area may be avoided for a short period of time (<1 month)	Community perception that the area is significantly damaged. Area loses appeal as residential area.	Community perception that the area has experienced major damage as a residential location and a recreational area and is a place to be avoided. .
Livestock	Cattle health and meat products	Little or no impact on current practices	Impacts on local meat retail industry, with some people put off buying meat, and lowered prices.	Reputational damage and loss of trust in the meat export industry, financial losses for the industry with several years required for recover	Partial closure of the meat export market, with financial losses for businesses around Kyneton, and Australia more broadly	Meat consumption and export ban for a significant period of time with extensive financial losses for businesses around Kyneton, and Australia
Regulatory	Legal / reputational	An internally reported incident, no external contact required	Contact with regulators regarding a breach, requiring some action.	Fines or sanction from regulatory body and requires immediate review of mitigation strategies.	Serious regulatory outcome leading to regulatory sanctions and large fines.	Regulatory outcome leading to cancellation of discharge licenses. Criminal/Civil charges against Directors and Officers.

6.2.5 Risk Calculation Method

6.2.5.1 Risk assessment approach for high concentration / low frequency risks

With consideration of likelihood and consequences, an overall risk rating can then be determined and these are presented in Table 29. This risk matrix has been adopted from EPA Publication 1695.1 (EPA 2018). In this risk matrix, likelihood and consequence are given relative scores which can be matched on the matrix to give a risk rating from low to extreme.

Table 29 Adopted risk matrix using EPA Framework methodology

		Consequence				
		Negligible	Minor	Moderate	Major	Extreme
Likelihood	Certain – weekly/monthly	Medium	High	High	Extreme	Extreme
	Likely – monthly/yearly	Medium	Medium	High	High	Extreme
	Possible- yearly/10 yearly	Low	Medium	Medium	High	High
	Unlikely – 10 – 100 years	Low	Low	Medium	Medium	High
	Rare – 100+ years	Low	Low	Low	Medium	Medium

6.2.5.2 Risk assessment approach for low to medium concentrations but higher frequency risks

Whilst lower concentrations / higher frequency WRP discharges could be assessed using the methods presented above, a different approach has been adopted with the level of risk is calculated based upon the combination of the threat score and consequence descriptors (as per AVIRA methodology). The matrix below (Table 30) was used to calculate the risk for each combination. This matrix has been developed and successfully used by GHD over a number of risk assessment projects. It is calibrated prior to use for each project, based on context, to ensure that various threat/consequence combinations give a risk that is sensible for the project.

Table 30 Risk Matrix for AVIRA methodology

		Consequence				
		Negligible	Minor	Moderate	Major	Extreme
Threat Score	5	M	H	VH	VH	VH
	4	L	M	H	VH	VH
	3	L	L	M	H	H
	2	L	L	L	L	L
	1	L	L	L	L	L

L- Low; M – Medium; H- High; VH – Very high

6.2.5.3 Risk rankings and descriptions

Rating risks presented above are a guide to decision making on risk management to eliminate or otherwise reduce the risk to an acceptable level. A description of risk rankings and their description are presented in Table 31.

Table 31 Description of risk ratings

Risk Level	Description
Extreme / Very High	Totally unacceptable level of risk. Stop work and/or take action immediately.
High	Unacceptable level of risk, controls must be put in place to reduce to lower levels.
Medium	Can be acceptable if controls are in place. Attempt to reduce to low.
Low	Acceptable level of risk. Attempt to eliminate risk but higher risk levels take priority.

6.3 Risk Analysis

6.3.1.1 Risk assessment approach for high concentration / low frequency risks

A list of parameters with their maximum values from the BNR plant over the period of record are presented in Table 27. These parameters of interest have a guideline value available and also have the potential for toxicity at the discharge point (or low oxygen event at the discharge point), the key parameters of interest here are ammonia as N and BOD.

For the ‘pre-control risk’ (inherent risk) an assessment of the likelihood of maximum ammonia and BOD events was undertaken and the frequency is described in Table 27 i.e. 1 event in 7 years. However, in determining the likelihood of the BNR plant discharging at the time of maximum concentration, an allowance must also be made that takes into account the probability that the BNR plant is actually discharging to the river (the BNR plant has in the 2017-2020 period discharged on approximately 50% of days, this is the expected frequency for future discharges). Also, when the BNR plant is discharging, the probability that it will be at the ratio of 1:2 also needs to be taken into account (the maximum discharge from BNR plant is limited to 7 ML/day, so any streamflow greater than 3.5 ML/day would the provide a higher dilution – a streamflow of 3.5 ML/day has a 50% probability of exceedance at Kyneton). As such, the likelihood of a maximum concentration event occurring is 1 in 7 years and the likelihood that the BNR plant is also discharging and at a discharge ratio of 1:2 results in a likelihood of event (1 in 7 years x 50%) or 1 in 14 years. The likelihood of occurrence of a maximum concentration event during a BNR discharge period (1 in 14 years) under a ‘pre-control risk’ (inherent risk) scenario, falls within the ‘unlikely’ category of 10-100 years.

For the ‘post controlled risk’ (residual risk) for ammonia and BOD, the BNR discharge will be diverted to storage (using continuously monitored online instrumentation – i.e. ‘interlocks’) once certain concentrations within the discharge are reached, ensuring the discharge with maximum concentrations that would otherwise reach the Campaspe River are diverted to storage. As such, the resulting concentrations for ammonia and BOD within the Campaspe River after controls are in place are considerably lower than the maximum measured values and are below guideline values resulting in a negligible consequence and low risk (reduced down from a medium risk in the pre controlled assessment).

Table 32 Key parameters and their frequency of maximum reading in BNR discharge

Parameter	Unit	Campaspe River guideline value	Guideline type	BNR Plant maximum value	Data count	Frequency of maximum reading (by data count)	Timespan of data collection	Frequency of maximum reading (by time)
Ammonia as N	mg/L	0.9 (at pH 8)	Maximum	6.7	375	0.27%	2015-2021	Once in 7 years
BOD	mg/L	None	-	17	374	0.27%	2015-2021	Once in 7 years
Electrical Conductivity	µS/cm	2000	75th percentile	680	14	7.14%	2015-2015	Once in 1 year
Nitrogen - Total	mg/L	1.05	75th percentile	15	331	0.30%	2015-2021	Once in 7 years
pH	pH units	8	75th percentile	8.5 (maximum)	327	0.31%	2015-2021	Once in 7 years
pH	pH units	6.8	25th percentile	7 (minimum)	327	0.31%	2015-2021	Once in 7 years
Phosphorus - Total	mg/L	0.055	75th percentile	0.79	330	0.30%	2015-2021	Once in 7 years

Table 33 Risk evaluation for aquatic ecology values (using maximum concentrations)

Stressor	Guide-line	Units	Concentration#			Likelihood	Consequence	Risk Rating	Comment
			Up-stream	Dis-charge	Downstream	Likelihood	Consequence	Risk Rating	
Ammonia as N	0.9*	mg/L	0.05	6.7	4.48	Unlikely	Major	Medium	'pre-control risk' (inherent risk)
			0.05	1	0.68	Unlikely	Negligible	Low	'post-control risk' (residual risk)
BOD	-	mg/L	1	17	11.67	Unlikely	Major	Medium	'pre-control risk' (inherent risk)
			1	5	3.67	Unlikely	Negligible	Low	'post-control risk' (residual risk)

*Ammonia-N guideline at pH of 8, however lower pH and colder temperatures result in an increased guideline value

#Concentration downstream calculated by mass balance using a 1:2 discharge scenario

6.3.1.2 Risk assessment approach for low to medium concentrations but higher frequency risks

The results of the risk evaluation for aquatic ecology values, primary and secondary contact, irrigation and stock watering are presented in Table 34 to Table 41.

For the risk assessment process, two seasonal scenarios were considered – summer (December - May) and winter (June - November). In order to calculate the resulting Campaspe River concentration downstream of the discharge point, a mass balance calculation was performed on the WRP discharge and the upstream river with a streamflow-to-discharge ratio was 1:2 (detailed as a proportion of 66.7%). Concentrations for the WRP discharge and the Campaspe River were median values for each parameter in summer and winter. Additional analysis was undertaken using 90th percentile concentrations.

Table 34 Risk Evaluation for aquatic ecology values (using median concentrations)

Stressor	Guide-line	Season	Concentration (medians unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
Electrical Conductivity (µS/cm)	2000	Summer	540	630	600	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	440	630	567	1	1	1	2	2	2	L	L	L	
pH (upper)	8	Summer	7.6	7.8	7.7	2	2	2	2	2	2	L	L	L	All below guideline
		Winter	7.5	7.6	7.6	2	2	2	2	2	2	L	L	L	
pH (lower)	6.8	Summer	7.6	7.8	7.7	2	2	2	2	2	2	L	L	L	All above guideline
		Winter	7.5	7.6	7.6	2	2	2	2	2	2	L	L	L	
Total Nitrogen (mg/L)	1.05	Summer	0.8	6.30	4.47	2	5	4	2	2	2	L	H	M	Higher risk in discharge, but mixing zone allowed with TN.
		Winter	0.9	6.55	4.67	2	5	4	2	2	2	L	H	M	
Total Phosphorus (mg/L)	0.055	Summer	0.09	0.19	0.16	3	4	4	2	2	2	L	M	M	Higher risk in discharge, but mixing zone allowed with TP
		Winter	0.07	0.18	0.14	3	4	4	2	2	2	L	M	M	
Ammonia -N (mg/L)	0.9	Summer	0.05	0.05	0.05	1	1	1	3	3	3	L	L	L	All below guideline
		Winter	0.05	0.05	0.05	1	1	1	3	3	3	L	L	L	
Nitrate -N (mg/L)	2.4	Summer	0.005	4.40	2.94	1	3	3	3	3	3	L	M	M	Mixing zone, as part of TN mixing zone
		Winter	0.02	4.5	3.01	1	3	3	3	3	3	L	M	M	

Table 35 Risk Evaluation for aquatic ecology values (using 90th percentile concentrations)

Stressor	Guide-line	Season	Concentration (90th %ile unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
Electrical Conductivity (µS/cm)	2000	Summer	672	667	669	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	564	667	633	1	1	1	2	2	2	L	L	L	
pH (upper)	8	Summer	7.97	8.2	8.1	2	3	3	2	2	2	L	L	L	Just above 75th percentile guideline
		Winter	7.7	8	7.9	2	3	2	2	2	2	L	L	L	
pH (lower)	6.8	Summer	7.97	8.2	8.1	2	3	3	2	2	2	L	L	L	All above guideline
		Winter	7.7	8	7.9	2	3	2	2	2	2	L	L	L	
Total Nitrogen (mg/L)	1.05	Summer	1.17	9.00	6.39	3	5	5	2	2	2	M	H	H	High risk in discharge, but mixing zone allowed with TN.
		Winter	1.66	9.36	6.79	3	5	5	2	2	2	M	H	H	
Total Phosphorus (mg/L)	0.055	Summer	0.157	0.42	0.33	4	5	5	2	2	2	M	H	H	High risk in discharge, but mixing zone allowed with TP
		Winter	0.13	0.4	0.31	4	5	5	2	2	2	M	H	H	
Ammonia -N (mg/L)	0.9	Summer	0.05	0.30	0.22	1	1	1	3	3	3	L	L	L	All below guideline
		Winter	0.05	0.4	0.28	1	1	1	3	3	3	L	L	L	
Nitrate -N (mg/L)	2.4	Summer	0.038	7.30	4.88	1	4	4	2	2	2	L	M	M	Mixing zone, as part of TN mixing zone
		Winter	0.19	7	4.73	1	4	3	2	2	2	L	M	L	

Table 36 Risk Evaluation for primary and secondary contact (using median concentrations)

Stressor	Guide-line	Season	Concentration (medians unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
E coli (primary) (orgs/100mL)	260	Summer	130	0	43	2	1	1	2	2	2	L	L	L	All below guideline
		Winter	66	0	22	1	1	1	2	2	2	L	L	L	
E coli (secondary) (orgs/100mL)	5500	Summer	130	0	43	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	66	0	22	1	1	1	2	2	2	L	L	L	
Ammonia -N (mg/L)	0.5	Summer	0.05	0.05	0.05	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	0.05	0.05	0.05	1	1	1	2	2	2	L	L	L	
Suspended solids (mg/L)	15	Summer	8.0	4.0	5.3	2	1	1	2	2	2	L	L	L	All below guideline
		Winter	4.0	3.0	3.3	1	1	1	2	2	2	L	L	L	
Nitrate -N (mg/L)	11.3	Summer	0.005	4.40	2.94	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	0.02	4.5	3.01	1	1	1	2	2	2	L	L	L	
Total Dissolved Solids (mg/L)	1000	Summer	260	410	360	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	250	370	330	1	1	1	2	2	2	L	L	L	

Table 37 Risk Evaluation for primary and secondary contact (using 90th percentile concentrations)

Stressor	Guide-line	Season	Concentration (90th %ile unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
E coli (primary) (orgs/100mL)	260	Summer	648	21	230	4	1	2	2	2	2	M	L	L	WRP discharge lower than upstream
		Winter	285	21	109	3	1	1	2	2	2	L	L	L	
E coli (secondary) (orgs/100mL)	5500	Summer	648	21	230	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	285	21	109	1	1	1	2	2	2	L	L	L	
Ammonia -N (mg/L)	0.5	Summer	0.05	0.30	0.217	1	2	1	2	2	2	L	L	L	All below guideline
		Winter	0.05	0.4	0.283	1	2	2	2	2	2	L	L	L	
Suspended solids (mg/L)	15	Summer	32.8	10.0	17.6	4	2	3	2	2	2	M	L	L	WRP discharge lower than upstream
		Winter	34.5	8.8	17.3	4	2	3	2	2	2	M	L	L	
Nitrate -N (mg/L)	11.3	Summer	0.038	7.30	4.88	1	2	1	2	2	2	L	L	L	All below guideline
		Winter	0.19	7	4.73	1	2	1	2	2	2	L	L	L	
Total Dissolved Solids (mg/L)	1000	Summer	340	440	407	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	342	410	387	1	1	1	2	2	2	L	L	L	

*Note 95th percentile concentrations used for *E. coli* to align with guideline

Table 38 Risk Evaluation for irrigation (using median concentrations)

Stressor	Guide-line	Season	Concentration (medians unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
Electrical Conductivity (µS/cm)	950	Summer	540	630	600	2	2	2	2	2	2	L	L	L	All below guideline
		Winter	440	630	567	1	2	2	2	2	2	L	L	L	
E coli (orgs/100mL)	100	Summer	130	0	43	3	1	1	2	2	2	L	L	L	All below guideline
		Winter	66	0	22	2	1	1	2	2	2	L	L	L	
Total Nitrogen (mg/L)	5	Summer	0.8	6.30	4.47	1	3	2	2	2	2	L	L	L	All below guideline
		Winter	0.9	6.55	4.67	1	3	2	2	2	2	L	L	L	
Total Phosphorus (mg/L)	0.05	Summer	0.09	0.19	0.157	3	4	4	2	2	2	L	M	M	Medium risk in discharge, but mixing zone allowed with TP
		Winter	0.07	0.18	0.143	3	4	4	2	2	2	L	M	M	

Table 39 Risk Evaluation for irrigation (using 90th percentile concentrations)

Stressor	Guide-line	Season	Concentration (90th %ile unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
Electrical Conductivity (µS/cm)	950	Summer	672	667	669	2	2	2	2	2	2	L	L	L	All below guideline
		Winter	564	667	633	2	2	2	2	2	2	L	L	L	
E coli (orgs/100mL)	100	Summer	648	21	230	5	1	4	2	2	2	H	L	M	WRP discharge lower than upstream
		Winter	285	21	109	4	1	3	2	2	2	M	L	L	
Total Nitrogen (mg/L)	5	Summer	1.17	9.00	6.39	1	3	3	2	2	2	L	L	L	All below guideline
		Winter	1.66	9.36	6.79	1	3	3	2	2	2	L	L	L	
Total Phosphorus (mg/L)	0.05	Summer	0.157	0.42	0.332	4	5	5	2	2	2	M	H	H	High risk in discharge, but mixing zone allowed with TP
		Winter	0.13	0.4	0.310	4	5	5	2	2	2	M	H	H	

Table 40 Risk Evaluation for stock watering (using median concentrations)

Stressor	Guide-line	Season	Concentration (medians unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
E coli (orgs/100mL)	100	Summer	130	0	43	3	1	1	2	2	2	L	L	L	WRP discharge lower than upstream
		Winter	66	0	22	2	1	1	2	2	2	L	L	L	
Nitrate -N (mg/L)	400	Summer	0.005	4.40	2.93	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	0.02	4.5	3.00	1	1	1	2	2	2	L	L	L	
Total Dissolved Solids (mg/L)	2500	Summer	260	410	360	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	250	370	330	1	1	1	2	2	2	L	L	L	

Table 41 Risk Evaluation for stock watering (using 90th percentile concentrations)

Stressor	Guide-line	Season	Concentration (90th %ile unless otherwise specified)			Threat score			Consequence			Risk Score			Comment
			Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	Up-stream	Dis-charge	Downstream	
E coli (orgs/100mL)	100	Summer	648	21	230	5	1	4	2	2	2	M	L	L	WRP discharge lower than upstream
		Winter	285	21	109	4	1	3	2	2	2	L	L	L	
Nitrate -N (mg/L)	400	Summer	0.038	7.30	4.88	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	0.19	7	4.73	1	1	1	2	2	2	L	L	L	
Total Dissolved Solids (mg/L)	2500	Summer	340	440	407	1	1	1	2	2	2	L	L	L	All below guideline
		Winter	342	410	387	1	1	1	2	2	2	L	L	L	

6.3.2 Additional risk assessment of ammonia

Risks associated with ammonia toxicity are examined further in this section. ANZG (2018) sets out the guideline for ammonia as related to pH, the key value being the guideline value of 0.9 mg/L at a pH of 8. As pH reduces, the guideline value increases.

A plot of pH and ammonia data (from 2015 to 2021, n = 327) for the BNR discharge when compared to the ANZG (2018) guideline is presented in Figure 48. Note that this data is the Kyneton BNR discharge before mixing with Campaspe River water. Also to note is that there was some ammonia data not plotted on the graph as there was no corresponding pH value for the same day (including one outlier on 2 August 2018 where ammonia as N was measured at 6.7 mg/L). The graph shows that the number of data points greater than the guideline value was 4 out of 327 (1.2%).

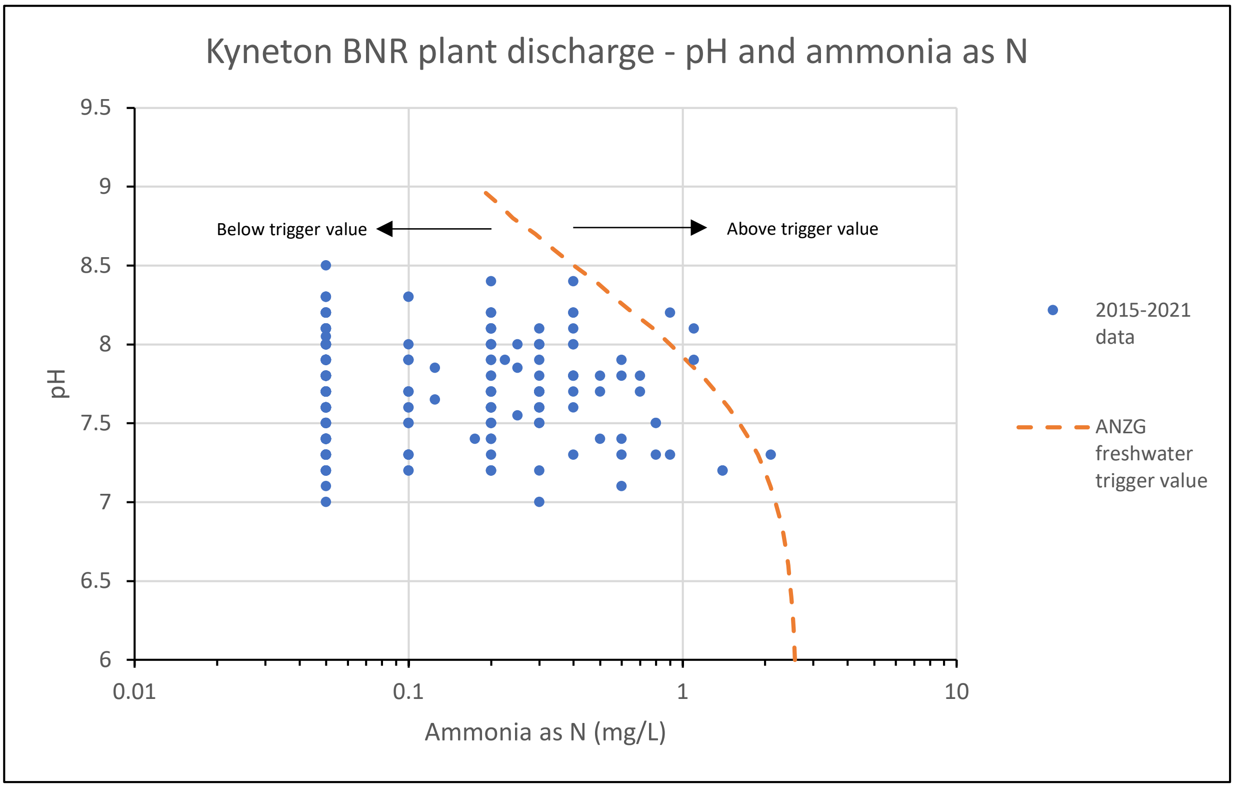

***Figure 48** Kyneton BNR plant discharge ammonia as N and pH compared to ANZG toxicity guideline*

Further investigation as to the risk of ammonia was undertaken using the USEPA (2013) guideline for ammonia toxicity, which includes references to both pH and temperature in the form of a 'thirty-day rolling average concentration of total ammonia nitrogen (in mg TAN/L) that is not to be exceeded more than once every three years on the average, the chronic criterion magnitude (CCC)' (see Figure 49).

In order to estimate the temperature of the BNR discharge, a graph of available temperature data each month for the BNR discharge and the Campaspe River is presented in Figure 50. The average temperatures are similar, although the BNR plant is slightly higher during winter and spring months. Average values for temperature for summer months was 17.4 deg C, autumn 13.4 deg C, winter 8.8 deg C and spring 12.5 deg C.

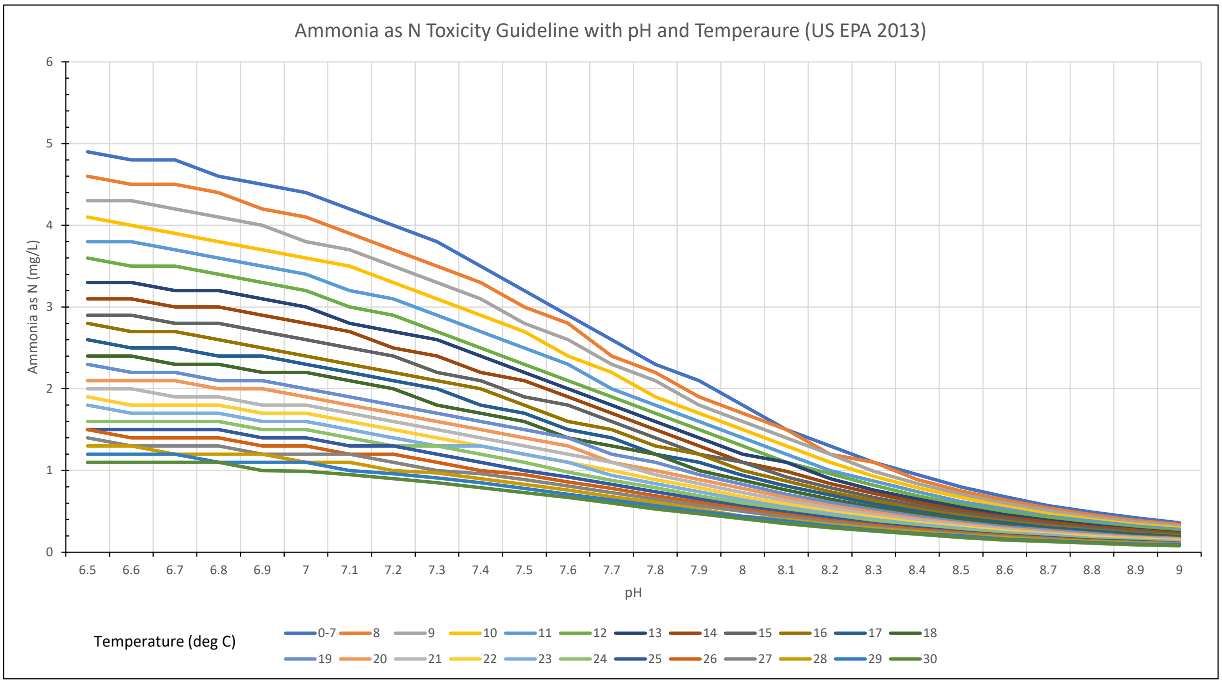

Figure 49 ***Ammonia as N toxicity guideline data with pH and temperature (source: US EPA 2013)***

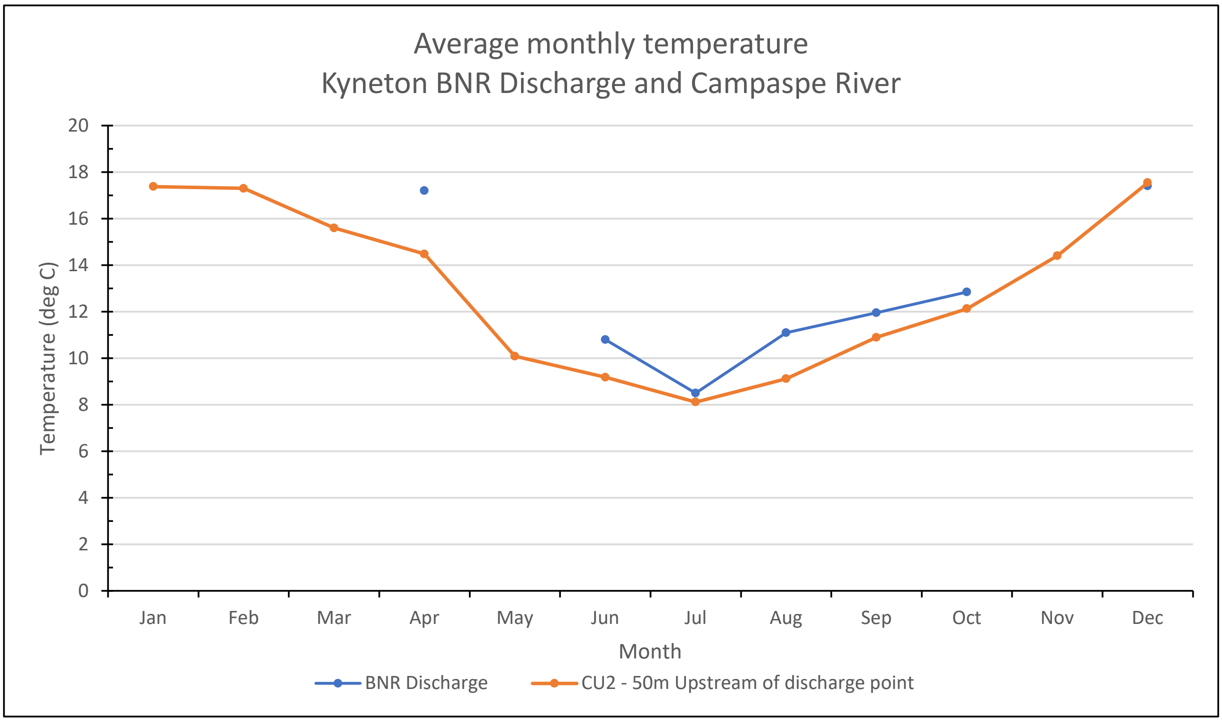

Figure 50 ***Average monthly temperature of Kyneton BNR discharge and the Campaspe River upstream***

The four ammonia / pH data points (out of a total of 327) that exceeded the ANZG guideline have been tabulated in Table 42. When comparing this data to the USEPA (2013) guideline, taking into account the expected temperature of the discharge, only one result (14/1/2021) has a value about the US EPA guideline. As such, using the USEPA methodology, the frequency of exceeding the guideline is relatively low (1 sample out of 327), and this would be considerably reduced when taking into account the '30 days duration rolling average' set out in the method.

Table 42 Assessment of Kyneton BNR ammonia toxicity of the four samples out of 327 that were above ANZG (2018) guidelines and then compared to US EPA (2013) guidelines

Date	Ammonia as N	pH	ANZG Guideline at the given pH	Ratio of ammonia to ANZG guideline	Temperature	US EPA guideline (based on pH and temperature)	Ratio of ammonia to USEPA guideline
	mg/L	pH units	mg/L		Deg C	mg/L	
16/07/2020	1.1	7.9	1.03	1.068	9	1.8	0.611
27/08/2015	2.1	7.3	1.88	1.117	9	3.3	0.636
14/01/2021	0.9	8.2	0.66	1.363	17	0.7	1.285
19/08/2021	1.1	8.1	0.78	1.410	9	1.4	0.785

6.3.2.1 Supplementary details on the risk of ammonia on the day of maximum recorded concentration and if that occurred under a 1:2 discharge scenario

The maximum BNR plant ammonia-N reading of 6.7 mg/L was observed on 2 August 2018. Ammonia risk to the receiving environment of the Campaspe River requires both pH and temperature to be taken into account, however, there was no pH or temperature data available for the BNR plant on 2 August 2018, but the long-term average pH is 7.5 and average temperature is 9 °C for the BNR plant in August. There was no data available for the Campaspe River upstream on that date, however, the long-term average value for ammonia is 0.05 mg/L, pH is 7.5 and temperature 8 °C in August. On the day of discharge (2 August 2018), discharge volume was 3.9 ML/day and streamflow at Kyneton gauge was 82.8 ML/day (a modelled value, as this date was prior to gauge installation) – giving a streamflow-to-discharge ratio of approximately 21:1.

The ammonia as N (total ammonia, or TAN) guideline is available within ANZG (2018) and USEPA (2013). For the ANZG (2018) guideline for 95% species level of protection (at pH 7.5) is guideline value is 1.61 mg/L The USEPA (2013) guideline provides two values – acute and chronic. For a pH of 7.5 and a temperature of 9 °C the acute guideline value is 13 mg/L and the chronic value is 2.8 mg/L. The acute value is deemed to be a 1-hour average, whereas the chronic value is a 30-day rolling average that is not to exceed 2.5 times the chronic value as a 4-day average within the 30-days, and is not to be exceeded more than once in three years on average.

Mass balance equations to determine the downstream concentration of ammonia as N during the actual discharge period in the June - October 2018 period are presented in Table 43 and in Figure 51. Results show that, due to the dilution available within the river, the resulting ammonia as N concentrations were well below the ANZG (2018) and USEPA (2013) guideline values, including the 30 day rolling average (used in the USEPA assessment).

Table 43 Mass balance calculation of downstream ammonia concentrations during period of maximum recorded BNR ammonia concentration

Date	BNR Plant		Campaspe Upstream		Campaspe Downstream (calculated by mass balance)	
	Ammonia as N	Discharge	Ammonia as N	Streamflow	Ammonia as N	Streamflow
	mg/L	ML/day	mg/L	ML/day	mg/L	ML/day
7/06/2018	0.05	3.4	0.05	14.3	0.050	17.7
14/06/2018	0.05	4.2	0.05	74.3	0.050	78.5
21/06/2018	0.05	3.2	0.05	76.5	0.050	79.7
29/06/2018	0.7	3.5	0.05	53.2	0.090	56.7
5/07/2018	0.05	3.5	0.05	40.8	0.050	44.3
12/07/2018	0.05	3.8	0.05	64.0	0.050	67.8
13/07/2018		3.5	0.05	51.5	0.047	55.0
19/07/2018	1.1	3.3	0.05	41.5	0.128	44.9
26/07/2018	0.05	3.8	0.05	89.7	0.050	93.4

Date	BNR Plant		Campaspe Upstream		Campaspe Downstream (calculated by mass balance)	
2/08/2018	6.7	3.9	0.05	82.8	0.350	86.7
3/08/2018		4.3	0.05	75.3	0.047	79.7
9/08/2018	0.05	4.0	0.1	302.4	0.099	306.4
16/08/2018	0.2	3.6	0.05	86.8	0.056	90.5
23/08/2018	0.05	3.3	0.05	85.0	0.050	88.3
30/08/2018	0.05	2.6	0.05	56.7	0.050	59.3
7/09/2018	0.05	3.8	0.05	41.1	0.050	44.9
13/09/2018	0.05	3.2	0.05	30.1	0.050	33.3
20/09/2018	0.05	1.1	0.05	22.1	0.050	23.2
27/09/2018	0.2	0.6	0.05	15.9	0.056	16.6
4/10/2018	0.2	0.6	0.05	11.9	0.057	12.5
11/10/2018	0.4	0.9	0.05	9.3	0.081	10.2
12/10/2018		0.9	0.05	8.1	0.045	9.0
18/10/2018	0.05	1.1	0.05	8.6	0.050	9.7
25/10/2018	0.1	0.9	0.05	4.5	0.059	5.5

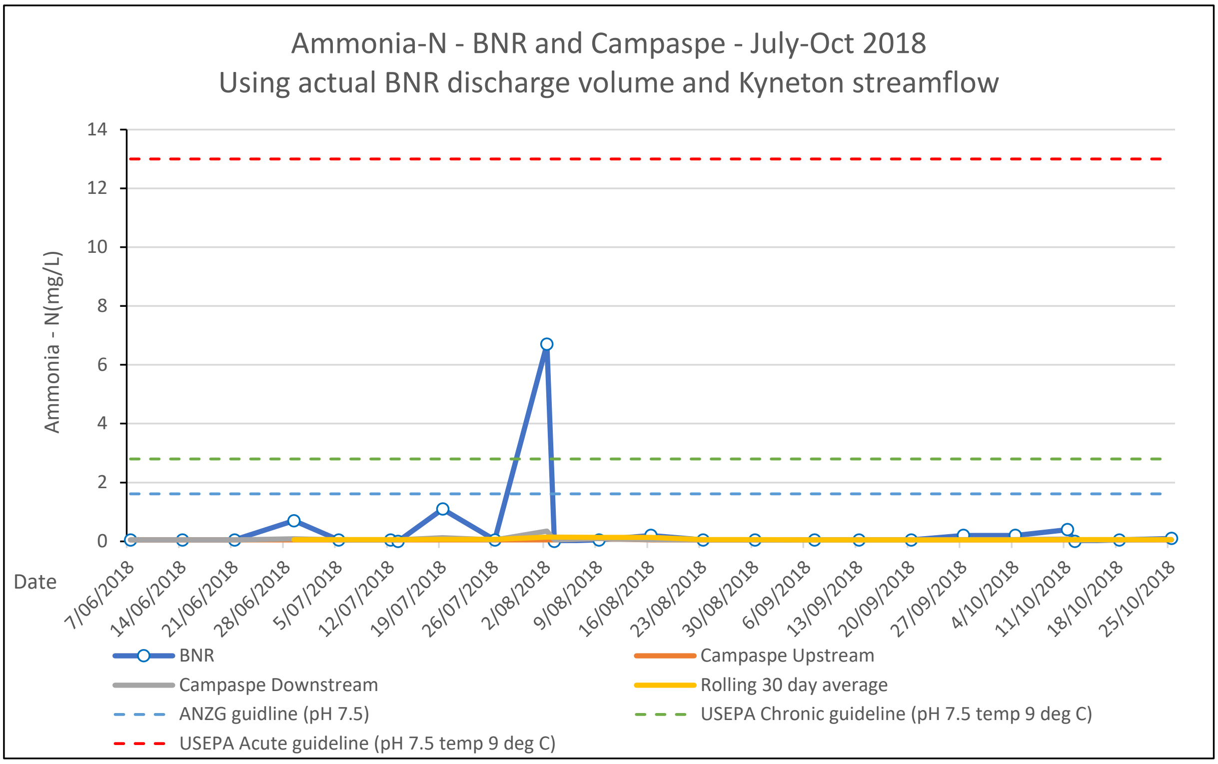

Figure 51 ***Ammonia as N during period during the maximum BNR ammonia concentration event***

Under the 1:2 discharge scenario, with the maximum ammonia as N concentration of 6.7 mg/L, mass balance calculations were performed, using some of the assumptions described above (in terms of time of year, temperature and pH), with results presented in Table 44 and in Figure 52. Results show that on the day of the high ammonia in the discharge (2 August 2018), the resulting ammonia concentration in the Campaspe River downstream (4.48 mg/L) is above the ANZG (2018) guideline value (1.61 mg/L), however comparing to the USEPA (2013) guidelines, the resulting concentration is below the acute guideline value (13 mg/L) but above the chronic guideline value (2.8 mg/L). The chronic guideline within USEPA (2013) allows a 30 day rolling average calculation of ammonia to be used when comparing to the guideline (and an upper limit of 2.5 times the chronic value as a 4-day average i.e. 2.5 x 2.8 mg/L = 7 mg/L within the 30-days). Using both the 30 day rolling average and 4 day upper limit, the resulting concentration in the Campaspe River remains below the USEPA (2013) chronic guideline.

It must be noted that this high concentration 1:2 discharge scenario would not occur under the future BNR plant operation – this is due to controls being in place to prevent such a discharge in the form of continuous monitoring arrangement of BNR discharge, which would divert any high ammonia water to storage, so it would not be discharged to the Campaspe River. This 1:2 scenario is only presented to show that, in the unlikely scenario that a high ammonia event occurred (under the same pH and temperature conditions presented in the worked example) and the discharge monitoring equipment failed to divert the discharge to storage, the resulting concentration of ammonia in the Campaspe River would unlikely be a 'toxic event' as it would not exceed the USEPA (2013) 30 day rolling average chronic guideline value (or the 4 day average maximum guideline).

Table 44 Calculation of downstream ammonia concentrations under 1:2 discharge scenario with a maximum recorded ammonia concentration

Date	BNR Plant		Campaspe Upstream		Campaspe Downstream (calculated by mass balance)	
	Ammonia as N	Discharge	Ammonia as N	Streamflow	Ammonia as N	Streamflow
	mg/L	ML/day	mg/L	ML/day	mg/L	ML/day
7/06/2018	0.05	2	0.05	1	0.050	3
14/06/2018	0.05	2	0.05	1	0.050	3
21/06/2018	0.05	2	0.05	1	0.050	3
29/06/2018	0.7	2	0.05	1	0.483	3
5/07/2018	0.05	2	0.05	1	0.050	3
12/07/2018	0.05	2	0.05	1	0.050	3
13/07/2018		2	0.05	1	0.017	3
19/07/2018	1.1	2	0.05	1	0.750	3
26/07/2018	0.05	2	0.05	1	0.050	3
2/08/2018	6.7	2	0.05	1	4.483	3
3/08/2018		2	0.05	1	0.050	3
9/08/2018	0.05	2	0.1	1	0.067	3
16/08/2018	0.2	2	0.05	1	0.150	3
23/08/2018	0.05	2	0.05	1	0.050	3
30/08/2018	0.05	2	0.05	1	0.050	3
7/09/2018	0.05	2	0.05	1	0.050	3
13/09/2018	0.05	2	0.05	1	0.050	3
20/09/2018	0.05	2	0.05	1	0.050	3
27/09/2018	0.2	2	0.05	1	0.150	3
4/10/2018	0.2	2	0.05	1	0.150	3
11/10/2018	0.4	2	0.05	1	0.283	3
12/10/2018		2	0.05	1	0.017	3
18/10/2018	0.05	2	0.05	1	0.050	3
25/10/2018	0.1	2	0.05	1	0.083	3

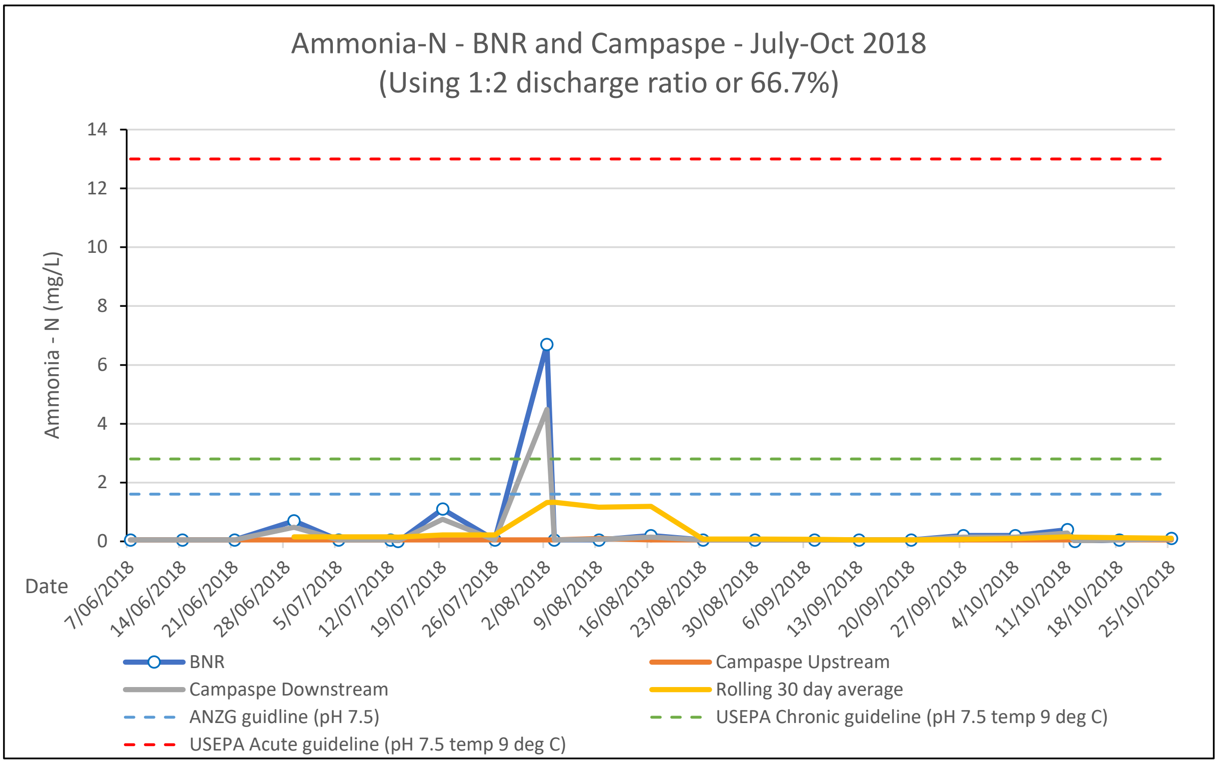

Figure 52 ***Ammonia as N under 2:1 discharge scenario around the maximum BNR ammonia concentration event***

6.3.3 Additional risk assessment of BOD

Risks associated with BOD in the BNR discharge to the Campaspe River are presented in this section. Whilst there is no guideline associated with BOD, there is a risk that high BOD will reduce the dissolved oxygen within the Campaspe River after mixing with BNR discharge water. The BOD of the BNR discharge is statistically similar (although differences are apparent for 'higher' e.g. 99th percentile values) to the Campaspe River upstream of the discharge point (see Figure 53). The maximum recorded BOD for the BNR discharge (n=374) was 17 mg/L and the 99th percentile value is 7 mg/L and 75th percentile of 3 mg/L. For the Campaspe River (n = 169), the maximum recorded BOD was 66 mg/L and the 99th percentile value is 13 mg/L and 75th percentile of 3 mg/L. It is acknowledged that the BNR discharge may exceed desirable (say 5 mg/L) concentrations of BOD, however, it is an infrequent occurrence and it is unlikely to have any long term or widespread impacts on the receiving waters after mixing.

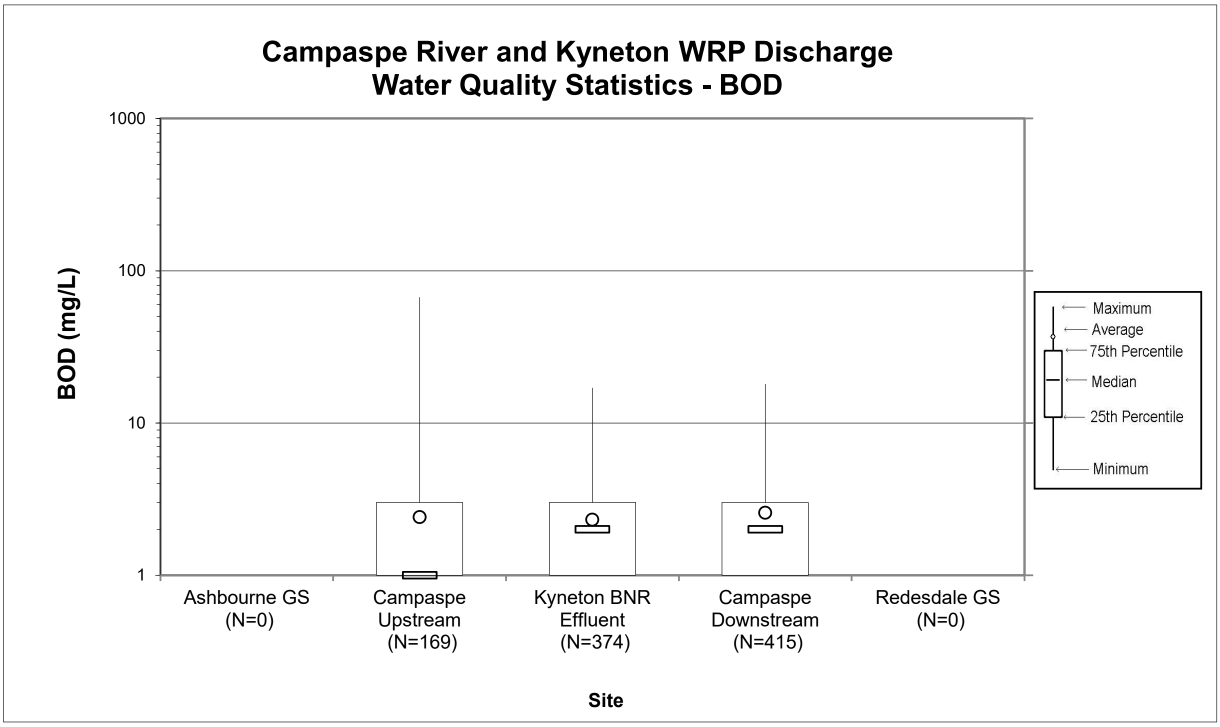

Figure 53 BOD statistics (2015-2021) Kyneton BNR discharge and the Campaspe River

6.3.3.1 Supplementary details on the risk of BOD on the day of maximum recorded concentration and if that occurred under a 1:2 discharge scenario

The maximum BNR plant biological oxygen demand (BOD) reading of 17 mg/L was observed on 25 June 2019. As stated above, there is no guideline value for BOD, however there is a risk that dissolved oxygen (%) (which has a 25th percentile value of 70%) may drop to undesirable levels as a result of excessive BOD. On the day of discharge (25 June 2019), the BNR discharge volume was 4.48 ML/day and streamflow at Kyneton gauge was 88.8 ML/day (a modelled value as this was prior to gauge installation) – resulting in a streamflow-to-discharge ratio of approximately 19:1.

It must be remembered however, that BOD is a 5 day reading, i.e. in the above event 17 mg/L of oxygen is needed over the following 5 days to replenish the oxygen consumed by biota. In order to determine the resulting concentration of dissolved oxygen and the estimated effect of BOD has on the receiving waters, modelling of dissolved oxygen in the Campaspe River would be required to understand the likely changes to the dissolved oxygen concentrations with distance downstream and time. The model needs to take into account the 5 day travel time for the BOD_5 reading– this time period is long enough for the water to travel to Lake Eppalock and during this travel time, there would be movement of the water as it transits down the Campaspe River, including re-oxygenation events over riffles and at Turnpin Falls and Barfold Gorge and also the potential for higher oxygenated waters joining the Campaspe River main channel from tributary inflows downstream of the discharge point.

The settling out of wastewater and other solids in Campaspe River also needs to be taken into account for BOD calculations. Typically the Streeter and Phelps model is used to determine dissolved oxygen in waterways, however Tyagi et al (1999) describes some shortcomings of this modelling approach : "*The conventional Streeter and Phelps model does not account for the settleable component of BOD. The Streeter and Phelps model is therefore of little value in the present day context of polluted streams in which part of the BOD removal necessarily takes place through sedimentation, especially when untreated or partially treated wastes are discharged into streams.*"

A drop in dissolved oxygen is expected for a BOD of 17 mg/L (using mass balance calculations, the downstream BOD is calculated to be 11.7 mg/L after mixing with the Campaspe River at a ratio of 1:2, assuming an upstream BOD of 1 mg/L). However, the natural variation of dissolved oxygen needs to take into account, particularly the time of day and year, and observed in the Campaspe River upstream of the discharge point. Minimum dissolved oxygen readings within the Campaspe River above the discharge point are in the 1 – 2 mg/L range . The lower limit for ERS guideline for dissolved oxygen (%) is a 25th percentile value of 70%, so whilst it is not ideal that dissolved oxygen may drop as a result of BNR discharge, there is some flexibility under the ERS for a periods of lower dissolved oxygen.

With respect to BOD, an interlock arrangement is not feasible. Instead, the dissolved oxygen sensor in the BNR plant will be used to identify potentially high-risk releases with respect to BOD and these will be appropriately managed in order to avoid toxic 'low dissolved oxygen events'.

The 1:2 scenario above is only presented to show that, in the unlikely scenario that a high BOD event occurred and the discharge monitoring equipment failed to divert the discharge to storage, the consequences for the Campaspe River are unlikely to be a toxic 'low dissolved oxygen event' and also, it would not breach of the 25th percentile guideline value of 70% dissolved oxygen, which statistically allows for an infrequent low dissolved oxygen event.

6.4 Risk Characterisation

6.4.1.1 Risk assessment approach for high concentration / low frequency risk

For the 'pre-control risk' (inherent risk) an assessment of the likelihood of maximum ammonia and BOD events was undertaken and the likelihood of these events occurring was in the order of 1 in 14 years i.e. within the 'unlikely' category of 10-100 years. The consequence of the maximum ammonia and BOD events were given a 'major' consequence rating, leading to a resulting risk assessment of 'Medium'.

For the 'post controlled risk' (residual risk) for ammonia, the BNR discharge would be diverted to storage (using continuously monitored online instrumentation – i.e. 'interlocks') once certain concentrations within the discharge are reached, ensuring the discharge with maximum concentrations that would otherwise reach the Campaspe River are diverted to storage. As such, the resulting concentrations for ammonia within the Campaspe River after controls are in place are considerably lower than the maximum measured values and are below guideline values resulting in a 'Negligible' consequence and 'Low' risk (down from a medium risk in the pre controlled assessment).

With respect to BOD, whilst an interlock arrangement is not feasible, using the dissolved oxygen sensor in the BNR plant, high risk releases with respect to BOD could be identified and appropriately managed.

6.4.1.2 Risk assessment approach for low to medium concentrations but higher frequency risks

For aquatic ecology, most parameters had low risks associated with them for both summer and winter discharges. The exceptions were total N and total P, which had high risks to the Campaspe River, and this is in the form of eutrophication of the waterway (i.e. a secondary effect rather than direct toxicity). These elevated nutrient concentrations in the Campaspe River as a result of the WRP are contained within a mixing zone (i.e. a distance downstream at which the concentrations return to upstream or ERS guideline limits).

Eutrophication of receiving waters in the Campaspe River from elevated nutrients within the BNR discharge is a potential secondary risk – i.e. the elevated nutrients may cause excessive macrophyte and algae growth, which in turn may lead to poor water quality. This may be expected within the mixing zone to a certain extent. AQUEST (2023) have provided some additional commentary on eutrophication risk within the Campaspe River: "*Nutrients and excessive plant growth are high throughout the upper Campaspe River* (including above the WRP discharge point). *Some areas have dense stands of rooted plants whereas other areas are affected by Azolla when flows cease to occur in the river. Willows that choke the channel also encourage longer term growth of Azolla*". As such, whilst there is a risk of eutrophication within the mixing zone and associated secondary risks, these events are already occurring within the waterway

Risks from ammonia in the BNR discharge on aquatic ecology of the Campaspe River are calculated as being low (noting that an assessment of the maximum ammonia value is set out in the section above). The BNR discharge (prior to mixing with the Campaspe River) was shown to be very infrequently (one sample in 327 during 2015-2021) above USEPA (2013) guideline values, with this value taking into account the effects of pH and temperature on the toxicity level. The USEPA guidelines also allows for a 30 day rolling average associated with calculating ammonia risk i.e. the one individual non-conformance measured in the data set of 327 is likely to conform under a rolling average assessment, especially when most ammonia data in the BNR discharge is so low compared to the guidelines.

The ammonia data was also compared to ANZG (2018) guidelines (which takes into account only pH) in which four samples out of 327 were above the guideline. After BNR discharge mixes with the Campaspe River (even at a streamflow to discharge ratio of 1:2 or proportion of 66.7%), resulting concentrations for ammonia would typically be well below ANZG (2018) guidelines, even for the four samples identified, because the Campaspe River is considerably lower in ammonia (an order of magnitude lower than the BNR discharge) and is also typically lower in pH compared to the BNR discharge. This assessment of low risk for ammonia is also shown within the risk assessment using the 'daily risk tool' as shown in Section 7.

Risks from BOD within the BNR discharge are also shown to be low, due to the infrequent nature in which BOD is elevated (BOD is more frequently elevated in the Campaspe River upstream than the BNR discharge). It is likely that there would be no long term effects of the BOD either spatially or chronically with regards to aquatic ecology values of the Campaspe River.

For primary and secondary contact, the risk assessment showed that there were low risks from the WRP discharge associated with *E. coli* in the Campaspe River, given that the concentrations of the discharge (post March 2021) are lower than the river. Note additional pathogen risks for primary and secondary contact are set out in Section 8.

For irrigation, there were some medium risks associated with total P, however, the consequences of this are considered to be low – the elevated total P would be confined to the mixing zone only. A low risk in with *E. coli* was identified for Class B recycled water (i.e. median < 100 orgs/mL), however, the discharge is currently of better quality than Class B recycled water and meets Class A recycled water criterion for E. coli (< 10 orgs/mL).

For stock watering, results for all parameters showed that there was low risk, including *E. coli*. Additional pathogenic risks for stock watering are covered in Section 8.

7. Discharge risk assessment using a 'Daily Risk Tool'

A daily risk assessment is presented in this section and is complimentary to the risk assessment using the EPA framework presented in Section 6. Both these assessments, when combined, provide a more robust overall risk analysis that takes into account the constantly changing nature of the risks to environmental values present in the Campaspe River that meets the requirements of the EPA framework.

A daily risk assessment was undertaken for a range of scenarios (including 'current' baseline conditions), and with predicted 2022 and 2036 discharges to the river based on expected inflows into the plant. The risk assessment essentially estimates the water quality impact of the Kyneton WRP discharge on the environmental values of the Campaspe River (aquatic ecology, primary and secondary contact, irrigation and stock watering). The daily risk tool was used to analyse data over a 3-year period from July 2017 to June 2020.

7.1 Risk assessment of discharge using the 'Daily Risk Tool'

The method used in the risk assessment determined risks from the discharge on a daily basis to the Campaspe River downstream of the WRP discharge point with consideration of guideline values for each parameter (where a guideline was available). The risk analysis method assumes that the higher the concentration of a parameter above the guideline value, the higher the risk (with a linear response). An overview of the method is presented in Appendix E.

Three discharge scenarios were investigated – the 'current baseline' and a 1:2 streamflow-to-discharge ratio ('proportion' of 66.7%) using both 2022 and predicted 2036 inflows into the Kyneton WRP. Proportion is calculated as the proportion of discharge in the combined downstream total; e.g. with a ratio of streamflow to discharge of 1:2 this is equivalent to 1 ML streamflow (upstream of the discharge point) and 2 ML discharge, total downstream is 3 ML, therefore 2 ML of discharge out of 3 ML total is a proportion of 66.7%

Basic water and mass balances were undertaken to determine the discharge volume and concentration of key parameters each day for the analysis period. Key aspects of the analysis were:

For the 'current baseline' (over a 3-year period from 2017-2020):

- Measured streamflow at Kyneton was used where available, and where not available, infilled with modelled data.
- Measured daily discharge volumes from the Kyneton WRP were used.
- Water quality for the Kyneton WRP discharge was used, where available, on a given day of discharge; otherwise, stochastically-generated water quality data was used.
- Campaspe River water quality upstream was used, where available; otherwise, stochastically-generated water quality data, based on values from 2007-2019, were used.
- Nutrient decay rates established in section 5.3 of this report were used to determine the mixing zone distance on a daily basis. These were used, where available, on a given day of discharge; otherwise, a stochastically-generated value was used.

For the 1:2 'streamflow-to-discharge' scenarios (2021 and 2036):

– Only BNR discharges were considered (i.e. no Lagoon 4 discharges).
– A similar time period to the baseline scenario (3 year period from July 2017 to June 2020) was used to allow for comparison of the scenarios.

- Inflow into the BNR and tradewaste for 2022 and 2036 were as per the Kyneton Master Plan (GHD 2021) The outflow to the river was determined using the updated water balance model, with discharge to the Campaspe River at a maximum allowable streamflow-to-discharge ratio of 1:2, any remainder of the outflow on each day was stored or irrigated.
- Discharge quality for the BNR plant was based on data from the 2015-2020 period (stochastically generated where actual data was not available on a given day). BNR plant *E. coli* data after March 2021 was used to represent expected future BNR *E. coli* discharges, given that there was an upgrade of the U.V. system from that date.
- Campaspe River water quality upstream was based on 2007-2019 data (stochastically generated where actual data was not available on a given day).
- The streamflow-to-discharge ratio was determined (estimated) based on streamflow in the Campaspe River near the discharge point (i.e. Kyneton gauge station) - if measured data was not available for a given day, modelled data was used.
- ERS (2021) and ANZG (2018) guidelines were used (including guidelines for *E. coli* for primary and secondary recreation, stock watering and irrigation).
- Nutrient decay rates established in section 5.3 of this report were used to determine the mixing zone distance on a daily basis and were used where available on a given day; otherwise a stochastically-generated value was used.

7.1.1 Current Baseline

Key outputs of the risk assessment for the current baseline are presented in Table 45. A graph of the risk score for each individual parameter to the beneficial use in the Campaspe River are presented in Figure 54. Results show that over the 3-year period, 1,456 ML were discharged with a total risk score of 12,141 (or a risk score per megalitre of discharge of 8.34 ML^{-1}). Mixing zones for total N and total P were 3.31 km and 5.29 km, as median values, respectively, and 13.21 km and 30.60 km for the 90th percentile values, respectively.

The mixing zones presented in this section of the report for total N and total P are a more accurate representation of mixing zones compared to those presented in sections 5.2.6 and 5.2.7 of this report. This is due to the more robust methods and use of measured decay rate data for nutrients within the Campaspe River downstream of the discharge point.

The average annual load to the Campaspe River was 5,056 kg/year for total N, and 2,040 kg/year for total P. The key risks to the Campaspe River were in the form of total N and total P, which would have an impact on both river health and irrigation (elevated nutrients can potentially lead to eutrophication of the waterway).

Table 45 2017-2020 baseline scenario - output from daily risk tool

Parameter	Unit	Baseline scenario	
Based on years		July 2017- June 2020	
Volume of discharge (BNR and Lagoon 4) – over 3 years	ML	1456	
Average annual discharge	ML/year	485	
Total Risk Score		12,141	
Risk score / volume	ML^{-1}	8.34	
		Total N	Total P
Mixing Zone - median	km	3.31	5.29
Mixing Zone - 90th percentile	km	13.21	30.60
Load Average Annual	kg/year	5,056	2,040

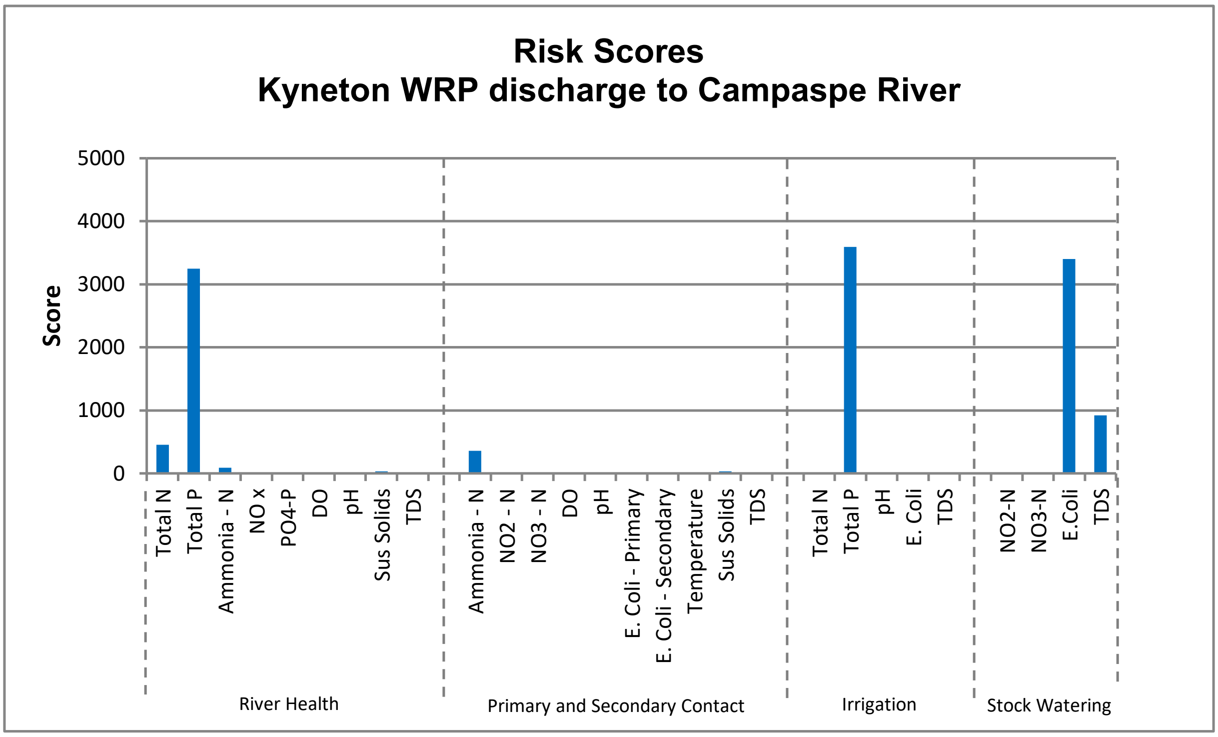

Figure 54 ***2017-2020 baseline scenario – discharge risk score***

7.1.2 2022 and 2036 scenarios

Key outputs of the risk assessment for the 1:2 streamflow-to-discharge scenarios are presented in Figure 55, Figure 56 and Table 46 for 2022 and 2036 scenarios.

Discharge volumes to the Campaspe River for the 2022 and 2036 scenarios are lower than the current baseline scenario. The key reasons for this, is that more irrigation area and storage is available under the new scenarios compared to the baseline.

There is a considerable reduction in risk scores, mixing zone distances and loads of total N and total P to the river from the 2022 and 2036 scenarios when compared to the baseline scenario. This is due mainly to the improved quality of BNR discharge compared to the combined BNR/Lagoon 4 discharge that is used in the current baseline scenario (particularly for total P in which BNR discharge is only around 10% of the concentration of the combine BNR/Lagoon 4 discharge). Also, *E. coli* results from the BNR discharge after the installation of the new UV unit means that risks are essentially reduced to zero for this parameter.

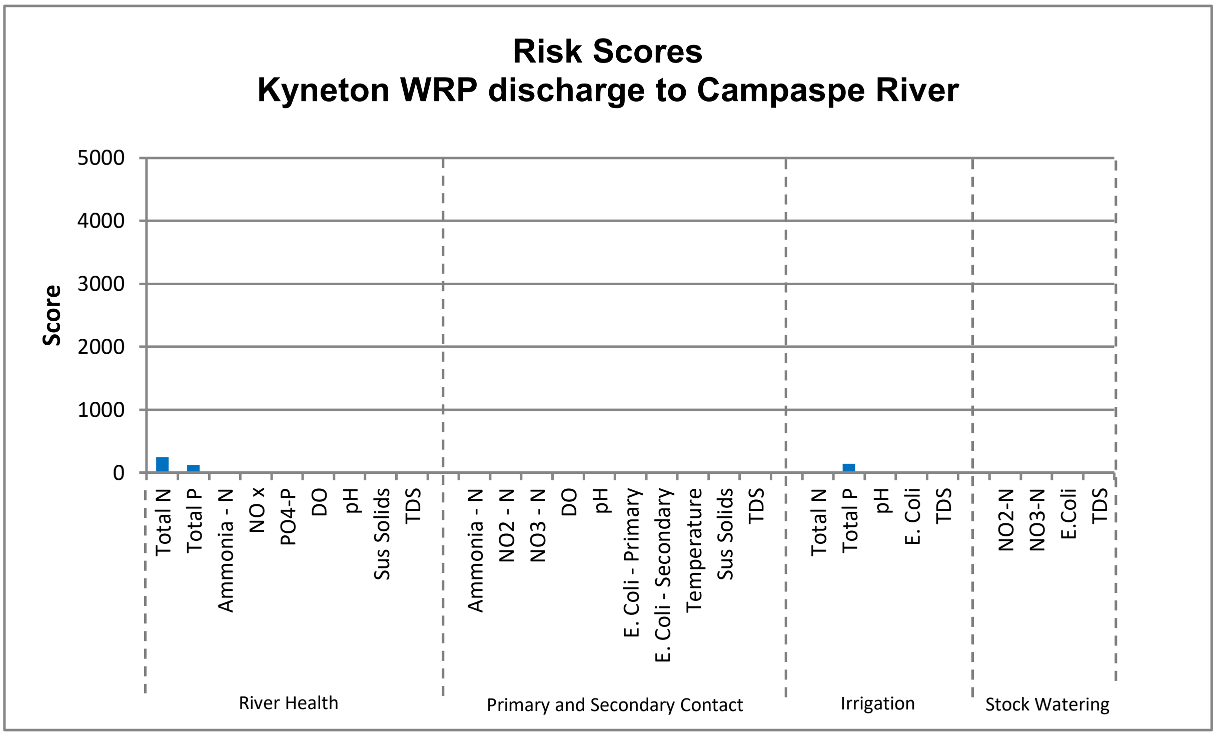

Figure 55 2022 scenario – discharge risk score profile

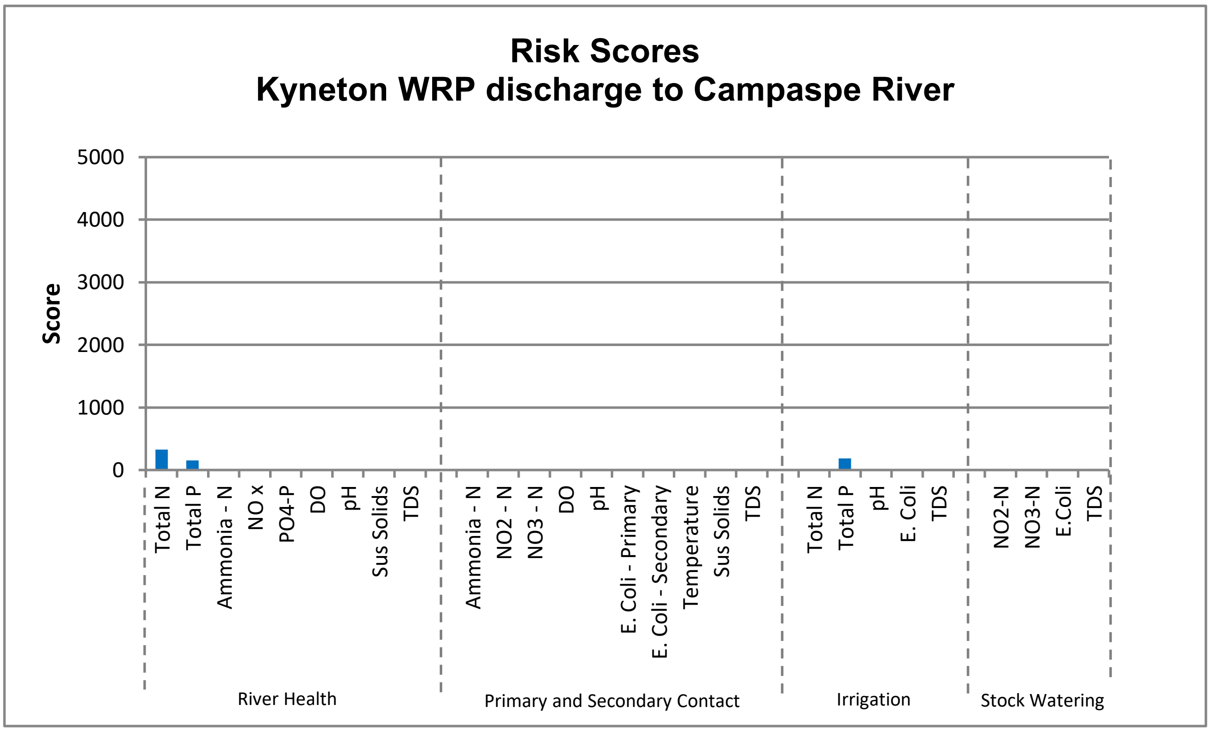

Figure 56 2036 scenario – discharge risk score profile

Table 46 Risk score and mixing zone assessment – 2017-2020 baseline scenario (BNR and Lagoon 4 discharge) and the 2022 and 2036 scenarios (BNR discharge only)

Metric	Scenario→ Units ↓	Baseline		2022		2036	
Discharge proportion of streamflow*		2017-2020 Baseline		66.7%		66.7%	
Ratio streamflow* to domestic discharge				1:2		1:2	
Ratio domestic to Lagoon 4				None		None	
Volume of discharge to river (total over 3 years)[#]	ML	1456		766		1,104	
Volume of discharge to river (average annual)[#]	ML/year	485		255		368	
Total Risk Score		12,141		521		687	
Risk score / volume	**ML^{-1}**	8.34		0.68		0.62	
		Total N	Total P	Total N	Total P	Total N	Total P
Mixing Zone - median	km	3.31	5.29	0.88	0.28	1.28	0.44
Mixing Zone - 90th %ile	km	13.21	30.60	4.57	1.80	6.07	2.45
Load to river (Average Annual – and reduction from baseline)	kg	5,056	2040	1,625 (↓ 3,431)	52 (↓ 1988)	2,349 (↓ 2,707)	77 (↓ 1,963)

*Streamflow measured (and modelled when no measured data available) at Wards Lane discharge point, based on Kyneton streamflow gauge. Proportion is calculated as the proportion of discharge in the combined downstream total; e.g. with a ratio of streamflow to discharge of 1:2 this is equivalent to 1 ML streamflow (upstream of the discharge point) and 2 ML discharge, total downstream is 3 ML, therefore 2 ML of discharge out of 3 ML total is a proportion of 66.7%

8. Pathogen Risk Assessment

As part of the broader assessment of risk of the discharge from the Kyneton WRP to the receiving waters of the Campaspe River, a pathogen risk assessment is presented in this section. It is a desktop assessment of the potential microbial hazard to users of water in the Campaspe River (either human or animal) downstream of the discharge point during the 2022 and 2036 Kyneton WRP discharge scenarios. The sections presented below step through various aspects of the pathogen risk assessment including: the existing conditions in the Campaspe River, characterising the microbial content of raw wastewater, an overview of the BNR process steps and their likely removal of pathogens, pathogen exposure pathways, comparison of required versus available treatment and an 'infected traveller' assessment.

8.1 Campaspe River pathogens assessment upstream of the WRP discharge point

The background concentrations of pathogens within the Campaspe River needs to be taken into consideration as part of the pathogen risk assessment. This is because the river, at any given time, may be of higher or lower quality than the Kyneton WRP discharge. Whilst no specific pathogen data is available for the Campaspe River (other than indicator data for *E. coli*), a range of references are presented below that discuss typical pathogens that are likely to be present in agricultural catchments, and the uncertainty associated with determining the effect of transport of pathogens in waterways.

Billington et al (2011) undertook a study on behalf of the Victorian Department of Health to provide an assessment of the health risk of cattle and other livestock accessing waterways upstream of drinking water offtakes. The study included a significant literature review, including the policy and regulatory context. The risks to public health were identified and the acceptability of the risk considered, along with a comparison of water treatment and catchment management costs, and disease outbreak and mitigation costs. Recommended buffer distances were also identified. Risks to public health due to pathogens being shed by livestock with access to waterways were identified as a sum of dry, wet and flood events in a year, in order to determine the annual disease burden. A representative case study estimated the risks to public health were 5 log above tolerable levels – i.e. unrestricted stock access to a waterway means the downstream water requires considerable treatment before human consumption is safe. The biggest risks associated with *Cryptosporidium* were with young calves and lambs having direct access to waterways. The report showed that a 'medium' risk profile for *Cryptosporidium* had been estimated for the North Central Catchment Management Authority (which includes the Campaspe River).

Bradford et al (2013) discussed that an understanding of the transport and survival of pathogens in agricultural settings was needed to assess the risk of pathogen contamination to water and food resources, and to develop control strategies and treatment options. The report noted knowledge gaps remained in predicting the fate and transport of pathogens in runoff water, and then through soil profiles and groundwater. There was shown to be considerable variability in pathogen migration pathways, leading to changes in the dominant processes that control pathogen transport over different spatial and temporal scales; i.e. intense rainfall events can generate runoff that can rapidly transport pathogens, whereas pathogen transport during drier times is more complex.

8.2 Overview of BNR treatment process

The Kyneton WRP domestic stream is an intermittently decanted biological nutrient removal (BNR) activated sludge plant (GHD, 2016). Treatment stages include screening, biological treatment, and UV disinfection, with additional process steps for nutrient removal, pH correction, sludge thickening, digestion and odour control. Microscreens, with 20 micron filters, operate before UV disinfection, which is described as ~35 mJ/cm^2. An overview of the treatment processes present in the domestic wastewater stream at the Kyneton WRP is presented in Table 47.

Table 47 Kyneton WRP – domestic treatment overview

Process	Note
Step Screen	
Grit Chamber	
Partitioned Anaerobic Reactors	BNR / Activated Sludge
Bioreactor	
Alum Dosing	
Clarifier	
Tertiary Micro Screens	20 micron
Ultra Violet disinfection*	35 mJ/cm^2 (350 J/m^2) (35000 $\mu W \cdot s/cm^2$)

*1 mJ/cm^2 = 1000 μW-sec/cm^2

8.3 Characterisation of microbial content of raw wastewater

Estimated pathogen concentrations in raw domestic wastewater (sourced from WHO, 2017; NRMMC, 2006; and AGWR, 2020) are presented in Table 48. These data are presented and used, because, for most pathogens, there are no concentration data available for the Kyneton BNR plant (or for the Campaspe River).

Table 48 Estimated concentrations (numbers per litre) of pathogens in raw domestic wastewater

Pathogen Group	Pathogen	WHO (2017)	AGWR (2020)	95th percentile AGWR
Bacteria	*Escherichia coli* (indicators)	$10^{5`}$–10^{10}	10^5-10^{10}	
	E. coli O157:H7		0-$10^{2.4}$ * (NHMMC, 2006)	
	Enterococci (indicators)	10^6–10^7	10^6-10^7	
	Clostridium perfringens (indicators)	10^4–10^6	10^4-10^6	
	Campylobacter	<1–10^5	<1-10^5	7,000
	Salmonella	<1–10^6	<1-10^5	
	Shigella	<1–10^4	<1-10^4	
	Vibrio cholerae	<1–10^6		
Viruses	Adenoviridae (adenoviruses)	<1–10^4	<1-10^4	
	Caliciviridae (noroviruses)	<1–10^6	<1-10^6	8,000
	Picornaviridae (enteroviruses)	<1–10^6	<1-10^6	
	Reoviridae (rotaviruses)	<1–10^5	<1-10^5	
	Somatic coliphage (indicators)	<1–10^9	<1-10^9	
	F-RNA phage (indicators)	<1–10^7	<1-10^7	
Protozoa	*Cryptosporidium hominis/parvum*	<1–10^5	<1–10^5	2,000
	Entamoeba histolytica	<1–10^2	-	
	Giardia intestinalis	<1–10^5	<1–10^5	

Pathogen Group	Pathogen	WHO (2017)	AGWR (2020)	95th percentile AGWR
Helminths	*Ascaris lumbricoides*	<1–10^3		5-50
	Trichuris trichuria	<1–10^2		

The estimates in Table 48 are sourced from WHO (2017) and AGWR (2020), with the estimate for *E. coli* O157:H7 sourced from NHMMC (2006). AGWR (2020) is a consultation draft update of NHMMC (2006), the Australian Guidelines for Water Recycling. The primary difference between these versions of the guidelines, regarding the characterisation of raw sewage, is a change from the use of rotavirus dose response data to norovirus dose response data in the calculation of human health risks. This is reflected in Table 48 in the estimate of 8000 noroviruses/L as the default estimate in raw sewage, rather than 8000 rotavirus/L in NHMMC (2006).

8.3.1 Measured data for microbiology

Microbial data available for the Kyneton WRP and the Campaspe River included *E. coli* (WRP and river) and helminth data (WRP only). An overview of the available data is presented below.

E. coli data for the Campaspe River is presented in Figure 57, and statistics on the data is presented in Figure 58. A comparison of statistics of *E.coli* data for Campaspe River and BNR discharge data is presented in Figure 59 and in Table 49. Results show the *E. coli* concentrations are considerably lower in the BNR discharge compared to the Campaspe River (and even more so after February 2021).

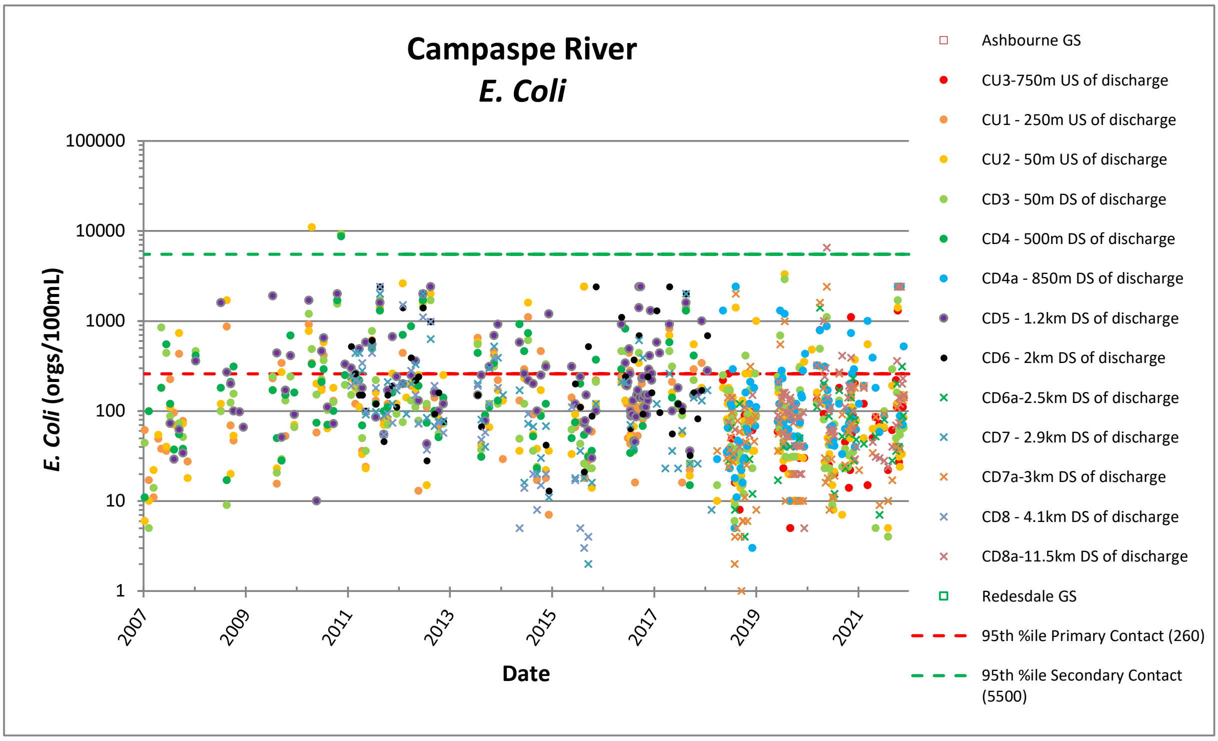

Figure 57 E. coli in Campaspe River upstream and downstream of the discharge point (all data 2007 – 2021)

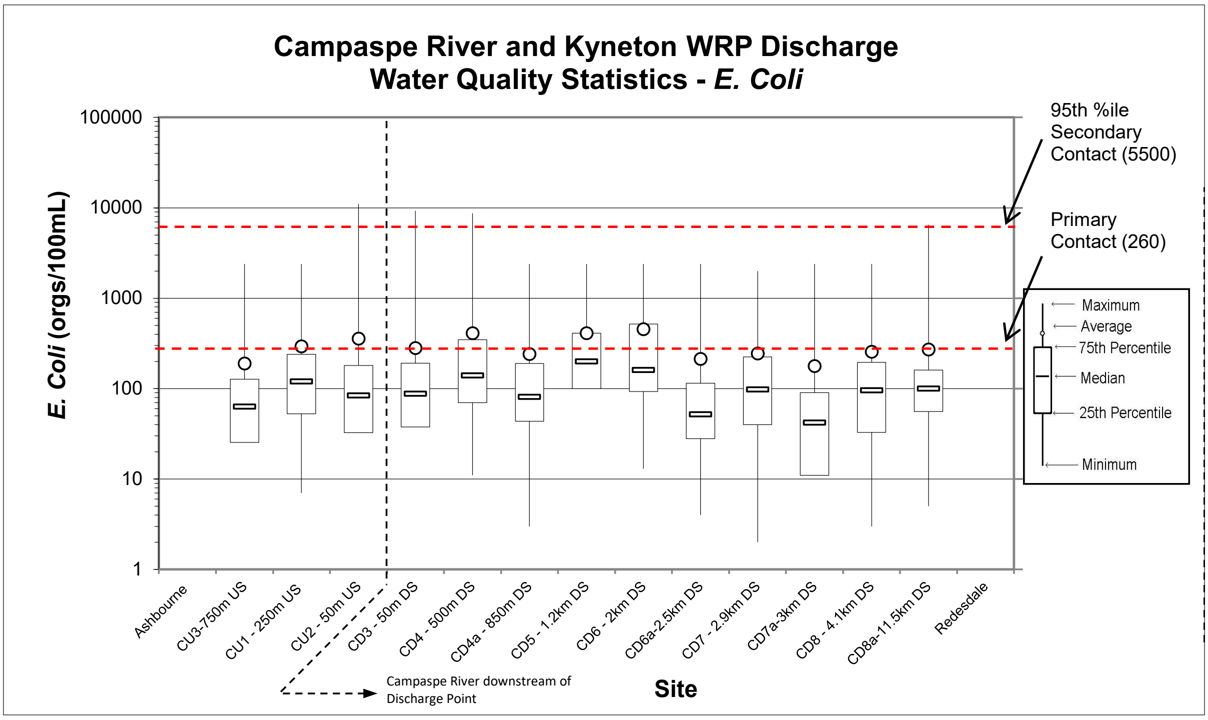

Figure 58 Statistics for E. coli data in Campaspe River upstream and downstream of the discharge point (all data 2007 – 2021)

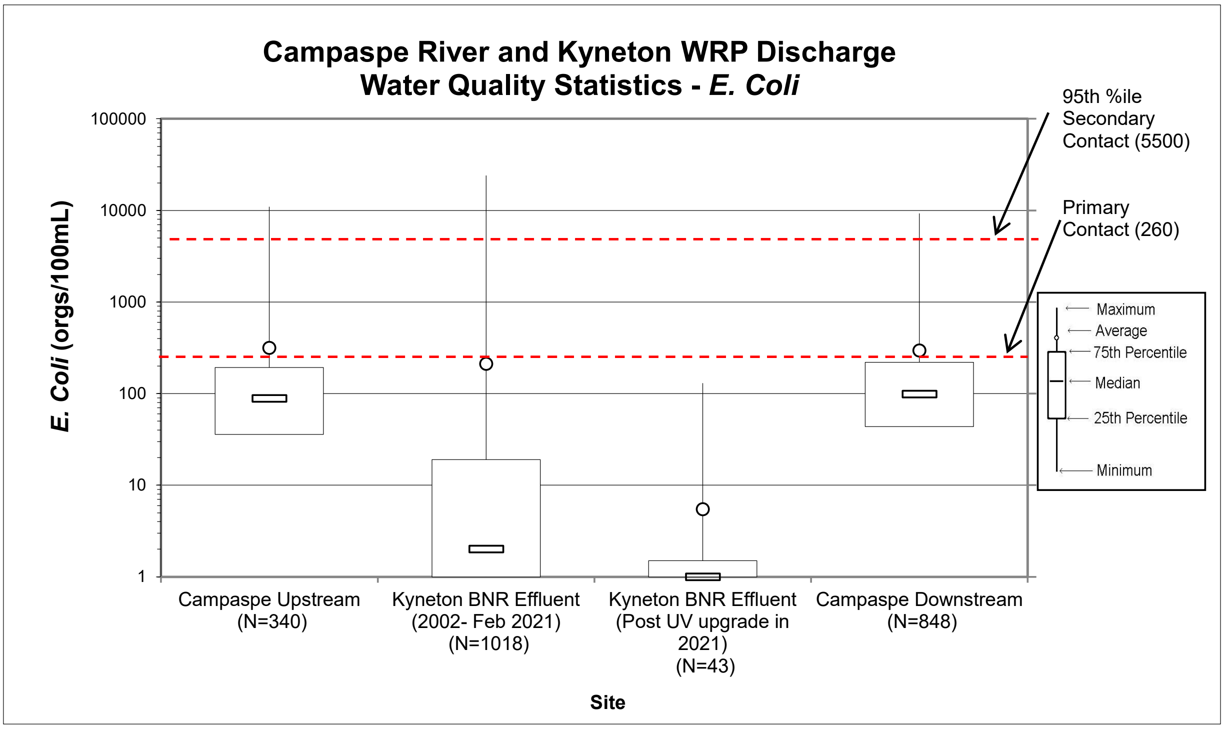

Figure 59 Statistics for E. coli data in Campaspe River upstream and downstream of the discharge point and Kyneton BNR treated discharge

Table 49 E. coli statistics for Campaspe River upstream and downstream of the discharge point and Kyneton BNR treated discharge

Site →	Campaspe River upstream of discharge point	Kyneton BNR treated discharge (2002- Feb 2021)	Kyneton BNR treated discharge (Post UV upgrade March 2021)	Campaspe River downstream of discharge point
	orgs/100 mL			
Maximum	11000	24000	130	9250
95th percentile	1410	616	20	1533
90th percentile	694	173	10	690
75th percentile	193	19	2	220
Median	89	2	0	99
25th percentile	36	1	0	44
10th percentile	17	0	0	20
Minimum	0	0	0	0
Average	315	212	5	297
Number	340	1018	43	848

Data for *E. coli* in the BNR influent and helminths in the influent and treated wastewater discharge are presented below in Table 50 and Table 51, respectively.

Table 50 E. coli statistics for Kyneton BNR influent

Site →	Kyneton BNR Domestic Influent
	orgs/100 mL
Maximum	1.60.E+07
95th percentile	1.60.E+07
90th percentile	1.60.E+07
75th percentile	1.40.E+07
Median	1.14.E+07
25th percentile	1.01.E+07
10th percentile	9.60.E+06
Minimum	9.15.E+06
Average	1.22.E+07
Number	10

Table 51 Helminth sampling results for Kyneton WRP influent and treated discharge

Helminth → Date ↓	*Ascaris lumbricoides*			*Taenia saginata*			Total Helminths		
Site →	Domestic Influent	BNR Discharge	Blended BNR and Lagoon 4 Discharge	Domestic Influent	BNR Discharge	Blended BNR and Lagoon 4 Discharge	Domestic Influent	BNR Discharge	Blended BNR and Lagoon 4 Discharge
Units →	Ova / L								
18/06/2019	0	0		0	0		0	0	
4/07/2019	0	0		0	0		0	0	
18/07/2019	0	0		0	0		0	0	
1/08/2019	0	0		0	0		0	0	
15/08/2019	0	0		0	0		0	0	
29/08/2019	0	0		0	0		0	0	
12/09/2019			0			0			0
19/09/2019	0			0			0		
26/09/2019	0	0		0	0		0	0	
10/10/2019	0	0	0	0	0	0	0	0	0
24/10/2019	0	0		0	0		0	0	
7/11/2019	0	0		0	0		0	0	
21/11/2019	0	0		0	0		0	0	
28/11/2019		0			0			0	
5/12/2019	0	0		0	0		0	0	
19/12/2019	0	0		0	0		0	0	
2/01/2020	0	0		0	0		0	0	
16/01/2020	0	0		0	0		0	0	
30/01/2020	0	0		0	0		0	0	
13/02/2020	0	0		0	0		0	0	
12/03/2020	0	0		0	0		0	0	
9/04/2020	0	0		0	0		0	0	
7/05/2020		0			0			0	
8/05/2020	0			0			0		
4/06/2020	0	0		0	0		0	0	
2/07/2020	0	0		0	0		0	0	
6/08/2020	0	0		0	0		0	0	
3/09/2020	0	0		0	0		0	0	
1/10/2020	0	0		0	0		0	0	
5/11/2020	0	0		0	0		0	0	
3/12/2020	0	0		0	0		0	0	
7/01/2021	0	0		0	0		0	0	
4/02/2021	0	0		0	0		0	0	
4/03/2021	0	0		0	0		0	0	
1/04/2021	0			0			0		
6/05/2021	0	0		0	0		0	0	
3/06/2021	0	0		0	0		0	0	
1/07/2021	0	0		0	0		1	0	

Helminth → Date ↓	***Ascaris lumbricoides***			***Taenia saginata***			**Total Helminths**		
5/08/2021	0	0		0	0		1	0	
2/09/2021	0	0		0	0		0	0	
7/10/2021		0			0			0	
14/10/2021	0			0			0		
4/11/2021	0	0		0	0		0	0	
Positive Samples	0	0	0	0	0	0	2	0	0
Total Samples	39	38	2	39	38	2	39	38	2

Risks to cattle drinking water downstream of the discharge point as a result of helminth egg ingestion are assessed as low. No *Ascaris lumbricoides* or *Taenia saginata* have been detected within the influent (n=39) or discharge (n=38). There were zero and two detections of total helminths in the influent (n=39) and discharge (n=38) – i.e. the helminths detected in the domestic influent were those other than *Ascaris* or *Taenia*. As shown in Table 52, the most probable number (MPN) of *Ascaris lumbricoides* or *Taenia saginata* in both the domestic influent and the BNR discharge is 0 helminth eggs (HE) per litre i.e. 0 HE/L. For total helminths, the MPN for influent is 0.053 HE/L and for the treated discharge is 0 HE/L.

Table 52 ***Most probable numbers for Helminth data for Kyneton WRP inflows and discharge (based on methodology from Jarvis et al 2010)***

Organism	Positive samples	MPN / L	Log_{10} MPN	SD of Log_{10} MPN	95% CI (Lower)	95% CI (Upper)
Domestic Influent						
Ascaris lumbricoides	0/39	0 (<0.026)	-	-	0	0.095
Taenia saginata	0/39	0 (<0.026)	-	-	0	0.095
Total Helminths	**2/39**	0.053	-1.3	0.31	0.013	0.22
BNR Discharge						
Ascaris lumbricoides	0/38	0 (<0.027)	-	-	0	0.097
Taenia saginata	0/38	0 (<0.027)	-	-	0	0.097
Total Helminths	0/38	0 (<0.027)	-	-	0	0.097

*the less than value is calculated by finding the value of the MPN if one sample was positive in a given number of samples.

Pathogen removal by treatment processes is discussed in section 8.4, including the expected amount of helminth removal. As both influent and discharge data were negative for *Ascaris lumbricoides* and *Taenia saginata*, the amount of removal cannot be estimated from the available monitoring data.

The most applicable published guideline concentration available for the downstream use of diluted discharge is <0.1 HE/L for agricultural usage (WHO, 2006).

To conclude, no *Ascaris lumbricoides* or *Taenia saginata* were detected in the monitoring of the plant influent (n=39) or treated discharge (n=38) between June 2019 and November 2021. These data indicate that these organisms were either not present or present at very low concentrations in the catchment population at that time. The number of samples taken gives increasing confidence in this conclusion, although it is also noted that the catchment population would be more likely to include people who have recently travelled to helminth-endemic areas in the future. The 2019-2021 period included extensive bushfires and then pandemic-related travel restrictions across eastern Australia, resulting in very low rates of travel generally, and particularly of international travel.

8.4 Pathogen removal by treatment processes

There are multiple references for the log removal of pathogens through various wastewater treatment units and trains. A key reference is the AGWR (NRMMC 2006) and relevant log removal values are presented in Appendix B. A summary of the information is presented in Table 54 for the domestic treatment train.

The microscreen process stage, as identified in Table 54 has a mesh size of 20 µm and would be expected to capture helminths with egg sizes greater than this diameter. Helminths of interest in this study, including *Taenia* spp., *Ascaris lumbricoides* and *Trichuris trichuria*, all have egg sizes that are greater (or potentially equal to, in the case of *Trichuris*) than 20 µm (see Table 53). Other helminths may have eggs less than 20 µm, however.

Table 53 Helminth egg sizes (Source: CDC 2019)

Organism	Common name	Egg size (micron)
Taenia spp.	Tapeworm	30 – 35 µm
Ascaris lumbricoides	Roundworm	45 – 75 µm (fertile eggs)
		Up to 90 µm (unfertilized eggs)
Trichuris trichuria	Whipworm	50-55 µm by 20-25 µm

Table 54 Log reduction values (LRVs) for pathogens achieved by wastewater treatment processes relevant to the Kyneton WRP (BNR plant)

Treatment process	Detail	Reference	Bacteria	Helminth	Protozoan	Viruses
Pre-treatment	Step Screen	-	0	0	0	0
	Grit Chamber	-	0	0	0	0
Activated Sludge Plant (ASP) / Biological Nutrient Removal (BNR)	Partitioned Anaerobic Reactors, Bioreactor, Alum Dosing, Clarifier	Vic. Department of Health (2013)	1		0.5	0.5
		SA Health (2019)	1	1	1	1
		WHO (2006) ASP & secondary		1-2		
		AGWR (NRMMC 2006)	1-3	0-2 ##	0.5-1.5	0.5-2
		WHO (2017)	3		2	2.5
Tertiary Micro Screens	20 micron	WHO (2004)	0	0-1 Estimated range – any eggs > 20 micron will be captured, if unit operating	0-1 Estimated range – any eggs > 20 micron will be captured, if unit operating	0
Ultra Violet Disinfection	35 mJ/cm^2 (formerly 20 mJ/cm^2)	Simhon et al 2019	2.5 (*E. coli*)			0.5-0.8 (Noroviruses)
		Brownell and Nelson (2006), interpolation of data)	-	0.3	-	-
		AGWR (NRMMC 2006)	2-4	-	0-3	>1.0 adenovirus >3.0 enterovirus and Hepatitis A
		Hijnen et al (2006) (note, a range of UV fluences were cited from 0.5-306 mJ/cm^2)	3.8 (PRD1) - 5.6 (B40-8)	-	2.4 (*Giardia muris*)- 3.0 (*C. parvum*)	4.1 (rotavirus SA-11) – 6.4 (adenovirus ST2)
Log Reduction Totals						
Median LRV#	Pre-treatment + ASP/BNR + Micro screens + UV		0 + 1.5 + 1.5 + 3	0 + 1 + 0.5 + 0.3	0 +1 + 0.5 + 1.5	0 + 1.5 + 0 + 0.8
	Total		6	1.8	3	2.3
Minimum LRV#	Pre-treatment + ASP/BNR + Micro screens + UV		0 + 1 + 0 + 2	0 + 0.5 + 0 + 0.3	0 + 0.5 + 0 + 0	0 + 0.5 + 0 + 0.5
	Total		3	0.8	0.5	1.0

#Median LRV case is determined as an 'estimated middle' of the range of presented LRVs for each treatment process, worst case is the lowest LRV value for each process

This range is generic for "secondary treatment". A minimum LRV for helminth treatment of 0.5 has been applied instead, based on more recent guidance in AGWR (2020), Table 3.3, where helminths are mentioned as follows: "*Conservative default values based on reported results.. These can be increased based on system specific testing for pathogen reductions. In the absence of such studies nominal log reduction values of 0.5 log for protozoa and up to 1 log for bacteria, viruses and helminths have been applied (State of Victoria 2013)*."

An estimation of the resulting pathogen concentration in the treated water from the domestic process stream is presented in Table 55.

Table 55 Domestic wastewater pathogen treatment estimates and resulting concentrations in discharge

Parameter	Unit	Bacteria		Helminth#	Protozoa	Viruses
Representative organism		*Campy-lobacter*	*E. coli**	-	*Crypto-sporidium*	*Norovirus*
Raw Influent%	Number/L	7000	160,000,000	0.22	2000	8000
	Log (number/L)	3.85	8.2	-0.66	3.3	3.9
LRV – Median		**6**	**6**	**1.8**	**3**	**2.3**
Resulting concentration	Number/L	0.007	160	0.0035	2	40
	Log (number/L)	-2.15	2.2	-2.46	0.30	1.60
LRV – Minimum		**3**	**3**	**0.8**	**0.5**	**1**
Resulting conc.	Number/L	7	160,000	0.035	630	8000
	Log (number/L)	0.85	5.2	-1.46	2.8	2.9

**E. coli* raw influent 95th percentile (n=10) is 16,000,000 *E. coli*/100mL = 160,000,000 *E. coli*/L.

#95th upper confidence limit for helminths in domestic influent MPN estimated to be 0.22 ova/L (see Table 52)

%95th percentile values derived from AGWR (see Table 48), unless otherwise measured.

8.4.1 Helminth removal by UV treatment processes

Standard guideline sources such as AGWR (2020) do not provide indicative guidance on the removal of helminths, (particularly of *Taenia*) from UV disinfection processes. This has been examined further here.

***Taenia* inactivation by UV exposure**

As the primary objective in this case is to characterise the amount of *Taenia* inactivation from UV treatment of the WRP treated discharge, a search for literature specific to this was conducted. This literature is summarised below.

Konno et al (1997) found that *Taenia taeniaeformis* eggs were very resistant to UV light, requiring a fluence of 720 mJ/cm^2 to achieve a 0.65-log reduction when compared to control eggs. This study was included in a systematic review by Hazell et al (2019), who made multiple observations about the paper:

– There were few details in how the fluence was calculated.
– There was a substantial difference in the number of cysts recovered from the controls in each of the experiments (4-30%), and it is unclear why this happened.
– In the same study, only 30 mJ/cm^2 was required for a 3-log reduction when the embryophore had been removed, suggesting that the embryophore is the key mechanism for UV resistance in *Taenia*, as has been observed with disinfection studies of the parasite *Ascaris.*
– An average fluence of 872 mJ/cm^2 to inactivate 1-log of *Taenia* was calculated, and of 1300 mJ/cm^2 to inactivate 2-logs.

Jansen et al (2021) also conducted a systematic review of helminth disinfection. For the effects of UV disinfection, Konno et al (1997), Lagapa et al (2001) and Willis and Herbert (1984) are cited.

The details of Lagapa et al (2001) were not determined. The examination of UVC exposure of *T. taeniaeformis* described in this paper, which includes the 254 nm UV wavelength used for water treatment, were summarised by Jansen et al (2021) as follows:

– The UVC exposure times were noted (30, 90, 270, 810, 2430 and 7290 seconds), but the intensity and/or fluence were not.
– UVC exposure had a significant effect on the number of cysterci from 90 seconds of exposure and greater.
– 100% reduction from 2430 seconds exposure and greater.

The details of Willis and Herbert (1984) were also not determined. As described by Jansen et al (2021), the experimentation exposed *Taenia multiceps* to 250 nm UV light for up to 48 hours. The effect was noted as the reduction of hatching after 24 hours to 3%.

***Ascaris* inactivation by UV exposure**

As the available literature examining the disinfection of *Taenia* by UV exposure is limited, and frequently only available as a summary, it does not appear to be definitive enough to allow the estimation of a LRV with a great deal of certainty. However, studies of the UV inactivation of *Ascaris* spp. have also been summarised here. As reviewed, *Taenia* and *Ascaris* eggs both include an embryophore structure, to which the resistance of the eggs to UV disinfection has been attributed (Konno et al, 1997; Hazell et al, 2017). *Ascaris* would appear to be a reasonable surrogate for quantifying *Taenia* disinfection by UV exposure, with both helminths notably UV-resistant, and with a greater amount of literature study of *Ascaris* inactivation from UV exposure available.

Brownell and Nelson (2006) examined *Ascaris suum* eggs exposed to UV fluences ranging from 0 to 800 mJ/cm^2. With a UV fluence of 50 mJ/cm^2, 0.44 ± 0.20-log (63.7%) inactivation of intact eggs was observed, whilst a fluence of 400 mJ/cm^2 resulted in 2.23 ± 0.49-log inactivation (99.4%). These authors noted that for the range of fluences recommended for the disinfection of drinking water (20 to 200 mJ/cm^2), that 0 to 1.5-logs of inactivation can be expected, although at typical fluences (of <100 mJ/cm^2) the inactivation may be less than 1-log.

Lucio-Forster et al (2005) exposed *Ascaris suum* eggs to UV fluences ranging from 0 to 1054 mJ/cm^2, using a collimated beam apparatus. Very high UV doses were required to achieve 100% inactivation of intact eggs.

Hazell et al (2019) reviewed multiple studies where *Ascaris* inactivation was examined. A very wide range in the inactivation data was described, with fluences from 11 to 3367 mJ/cm^2 required to achieve a 1-log reduction. Of these studies, Brownell and Nelson (2006) was described as the only study using the industry standard protocol to evaluate fluence, although Lucio-Forster et al (2005) applied some correction factors for reflection, absorption and divergence of the UV beam. These two studies estimated fluences of 100 and 84 mJ/cm^2 required to inactivate 1-log of intact single cell eggs, although greater divergence was evident for 2-log inactivation (with fluences of 328 and 168 mJ/cm^2 in the two studies). The results from the other studies reviewed by Hazell et al (2019) are not included here, due to the methodological problems described in the review.

Stevens et al (2017) describe helminth eggs as relatively thick and multilayered, and resistant to chlorine and UV disinfection, citing Guadagnini et al (2013) and Wharton (1983). Details of these disinfection studies were not determined.

8.4.1.1 Plausibility check of expected log reduction for *E. coli* and helminths in the domestic process stream

For *E. coli*, within the BNR treated water discharge, the long-term median concentration (post February 2021 after installation of new UV system) is 0 orgs/ 100 mL, the 95th percentile is 20 orgs/100 mL, and the maximum measured concentration is 130 orgs/100 mL.

Median LRV Case

Using an estimated starting concentration of *E. coli* in raw domestic sewage of 1.6×10^8 orgs/L (95^{th} percentile value), and a 6-log reduction through the available treatment train, the results indicate 1.6×10^2 orgs/L (or 16 orgs/100 mL), which is approximately the same as the measured 95^{th} percentile value of 20 orgs/100mL. As such, the median case log reduction for bacteria may be a reasonable estimate with a value of 6.

Minimum LRV Case

Using the minimum LRV case of only a 3-log reduction of *E. coli* by treatment processes, the resulting concentration is 1.6 x 10^5 orgs/L (i.e. 1.6 x 10^4 or 16,000 orgs/100 mL), which is considerably higher than the measured maximum of 130 orgs/100 mL. As such, the worst case log reduction for bacteria might be closer to 5 than the estimated value of 3.

Helminths – the 95^{th} percentile MPN value for domestic (BNR) treated water discharge is 0.22 ova/L. This concentration is higher than the influent 95^{th} percentile MPN, due to less samples being available to statistically calculate the concentration. As such, a meaningful comparison of the reduction in the helminth egg concentration through the LRV process and from the measured data cannot be made.

8.5 Pathogen exposure pathways and consequences

A number of beneficial uses of the river water downstream of the Kyneton WRP have been identified. The exposure pathways to humans and stock animals are summarised as follows:

Human exposure pathways

- Swimming and other water-contact recreational activities, including fishing
- Garden irrigation
- Raw drinking water supply.

Stock animal exposure pathways

- Stock watering
- Pasture irrigation

Whilst swimming has been identified at two points, which are 20 km (Turpins Falls) and 34.6 km (Barfold Gorge) downstream of the discharge point, activities such as swimming and fishing could potentially also occur closer to the discharge point than these two sites.

Using the estimated concentration of a particular pathogen in river water at the point of exposure, a QMRA can be carried out to estimate the risk for that pathogen from the exposure pathway. The QMRA approach followed is described in NRMMC (2006), which examines a number of reference pathogens in a variety of end uses for recycled water, informs the approach taken in WSAA (2015), and examines *Cryptosporidium* risks in source waters for drinking water supplies. These assessments include a number of assumptions, regarding the volume of water consumed daily, pathogen infectivity, probability of infection per organism, proportion of infection leading to illness, the calculation of disability adjusted life years (DALYs) per case, and the requirement to treat to an acceptable risk of one µDALY for the examined end use.

The amount of treatment, or Log Reduction Value (LRV), to treat raw sewage to a risk of one µDALY for selected reference pathogens can be calculated as described in NRMMC (2006). The dose-response information relevant to the pathogens of interest is combined with the exposure (in volume of water consumed, multiplied by the frequency of consumption per year) to calculate the LRVs required for a specific end use. The LRVs for the reference pathogens are calculated as:

Log (number of organisms in sewage x exposure (L) x frequency (per year) / dose-response constant)

The default concentrations of reference pathogens (95^{th} percentile concentrations from data, AGWR, 2020) in raw domestic sewage are:

- *Cryptosporidium*: 2,000 oocysts/L
- Norovirus: 8,000 viruses/L
- *Campylobacter*: 7,000 organisms/L

For the trade waste, the following values were used (sourced from MLA (2017)):

- Cryptosporidium: 49 oocysts/L
- Norovirus: 0 viruses/L
- Campylobacter: 7,000 organisms/L

The dose response constants equivalent to 10^{-6} DALYS per person per year (DALYds) defined for the reference pathogens (AGWR, 2020, Table A2.3) are:

– Cryptosporidium: $4.2x10^{-3}$
– Norovirus: $4.2x10^{-3}$
– Campylobacter: $7.3x10^{-3}$

For the examined end uses, the following assumptions about exposure and frequency have been made:

– ***Swimming***: Assumed consumption of water of 200 mL from recreational use, as per NHMRC (2008) notes for Table 9.3. Recreation assumed to be seasonal, and occurs 100 times per year.
– ***Fishing***: Assumed consumption of water of 20 mL from recreational use, as less likely to ingest water than during primary contact recreation. Recreation assumed to be seasonal, and occurs 100 times per year.
– ***Garden application***: These are composite values, as used in NRMMC (2006) Table 3.7.
– ***Drinking water***: Assumed consumption of 2 L water per day from tap (WHO, 2004), every day of a year.

The calculated LRVs are tabulated in Table 56. It is noted that the LRVs are for raw sewage as a source, and that the drinking water supply end use LRVs also incorporate treatment at a downstream water treatment plant.

Table 56 Log reductions for uses of recycled water from treated domestic and trade waste sewage (using NRMMC 2006 inputs)

Beneficial use	Exposure (L) x freq (per year)	*Cryptosporidium* LRV		Rotavirus LRV		*Campylobacter* LRV	
		Domestic	Trade waste	Domestic	Trade waste	Domestic	Trade waste
Swimming (primary contact recreation)	20 (0.2 x 100)	6.4	4.8	7.8	0	6.6	6.6
Fishing (secondary contact recreation)	2 (0.02 x 100)	5.4	3.8	6.8	0	5.6	5.6
Garden irrigation (sprays)*	0.2	4.4	2.8	5.8	0	4.6	4.6
Garden food crops**	0.09	4.1	2.4	5.5	0	4.2	4.2
Drinking water supply	730 (2 x 365)	8.0	6.3	9.4	0	8.1	8.1

*: Values taken from NRMMC (2006), Table 3.7. Includes ingestion of sprays and infrequent ingestion of water.

**: Values taken from NRMMC (2006), Table 3.7. Includes ingestion of lettuce (0.005 x 7) and other produce (0.001 x 50).

8.5.1 Summary of recreational guidelines and assessment of *E. coli* data in BNR discharge and Campaspe River

The classification of sites in Australia for recreational suitability is performed using a combination of sanitary survey information and long-term microbial indicator monitoring data. This approach is different to that taken with a quantitative microbial risk assessment (QMRA); however, it is very briefly examined here to provide context to the QMRA aspects of swimming and/or fishing at downstream sites in the Campaspe River.

The national guidelines for managing risks in recreational water (NHMRC, 2008) classify recreational sites according to recreational suitability, from A (very good) to D (poor). This classification is primarily intended to be based on long-term *Enterococci* monitoring, which is not available for the Campaspe River or the WRP discharge. A similar approach is taken in ERS (2021), with management of risks to environmental values in waters, which classifies recreational suitability in freshwater from long-term monitoring of *E. coli* or *Enterococci*.

The microbial assessment category in ERS (2021), based on the 95th percentile concentration (determined using the Hazen method) of *E. coli*, is summarised as follows:

– Category A: <130 *E. coli*/100 mL. Suitable for primary and secondary recreation.
– Category B: 130-260 *E. coli*/100 mL. Suitable for primary and secondary recreation.
– Category C: 261-550 *E. coli*/100 mL. Suitable for secondary recreation only.
– Category D: 551-5,500 *E. coli*/100 mL. Suitable for secondary recreation only.
– Category E: >5,500 *E. coli*/100 mL. Not suitable for any contact recreation.

These categorisations provide an assessment of the suitability of the water for primary contact recreation (swimming) and secondary contact recreation. Secondary contact is defined in ERS (2021) as an activity where the human limbs are regularly wet and in which greater contact (including swallowing water) is unusual (e.g. boating, fishing, wading), and includes occasional and inadvertent immersion through slipping or being swept into the water by a wave). Risks defined by these categories can be compared with the risks estimated by the QMRA approach.

The Hazen method was used to determine the 95^{th} percentile for *E. coli* concentrations and results are presented in Table 57. The BNR discharge (post February 2021) is of considerably better quality than the Campaspe River upstream and downstream of the discharge point. Results show that the BNR discharge is within 'Category A - suitable for primary and secondary recreation' whilst the Campaspe River upstream and downstream of the discharge point is within 'Category D - suitable for secondary recreation only'.

Table 57 Comparison of E. coli data (95^{th} percentile) results to ERS (2021) long term microbial environmental quality indicators for primary and secondary contact recreation

Site	*E. coli* (95^{th} percentile)	ERS (2021) Category
BNR discharge (post Feb 2021)	20 orgs/ 100 mL	A - Suitable for primary recreation
Campaspe River upstream	1,410 orgs/100 mL	D - Suitable for secondary recreation only
Campaspe River downstream	1,532 orgs/100 mL	D - Suitable for secondary recreation only

8.6 Comparison of required LRVs for beneficial use and LRVs determined for the domestic process stream

A comparison between the log reduction values required for the treatment of raw domestic wastewater, and those available at Kyneton WRP are presented in Table 58 for the median case, and Table 59 for the worst case. Results show that a number of the identified beneficial uses would not be protected under current treatment processes (more so under the worst case). However, there are a number of factors that need to be taken into consideration, including dilution with river water and die-off with time.

There will be dilution of the domestic discharge with river water in the Campaspe River, and this will provide a small log reduction (depending on the discharge scenario and the quality of the Campaspe River upstream). The quality of the Campaspe River water upstream for *Cryptosporidium*, Norovirus and *Campylobacter* has not been characterised. This makes the characterisation of the pathogen risks resulting from discharge scenarios to be speculative. *E. coli* data (see Table 49) shows that the concentration of *E. coli* in upstream river water is typically higher than the discharge (and potentially higher for other pathogens, including *Cryptosporidium*). As such, there is only an increase in risk to the identified beneficial uses if the pathogen concentration within the discharge is higher than the concentrations already present in the Campaspe River. Sources of pathogens in the Campaspe River catchment include septic tanks, urban runoff, agricultural runoff, livestock access and human access to the waterway.

In-stream die off may also provide a log-reduction 'credit'; however, it is assumed that this will be relatively small for the identified pathogens. Calculation of this metric is difficult because of the complication of additional sources of pathogens directly downstream of the discharge point (i.e. additional cattle grazing, septic tanks etc.).

Table 58 Log reductions required and available in the BNR process train (median LRV case, AGWR 2020 inputs)

Beneficial use	*Cryptosporidium*			Norovirus			*Campylobacter*		
	Required	Available	Difference	Required	Available	Difference	Required	Available	Difference
Swimming (primary contact recreation)	7.0	3	4.0	7.5	2.3	5.2	7.3	6	1.3
Fishing (secondary contact recreation)	6.0	3	3.0	6.5	2.3	4.2	6.3	6	0.3
Garden irrigation (sprays)	5.0	3	2.0	5.5	2.3	3.2	5.3	6	-0.7
Garden food crops	4.7	3	1.7	5.2	2.3	2.9	4.9	6	-1.1
Drinking water source*	8.6	3	5.6	9.1	2.3	6.8	8.8	6	2.8

Greyed results mean a shortfall in log reduction

*See commentary on drinking water source below.

Table 59 Log reductions required and available in the BNR process train (minimum LRV case, AGWR 2020 inputs)

Beneficial use	*Cryptosporidium*			Norovirus			*Campylobacter*		
	Required	Available	Difference	Required	Available	Difference	Required	Available	Difference
Swimming (primary contact recreation)	7.0	0.5	6.5	7.5	0.8	6.7	7.3	3	4.3
Fishing (secondary contact recreation)	6.0	0.5	5.5	6.5	0.8	5.7	6.3	3	3.3
Garden irrigation (sprays)	5.0	0.5	4.5	5.5	0.8	4.7	5.3	3	2.3
Garden food crops	4.7	0.5	4.2	5.2	0.8	4.4	4.9	3	1.9
Drinking water source*	8.6	0.5	8.1	9.1	0.8	8.3	8.8	3	5.8

Greyed results mean a shortfall in log reduction

*See commentary on drinking water source below.

For drinking water source, the nearest offtake for a community drinking water supply is Lake Eppalock (51 km downstream, in which the Campaspe River mixes with reservoir water), it is then treated to drinking standard with appropriate pathogen log reduction for human consumption. Downstream of the Kyneton WRP discharge point on the Campaspe River but prior to Lake Eppalock, landholders can divert river water for stock and domestic purposes, although it is considered unlikely that it would be directly consumed by humans (given that rainwater tank supply for direct consumption is common in rural areas).

8.7 Further information on virus removal using the Quantitative Microbial Risk Assessment (QMRA) method

8.7.1 Background

Additional information has been prepared in response to a meeting between Coliban Water, EPA and GHD held on Monday 7 March 2022, to provide additional information with regards to virus log removal values (LRVs) for discharges from the Kyneton Water Reclamation Plant (WRP) to the Campaspe River, and the impact that the assessed LRVs may have on downstream beneficial uses. A key area of discussion was whether the assessment of microbial risk to downstream users should be equivalent to 1 x 10^{-6} DALY per person per year (i.e. 1μDALY pppy).

Details of the additional information are presented in Appendix C.

8.7.2 Summary of findings

Under normal operating conditions, the upgraded UV unit at the Kyneton WRP is likely to result in significant inactivation of a range of human infectious viruses. Whilst it is not currently possible to calculate a DALY value for viruses in recreational waters, mainly because of a lack of relevant dose-response models, the exposure volumes associated with primary contact recreation are small, which gives confidence that the health risks associated with discharge are being managed to an acceptable level.

An additional level of protection is provided by the fact that discharges to the waterway do not normally occur at times when primary contact recreation is most likely to occur along the river.

8.8 'Infected traveller' assessment

8.8.1 Overview

Calculations in this section are presented to essentially provide answers to the following questions around a traveller infected with helminths arriving in Kyneton:

- If one infected traveller arrives and stays in Kyneton (or surrounding areas connected to the sewage network), using the sewerage system via a daily bowel movement, what is the number of helminth ova being put into the system?
- What is the number of ova in the influent into Kyneton WRP every day whilst the infected traveller is in town?
- What is Kyneton WRP's current ability to remove the helminth ova and what is the expected concentration in the discharge to the Campaspe River?
- What concentration in the discharge to the creek would result in an unacceptable risk to cattle downstream?
- What is the number of concurrent infected travellers arriving and staying in Kyneton that would result in the risk to cattle downstream of the discharge point becoming unacceptable?

8.8.2 Human helminth egg (HE) shedding rates

Stevens et al (2017) cites an average estimate of *Taenia saginata* shedding in human infections of 4,688 helminth eggs (HE) per gram of faeces (CDC, 2016; and Murrell, 2005), with an average excretion of 128 g of faeces per day (Rose et al, 1996). Using these estimates, human infection can be expected to result in the shedding of approximately 600,000 HE per person per day.

8.8.3 Kyneton WRP treated water volumes

The Kyneton WRP treated water volumes have been assessed within Section 3.2 of this report. It was noted that discharge during winter and spring (between June and November) was greater than during summer and autumn (between December and May), due mainly to the availability of streamflow in the Campaspe River. Median daily discharge during winter and spring was 2.574 ML/day, and for summer and autumn was 0 ML/day.

If a single traveller or small number of people within the sewerage catchment are shedding helminths, the highest concentration in WRP inflows would result when the inflow volumes are minimal and provide the least dilution. From examination of the inflow volume data during 2019-2021 for the domestic BNR plan, the minimum inflow recorded was 1.116 ML/day on 19/4/2019.

Using the shedding rate of 600,000 HE/person/day, with one person infected with *Taenia saginata* in the sewer catchment, an influent concentration of 0.54 HE/L can be calculated. This represents a worst-case, maximum concentration from a single infected traveller.

For the 2036 scenario, the population of the sewerage catchment is projected to be 1.37 times the 2020 size, with a corresponding increase in the inflow volume. This projection is drawn from Kyneton Town Vision (GHD, 2021), with details of wastewater connections and the resultant estimated population shown in Table 60. Using the minimum inflow volume of 1.116 ML/day, multiplied by 1.37, the projected minimum inflow volume in 2036 can be calculated as 1.53 ML/day. For a similar scenario of a single infected traveller, a maximum inflow concentration of 0.39 HE/L is estimated.

Table 60 Kyneton WRP domestic wastewater connections and population growth from Kyneton Town vision (GHD 2021)

Sewer Catchment area	Residential Wastewater Connections		Estimated Population (connections x 2.3 people per connection)	
Year →	**2020**	**2036**	**2020**	**2036**
Kyneton	2,188	3,497	5032	8043
Malmsbury	251	455	577	1047
Tylden	108	108	248	248
Trentham	552	981	1270	2256
Total	3,099	5,041	7,127	11,594

Note data in the table above does not include commercial customers or other non-residential customers

8.8.4 WRP Helminth LRV

The log removal value (LRV) for helminth eggs (HE) within the Kyneton WRP was estimated as 1.5-2.5 logs, based on suspended solids removal during treatment (see difference between influent and treated wastewater for the BNR plant in Figure 60 and Table 61 – in which around a 2 log reduction is achieved), and on literature values for helminth removal by different water treatment processes (see Table 54). For the purposes of scenario testing, the median removal of HE by the Kyneton WRP domestic stream has been assumed to be 2 logs, and the worst-case removal as 1.5 logs.

Some additional helminth removal could be expected from the WRP UV treatment unit. However, under worst-case conditions, increased WRP treated wastewater discharge turbidity could potentially result in reduced disinfection effectiveness and a lesser applicable LRV. As a most conservative assumption, no disinfection from UV has been assumed under those circumstances.

For comparison, scenarios with 3-log and 4-log removal have been examined. Stevens et al (2017) discussed a 3-log HE removal threshold, based on the hydraulic residence time of an activated sludge plant and lagoons. The Australian Guidelines for Water Recycling (AGWR, see NRMMC, 2006) specify treatment to achieve a 4-log removal of HE in order to manage helminth risks in agricultural waters.

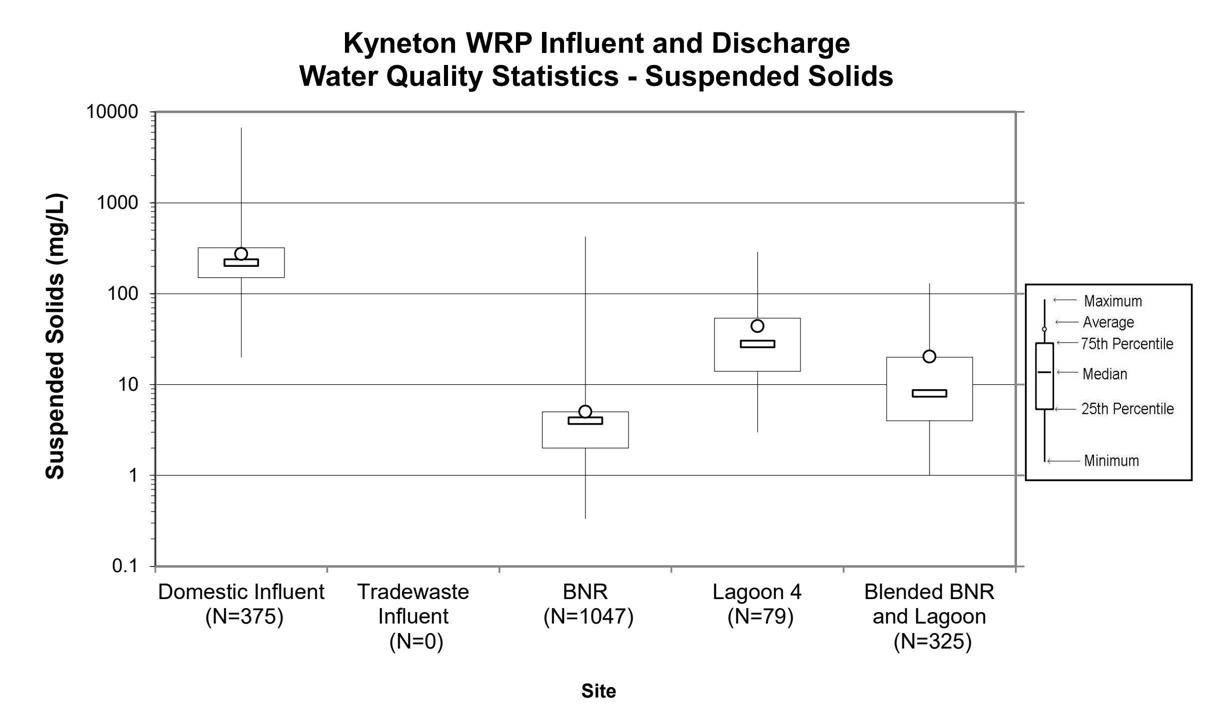

Figure 60 Statistics for suspended solids data Kyneton WRP influent and treated wastewater

Table 61 Suspended solids statistics for Kyneton BNR influent and treated wastewater

Site →	Domestic Influent	Tradewaste Influent	BNR	Lagoon 4	Blended BNR and Lagoon
	mg/L				
Maximum	6700		426	290	130
90th percentile	430		7	90	65
75th percentile	320		5	54	20
Median	220		4	28	8
25th percentile	150		2	14	4
10th percentile	91		1	9	2
Minimum	20		0	3	1
Average	275		5	44	20
Number	375	0	1047	79	325

8.8.5 Dilution in Campaspe River

The median winter-spring WRP discharge to the Campaspe River from Kyneton WRP was 2.574 ML/day (during 2017-2020) and historically, the streamflow to discharge ratio has been 5:1, although streamflow has been measured at Redesdale, which typically would have more water flowing past it than the current measurement location of the Kyneton gauging station. Measured streamflow to discharge ratios for the 2017-2020 period showed a median of 14.5 (see section 3.2.1). Future discharge scenarios are anticipated to be a 1:2 streamflow to discharge ratio (although it is unlikely that discharge will occur every day of the year, given irrigation is a preference to discharge to river).

Some removal of helminth eggs (HE) can be expected in transit between the WRP discharge point and the downstream location of cattle grazing. Sengupta et al (2011) examined the settling velocities of various HE in tap water and wastewater, with results indicating that in low quality waters, HE are incorporated into particle flocs. Whilst mixing zones are examined mixing zones in the creek, this did not include estimated particle removal, due to limited data.

No estimate of HE removal during creek transit has been made in this QMRA, and this is identified as a knowledge gap for further consideration.

8.8.6 Acceptable risk threshold

It is necessary to define a concentration threshold that presents an unacceptable risk to downstream cattle for the purpose of scenario testing. This threshold is not currently standardised. For scenario testing, the WHO (2006) guideline value for agriculture (<0.1 HE/L), and a more conservative threshold (based on 1 HE being able to cause infection, and considering the daily water ingestion volume for cattle from literature values) have been considered.

An average volume of water consumption by cattle of 80 L/head/day is cited for long-term demand (Agriculture Victoria, 2015). This is described as estimated for north and west Victoria, noting that consumption will reduce significantly in cooler weather. Similarly, NSW DPI (2014) estimates the average water requirements of dry stock to range between 35-80 L/head/day, noting that consumption in summer will be about 40% higher than in winter.

Using these estimates, average stock consumption of water has been estimated as 80 L in summer, and 60 L in winter. The assumed concentration threshold for infection (1 HE/day) is reached if 80 L of water with 0.0125 HE/L is consumed, or if 60 L of water with 0.0167 HE/L is consumed.

For the described scenarios, discharge to the river would typically not occur under summer conditions, given the irrigation demand present during that season. Consequently, the winter stock consumption rate (60 L/head/day) and infection threshold (0.0167 HE/L) are examined further here.

8.8.7 Scenario testing

The described inputs are tested as scenarios in a QMRA, as presented in Table 62.

- The scenarios incorporate the environmental conditions (winter only) and the assumed LRV of helminths by the WRP (1.5-log, 2-log, 3-log or 4-log). The outputs of the QMRA include:
- The estimated concentration of *T. saginata* eggs per litre in the downstream creek, based on one person in the sewer catchment shedding this pathogen;
- The number of people shedding *T. saginata* that would be required for the concentration in the creek water to exceed the WHO agriculture guideline of <0.1 HE/L; and
- The number of people shedding *T. saginata* that would be required for the concentration in the creek water to result in cattle consuming 1 HE per day or more.

Table 62 QMRA for Campaspe River water consumption by cattle

		Formula	Winter 2022				Winter 2036			
	Log reduction value achieved by the WRP →		1.5 log (minimum LRV)	2 log (median LRV)	3-log	4-log	1.5 log (minimum LRV)	2 log (median LRV)	3-log	4-log
A	Influent load (HE/person/day)		600,000	600,000	600,000	600,000	600,000	600,000	600,000	600,000
B	Influent volume (ML/day)		1.116	1.116	1.116	1.116	1.53	1.53	1.53	1.53
C	Influent concentration (HE/L/person)	A/B	0.54	0.54	0.54	0.54	0.39	0.39	0.39	0.39
D	HE LRV from WRP (log)		1.5	2	3	4	1.5	2	3	4
E	Treated wastewater concentration (HE/L/person)	C/10^D	0.0170	0.0054	0.0005	0.0001	0.0124	0.0039	0.0004	0.0000
F	Dilution of treated wastewater in waterway		0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
G	Waterway concentration (HE/L/person)	E*F	0.0114	0.0036	0.0004	0.0000	0.0083	0.0026	0.0003	0.0000
H										
I	WHO agriculture guideline (HE/L)		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
J	Waterway water meets guideline (fold)	I/G	8.8	27.8	277.6	2776.1	12.0	38.1	380.6	3806.0
K										
L	Cattle water consumption (L/day)		60	60	60	60	60	60	60	60
M	Avoid infection threshold (HE/day)		1	1	1	1	1	1	1	1
N	<1 HE consumption threshold (HE/L)	M/L	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167	0.0167
O	Waterway water meets guideline (fold)	N/G	1.5	4.6	46.3	462.7	2.0	6.3	63.4	634.3

8.8.8 Discussion on 'Infected Traveller' assessment

The concentrations of helminth eggs (HE) in the Campaspe River were estimated under different scenarios, including summer and winter flow conditions, and different HE removal estimates by the WRP (1.5-log, 2-log, 3-log and 4-log). The estimates of HE concentrations under these conditions when one infected person is present in the sewerage catchment are presented in Table 2, along with the risk threshold tested for the creek water, and the number of infected persons that would need to be present in the catchment to exceed the risk threshold

Table 63 Estimated number of infected persons to exceed infection thresholds, Kyneton BNR scenarios

Scenario	Risk threshold (WHO)	# infected persons to exceed t'hold	Risk threshold (<1 HE/day consumption)	# infected persons to exceed t'hold
Winter 2022, 1.5 LRV	<0.1 HE/L	8.8	<0.0167 HE/L	1.5
Winter 2022, 2 LRV	<0.1 HE/L	27.8	<0.0167 HE/L	4.6
Winter 2022, 3 LRV	<0.1 HE/L	278	<0.0167 HE/L	46.3
Winter 2022, 4 LRV	<0.1 HE/L	2,776	<0.0167 HE/L	463
Winter 2036, 1.5 LRV	<0.1 HE/L	12.0	<0.0167 HE/L	2.0
Winter 2036, 2 LRV	<0.1 HE/L	38.1	<0.0167 HE/L	6.3
Winter 2036, 3 LRV	<0.1 HE/L	380.6	<0.0167 HE/L	63.4
Winter 2036, 4 LRV	<0.1 HE/L	3,806	<0.0167 HE/L	634.3

As discharges to the Campaspe River are most likely to occur during winter periods, no summer scenarios have been examined.

The closest that HE concentrations in the waterway come to exceeding an acceptable risk threshold is in the 2022 scenario with worst-case HE removal by the WRP (1.5 LRV), using the threshold of <1 HE consumed per head of cattle per day. The risk threshold (0.0167 HE/L) was 1.5-times greater than the estimated creek concentration (0.0047 HE/L), and so two cases of people shedding *T. saginata* in the sewer catchment would exceed the risk threshold. Similarly, the same scenario, but with median HE removal by the WRP (2.0 LRV), resulted in the risk threshold being 4.6-times greater than the estimated creek concentration, and so five shedding cases in the township would exceed the risk threshold. The other tested scenarios estimate an increasingly large number of shedding cases being required to exceed the described risk thresholds.

It is concluded that:

– The risk is the highest during periods when the WRP inflow is at its lowest, as this results in the least dilution of any (rare) shedding cases in the sewerage catchment population.

– The conservative estimated waterway concentration of HE during worst-case conditions (2022 inflow, 1.5 LRV) was 0.0114 HE/L, resulting from one infected person in the sewerage catchment. This concentration is below the WHO guideline of 0.1 HE/L, and a more conservative threshold of 0.0167 HE/L, which was based on cattle consuming <1 HE/day.

– The risk threshold of 0.0167 HE/L will be exceeded when two, or more than two, people in the township are infected, under the 2022 scenario with 1.5 LRV at the WRP.

8.8.8.1 Recent research on the risk of cysticercus bovis (beef measles) in cattle exposed to recycled water

The following is paraphrased from the Stevens et al (2021) paper ‘The probability of cysticercus bovis detection in livestock from exposure to recycled water in non-endemic countries’.

Stevens et al (2021) undertook a study to assess the probability of cysticercus bovis (CB, also known as beef measles) infection of cattle in a country where *Taenia saginata* is not endemic (i.e. Australia) using QMRA methodology. The study used a dose response curve and estimation of typical *T. saginata* numbers collected from sewage samples across multiple wastewater treatment plants (WWTPs) in south east Australia.

A low concentration of *T. saginata* eggs was measured <0.1 HE/L and estimated through literature to be 0.003 HE/L (using a previously determined ratio of *Taena:Ascaris*). Concentrations at this level were determined to require a 2.2 Log_{10} Reduction Value (LRV) to maintain the baseline risk of CB estimated for Australia. However, an LRV of 3.5 is recommended for the management of future outbreaks of Taeniasis in the human population (CB in cattle), with monitoring of sewage to confirm this.

Several management activities could allow for credit towards the required LRV in the wastewater plant ranging from 0.5 – 2 LRV - e.g. restriction of recycled water use for livestock drinking water, the years of exposure for cattle to sites irrigated with recycled water, and the use of fodder off-site. If these measures were not available, a HE LRV of 4.0 is recommend for WWTPs to ensure adequate protection of systems with no on-site controls

8.9 Knowledge gaps and conservatism with pathogen risk assessment

The analysis of pathogen risk arising from Kyneton WRP discharges to the Campaspe River and their impact on beneficial uses downstream has shown there to be potential risks under some scenarios. However, it must be noted that there are a number of areas of knowledge gaps (or opportunities for the collection of additional data) with the pathogen risk assessment associated with the Kyneton WRP discharge. There is also some inbuilt conservatism within the assessment. The knowledge gaps and conservatism include:

– No data is available data to accurately characterise pathogen concentrations of raw sewage and raw trade waste (except *E. coli* and helminths for which some data is available).
– There is no definitive data on the log removal of pathogens through each treatment train process in both the domestic and trade waste streams.
– Pathogens within the Campaspe River, particularly upstream of the discharge point, are not adequately characterised, and it is important to quantify this risk in order to accurately assess the risk of the WRP discharge to downstream beneficial uses.
– There is no detailed information on water diversion frequency or volume downstream of the discharge point (i.e. how often do landholders divert river water for garden irrigation or other domestic or onsite uses?).
– There is no data available for frequency of recreation use, such as swimming at Turpin Falls and Barfold Gorge, and how often repeat visitation occurs.
– Risks were determined as if the Kyneton WRP discharge would occur every day (this would not occur in reality, especially in dry years with high irrigation demand).
– The higher end of pathogen concentrations (i.e. 95^{th} percentile values) were typically used for the assessment, and whilst this is accepted QMRA methodology, it may be considered overly conservative.

9. Nutrient and pathogen load assessment and offsetting

Land management projects to offset impacts of discharge and nutrient loads from the Kyneton WRP to the Campaspe River have been investigated using the Water Quality Offsets Framework (Alluvium 2015). The offset projects are in the form of 1) riparian revegetation, which would reduce nutrients and sediment being transported from grazing land into the Campaspe River and, 2) fencing along waterways to eliminate direct cattle access from the watercourse (therefore avoiding direct excretion into the waterway by cattle).

Discussions with North Central Catchment Management Authority (NCCMA) identified four offset project sites where Coliban Water has funded stream restoration projects that required willow removal, revegetation and fencing upstream of the Kyneton WRP discharge point. These are identified as Site A (near the Kyneton Racecourse), and Site B (Pleasant Hill Road), Site C (Carlsruhe Station Road) and Site D (Hoopells Lane), and have a total of 568.3 ha located upstream of the Kyneton WRP discharge point along the Campaspe River – see Figure 61.

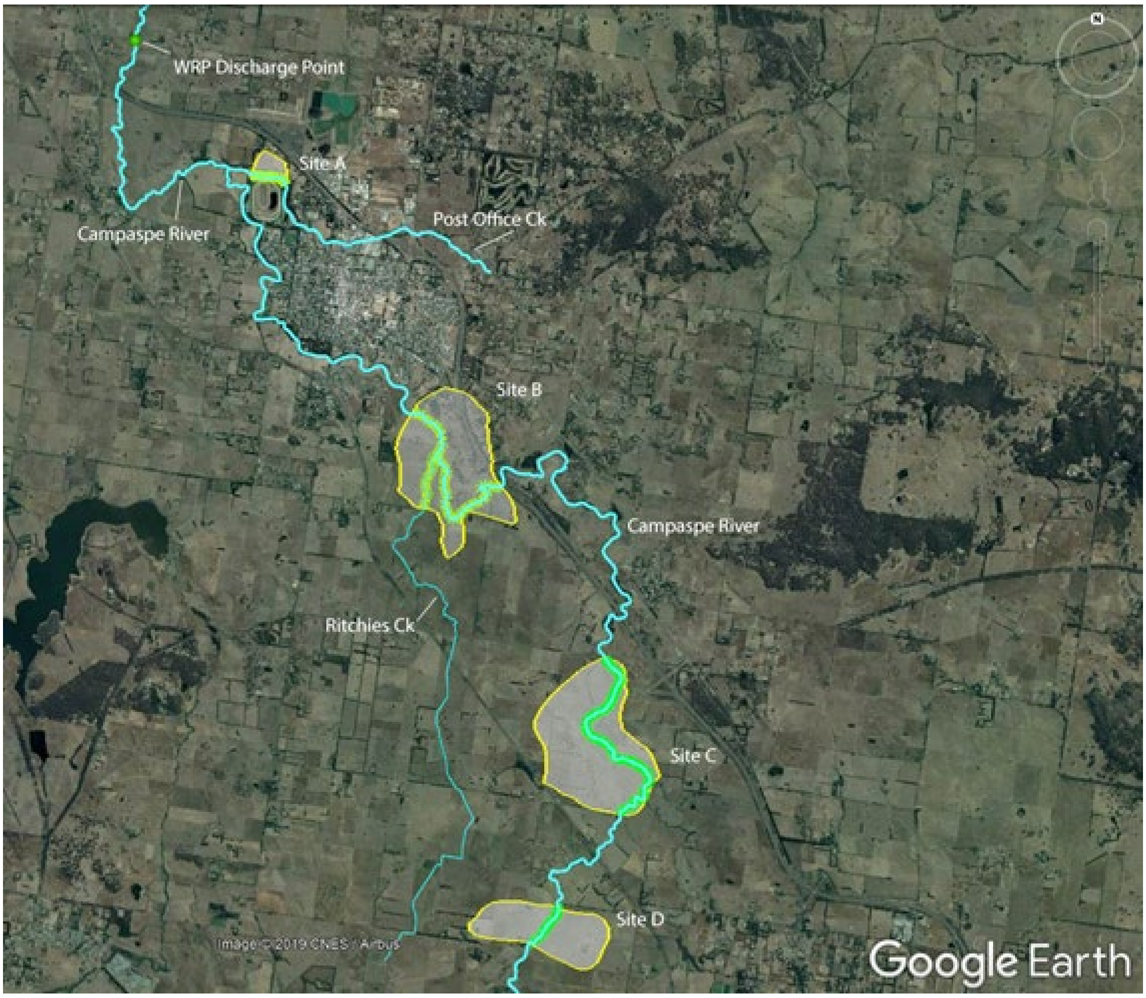

Figure 61 **Riparian revegetation project: Sites A, B, C and D (highlighted in green) on the Campaspe River near Kyneton**

The nutrient load reduction that could be achieved through a riparian revegetation project has been quantified by referring to recent work undertaken in the ACT - an investigation of Best Management Practices (BMPs) undertaken for ACTEW Water (now Icon Water) to investigate improved water quality in ACT drinking water catchments (GHD 2013b). The project involved on ground experiments, including rainfall simulation of various land management practices, including strategies such as a 10 m riparian zone, and providing alternative sources of water for cattle so they did not have direct access to the waterway. Other examples of nutrient load reduction afforded by riparian zones were obtained and compared from across Australia.

9.1 Offsets Framework

The Water Quality Offsets Framework (Alluvium (2015)) was developed to assist Victorian water authorities assess and implement potential options for offsetting the water quality impacts of wastewater discharges to waterways. Using the determined load values from the preferred Kyneton WRP discharge option, offset calculations have been undertaken in accordance with the Water Quality Offsets Framework.

9.2 Determining the nutrient and pathogen generation from land use and direct cattle excretion into waterways

9.2.1 Nutrient and pathogen generation associated with agricultural land

The annual load of nutrients, sediments and other pollutants sourced from agricultural land can vary depending on a wide range of factors. The factors which influence pollutant generation rates include (from DPI (2007)):

– Land management practices;
– Timing of fertilizer application;
– Crop type;
– Stocking rates;
– Soils and geology;
– Groundwater interaction;
– Rainfall; and
– Presence of erosion (particularly tunnel erosion).

There are a wide range of nutrient and sediment catchment load generation rates referenced in the literature – the Catchment Management Support System (CMSS) Nutrient Data Book (Marston et al 1995), provides a literature review of various land management practices and measured nutrient generation rates. Examples of nutrient generation rates from the CMSS Nutrient Data Book for land in Australia (in particular pasture / agriculture) and from other references are presented in Table 64.

Table 64 Suspended solids statistics for Kyneton BNR influent and treated wastewater

Reference	Land Use	Total N generation rate (kg/ha/year)	Total P generation rate (kg/ha/year)
Wood G. (1986)	Grazing	4.6	0.2
Cullen and Rosich (1979)	Rural	-	0.3
Costin (1980)	Improved pasture	0.62	0.12
Bott (1993)	> 70% agriculture runoff 50 – 150 mm year	0.03 – 0.4	-
Cullen (1991)	Native pasture	-	0.2
	Improved pasture	-	0.6
Cullen and Rosich (1979)	Rural	-	0.3
ACT Govt Water Quality study (GHD 2015b)	Agricultural / grazing	1.22	0.13
Landscape Logic (2010) – Tasmanian land use study	Grazing modified pasture	1	0.24
Atech Group (2000) – Murray Darling Basin study	Unimproved pasture	2.2 (range 1.1 – 3.3)	0.1 (range 0.05 – 0.35)
	Improved pasture	3.3 (range 0.6 – 4.6)	0.3 (range 0.1 – 0.7)

Reference	Land Use	Total N generation rate (kg/ha/year)	Total P generation rate (kg/ha/year)
Conservative estimate (average)		**2.1**	**0.28**
Maximum potential estimate		**2.8**	**0.28**

Nutrient generation from agricultural land for Kyneton at Sites A, B, C and D combined are presented in Table 65. The generation rates are presented in terms of both conservative and maximum potential estimates.

Table 65 Annual nutrient generation (sourced from land) - Site A, B, C and D combined

	Units	Conservative		Maximum Potential	
Parameter→		Total N	Total P	Total N	Total P
Area	ha	568.3			
Nutrient Generation Rate	kg/ha/year	2.1	0.28	2.8	0.28
Nutrient Generation	**kg/year**	**1193**	**159**	**1591**	**159**

9.2.1.1 Pathogen Generation

An estimation of pathogen generation by cattle within the agricultural areas Sites A – D is as follows. It is assumed that a cow produces 2.31 kg of manure (dry component) out of 42 kg/day wet manure (a ratio of 5.5% dry to wet was obtained from Font-Palmer (2019), UMass Extension (2010)) and this is equivalent to 843.15 kg/year/head. A characterisation of pathogens in cow manure is presented in Table 66 along with an estimation of pathogen numbers (for key representative organisms) and faecal indicator numbers (for *E. coli*, enterococci and *C. perfringens*) generated from each cow and across the sites A-D. (The area under grazing is 568.3 ha, and the assumed stocking rate is 0.5 head/ha).

Table 66 Pathogen and indicator characterisation of cattle manure

Pathogen	Organisms per gram of manure (dry weight)*	Number per individual cattle per year	Number per all cattle in Sites A-D per year
E. coli O157:H7	$10^{3.08}$		
Campylobacter	$10^{1.8}$-$10^{4.5}$ (assume 10^{3})	843,150,000	2.396 E+11
Salmonella	$10^{2.6}$-$10^{4.6}$		
Cryptosporidium	$10^{-0.3}$-$10^{3.2}$ (assume 10^{2})	84,315,000	2.396 E+10
Giardia spp.	$10^{0.2}$-$10^{3.5}$		
Enteroviruses	-		
Helminths ova	0		
E. coli	10^{5}-$10^{6.7}$ (assume 10^{6})	8.432 E+11	2.396 E+14
Enterococci	$10^{2.4}$-$10^{6.8}$		
C. perfringens	$10^{2.3}$		

*Adapted from Table 9 in USEPA 2010

Note that no value for norovirus is provided for cattle manure at this stage. References with regards to human noroviruses in cattle faecal material, including Mattison et al (2007) and Villabruna (2019), have been reviewed. A brief summary of findings is as follows:

– This is still very much a research topic, and it is too early to consider human noroviruses as having animal reservoirs, or vice versa.
– Evidence of transmission of animal noroviruses to humans is sparse and not well established.
– It is not clear whether human noroviruses detected in animal faeces are present due to the animal ingesting the virus, rather than an active infection.

On this basis, virus risks from animal faecal material have been excluded in pathogen load calculations and in QMRAs examining risks to human populations.

9.2.2 Nutrient generation from direct excretion into waterway by livestock

Livestock which have direct access to a waterway have an opportunity to directly excrete into the water, and this is a direct pathway for nutrients (and other contaminants) into the waterway. An estimation of the nutrient load into the Campaspe River from direct livestock access requires a number of assumptions to be made about the livestock and their behaviour, these include:

- Livestock type;
- Time spent in or near to water (may be influenced by alternative water and shade);
- Stocking rate (depends on land type / soil type / climate);
- Likelihood of excretion when near water (known to increase);
- Excretion rate; and
- Life stage (e.g. calf, weaner, pregnant cow etc.).

An estimation for each of the variables for excretion of livestock into a waterway is presented in Table 67.

*Table 67 Livestock estimates for direct excretion into waterways**

Parameter	Value
Livestock type / life stage	Cattle, adult 500 kg cow
Time spent or near to water.	2 hours / day (8.3%)
Stocking rate	0.5 head / ha
Likelihood of excretion when near water	50% increase
Excretion rate	Total N - 100 kg / head / year
	Total P - 15 kg / head / year

*Data was obtained from Senn et al (2012) and may be better adapted for Kyneton if specific data is available.

In order to determine actual stocking rates across Sites A to D, the number of livestock run on each property within the catchment areas was obtained (see Table 68).

Table 68 Livestock number estimates for landholders within Sites A - D

Landholder	Cattle Numbers		Sheep Numbers	
	Minimum	Maximum	Minimum	Maximum
1	50	50		
2	150	150		
3	50	70		
4			80	100
5	100	100	100	100
6	30	50		
7	50	80		
Total	430	500	180	200

MLA (2019) provides some data on the feed requirements (and presumably nutrient generation) of cattle and sheep: “The Dry Sheep Equivalent ‘DSE’ is used as a method of standardising an animal unit and is the amount of feed required by a two year old, 50 kg Merino wether to maintain its weight. Applying this principle, one 50kg dry goat is equivalent to one DSE and one yearling steer is equivalent to about 8 DSE, whereas a lactating cow may be equivalent to as much as 25 DSE”.

For the purposes of this report, a cow is assigned a DSE of 8 and a sheep a DSE of 1. Therefore, 180 / 200 sheep presented in Table 68 is the equivalent of 22 / 25 cows. The total number of cows (and equivalent sheep) is calculated to be 452 / 525 and the total area grazed is 568.3 ha within Sites A-D. This provides a stocking rate of 0.8 / 0.92 head per hectare, which is higher than the 0.5 value used in Table 67 and, as such, calculations for nutrient generation may be slightly conservative.

Combined results for Sites A, B, C and D are presented in Table 69, with 3,538 kg/year for total N and 531 kg/year for total P.

Table 69 Nutrient load from direct cattle excretion into the Campaspe River at Sites A, B, C and D combined

Parameter	Time that cattle spend near water	Stocking Rate	Grazing area	Increased likelihood of excretion when cattle near water	Excretion Rate	Final nutrient load of direct excretion from cattle
		head / ha	ha		kg/year	kg/year
Total N	8.3%	x 0.5	X 568.3	x 150%	x 100	3538
Total P					x 15	531

Using the pathogen generation data from Table 66, an estimate of the direct pathogen loading into the Campaspe River via direct excretion is presented in Table 70.

Table 70 Pathogen and indicator load from direct cattle excretion into the Campaspe River at Sites A, B, C and D combined

Parameter*	Time that cattle spend near water	Stocking Rate	Grazing area	Increased likelihood of excretion when cattle near water	Excretion Rate per head	Final pathogen load of direct excretion from cattle
		head / ha	ha		Number / year	Number/year
Campylobacter	8.3%	x 0.5	X 568.3	x 150%	x 843,150,000	2.983 E+10
Cryptosporidium					x 84,315,000	2.983 E+09
E. coli					x 8.432 E+11	2.983 E+13

*Note norovirus has been excluded due to current lack of reliable data in cattle manure

9.3 Pollutant removal through revegetated riparian zones

GHD (2013b) investigated best land use management practices (BMPs) in ACTEW Water (now Icon Water) catchments and undertook field investigations to examine a range of catchment management practices to assess their effectiveness to reduce catchment contaminant loads (in particular nutrients, suspended solids, pathogens and pesticides).

The study, conducted in a section of the Upper Murrumbidgee River, is one of the few field investigations undertaken in Australia that assess the effectiveness of riparian revegetation. It considered the following management practices: (a) Wooded riparian buffer; (b) Grassed riparian buffer; (c) Alternate water and shade; and (d) Contours swales and barriers.

The results of the experiment showed a range of pollutant reductions, achieved through each of the management practices. An 80% reduction of pollutants was adopted as the target for wooded riparian buffer of 10 m width for total N, total P and suspended solids. Whilst larger reductions were obtained in the field experiment, it was unclear how revegetation will work at reducing pollutants over a longer period of time – as such, a conservative value of 80% was chosen. The study produced a ranked list of potential BMPs that ACTEW Water could use to inform management decisions regarding catchment improvement works, based on costs and pollutant reduction efficacies.

A literature review of results from over 50 projects from Australia and international examples of land management / best management practices and their removal efficacy of pollutant was undertaken by GHD recently. For each project and best management practice type, a percent removal of pollutant was obtained. Data was collated and an average percent removal value (along with the standard deviation) is shown below in Table 71.

Table 71 Best Management Practice and expected pollutant reduction - percent reduction – average and (standard deviation)

Best management Practice	Nitrogen	Phosphorus	Sediment	Pesticides
Alternate water and shade	10 (34.4)	-10	38	-
Contour / Swale	55.6 (31.6)	64.1 (37)	52.3 (38.6)	42.8 (15.2)
Fencing	-8.3 (60.7)	76	58.5 (33.2)	-
Pond	31.7 (22.1)	55.7 (10.1)	69.6 (5.5)	-
Riparian buffer - Grassed	48.9 (25.1)	46.9 (39.4)	80.2 (9.7)	74.8 (19.4)
Riparian buffer - Wooded	43.5 (27.6)	50.7 (24.3)	74.5 (14.8)	-
Wetland	45.6 (23.6)	12.3 (61.4)	58.7 (24.2)	88

The ACTEW work estimated an 80% reduction of nutrients through a 10 m riparian zone was achievable, and that data in Table 71 shows a 10 m riparian buffer (wooded) is expected to remove 43.5% of total nitrogen, 50.7% of total phosphorus and 80.2% of sediment on average. As such, a conservative estimate of the combined data from the two references is a nutrient and sediment removal of 50%. An overview of the conservative estimate of nutrient reduction (with a 10 m riparian width) and a maximum potential nutrient reduction (with a 15 m riparian width – a preferred width of North Central Catchment Management Authority's revegetation programs) is presented in Table 72 – namely 50% reduction under a conservative estimate and 80% under a maximum potential reduction.

Table 72 Nutrient reduction through riparian revegetation

	Units	Conservative		Maximum Potential	
Parameter		Total N	Total P	Total N	Total P
Riparian Width	m	10	10	15	15
Nutrient Reduction	**%**	**50%**	**50%**	**80%**	**80%**

9.3.1.1 Pathogen Removal

The GHD (2013b) study also investigated phage transport through a vegetated buffer and showed that there was 100% removal, and this was mainly due to the applied 'rainfall' not being able to cause enough runoff to transport any phage.

Wilkes et al. (2013) undertook a study to assess the impact of cattle pasturing/riparian zone protection on: pathogen (bacterial, viral, parasite) occurrence, concentrations of faecal indicators, and quantitative microbial risk assessments (QMRA) of the risk of Cryptosporidium, Giardia and Escherichia coli O157:H7 infection in humans. Results showed some reduction as a result of riparian zones and that cattle exclusion measures did not have an equal effect on all microorganisms. They also showed that cattle access to waterways increases the likelihood of *E. coli* being present in the watercourse.

Kay et al. (2019) investigated the effect of installing stream bank fencing on a 271 m length of the River Tamar in South East England to exclude cattle access. Key indicators included the faecal indicator organisms *E. coli*, intestinal enterococci and phage. The study considered the movement of cattle and showed that they typically spend a disproportionate amount of time in or near the water along unfenced streams, and direct defecation into the water was common. Another key transmission route was from cowpats deposited adjacent to the waterway being washed off during rainfall events.

Total exclusion of cattle from the waterway using fencing (and supplying an alternative source of drinking water for the cattle) showed $\log_{10}$ reduction of pollutant loads of 0.842 for *E. coli* and intestinal *enterococci* of 2.206. Given there is a range of pathogen removal data through riparian zones from multiple studies, an estimate is made (and can be updated with better data as available) as shown in Table 73.

Table 73 Pathogen reduction through riparian revegetation

	Units	Conservative	Maximum Potential
Riparian Width	m	10	15
Pathogen Reduction	**%**	**80%**	**95%**

9.4 Allowances for uncertainty in offsets relating to riparian revegetation and direct excretion of cattle into waterways

There are three types of offsets defined in the Water Quality Offsets Framework:

– Type 1: Same currency (i.e. the parameters causing the impacts), same beneficial use as the impact to be offset.
– Type 2: Different currency, same beneficial use.
– Type 3: Different currency, different beneficial use.

The riparian revegetation projects and fencing to remove cattle from the waterway would both be able to directly offset nutrients entering the Campaspe River. This aligns with offsets of Type 1: same currency and same beneficial use. Total N and total P are the ‘currency’ and the beneficial uses are the same as those defined in the Kyneton ERA (GHD 2015): river health / aquatic ecosystems, primary and secondary contact, irrigation and stock watering.

Within the offset framework, ‘ratios’ or ‘factor of safety’ are a concept used in the design of offsets schemes to manage issues of scientific uncertainty. This may have the effect of avoiding costly scientific studies into each case to prove their effectiveness. Ratios, or ‘factors of safety’, address three different categories of uncertainty:

– The uncertainty and reliability of the offset action proposed (i.e. an equivalence factor).
– The time to implement the offset option (i.e. a time factor).
– The location of the offset action relative to the impact (i.e. a location factor).

To use the ‘factors of safety’, an appropriate number is determined for each of the categories (equivalence, time, location) from the Water Quality Offsets Guideline and these numbers are multiplied together. The resulting value is a factor that increases that amount of the offset required in order to take into account the uncertainty and risk associated with the proposed activity.

9.4.1 Riparian Revegetation

Riparian revegetation was assessed against 10 criteria set out in the Offsets Framework – see Table 74. The multiplication factor for nutrient removal is 2 (equivalence) x 1.5 (time) x 1 (location) = 3.

9.4.2 Removal of cattle directly excreting into a waterway

Removal of cattle that were directly excreting into a waterway is assessed against 10 criteria set out in the offsets framework – see Table 74. The multiplication factor for nutrient removal is 1 (equivalence) x 1 (time) x 1 (location) = 1.

Table 74 Phase 3 criteria for assessing offset options using riparian revegetation and cattle waterway exclusion

Offset Criteria	Comment from offset framework	Riparian Revegetation	Removal of cattle from waterway eliminating direct excretion
Equivalence	Demonstrated by modelling/measurement to predict the equivalent amount of the parameter (may include ratios for timeliness, uncertainty of offset action and/or location) High Reliability (high level of control, small variance in performance, established technology) (1:1) Medium Reliability (control intermittent such as a constructed wetland, medium but well understood variance in performance, established technology) – (use a ratio of 1.5:1) Low Reliability (minimum control such as works requiring private landholder to maintain, high variance, novel technology) (use a ratio of 2:1)	Low Reliability use a ratio of 2:1 – i.e. the equivalence factor = 2	High Reliability use a ratio of 1:1 – the equivalence factor = 1
Alignment with management priorities	Offset action has been assessed (through equivalence) of addressing the exact impact of the base case so alignment with management priorities less important.	Would meet management priorities of base case through 'equivalence'.	
Additional	Needs to be additional to any funded works. Does not preclude offsets from piggybacking on other planned works. Consideration needs to be given if the offset action is a regulated activity or responsibility for another party. While in most cases this would not be available as an offset there may be exceptions if the risk to beneficial uses is demonstrated.	The proposed riparian works would be additional.	Removal of cattle from waterway would be additional.
Measurable	Will be situation dependant (i.e. a diffuse source of nutrients such as stormwater would be modelled, point source discharge could be measured) Offset proposals should include either: • Adequate demonstration of relevant scientific literature to give confirmation of the outcome (for approval by the offsets technical panel) • Details of a monitoring program to confirm results	Scientific literature available with regards to riparian zone removal of pollutants such as ACTEW Water's Best Management Practice investigation. Can estimate nutrient generation from agricultural land using models or other methods.	Literature available as a first estimate. On site measurement would be able to provide more confidence.
Timely	The offset should be operating prior or at the same time as the impact. Ratios for timing multiply the predicted output (i.e. kg pollutant/Ml) by the following factors: • Before or at time of impact (1:1) • 0-3 years post impact (1.5:1) • 3+ years (2:1) All offsets will be time bound (usually over the same period as a water authority regulatory period)	The timing of the installation and establishment of the riparian zone would be 0-3 years post the Kyneton WRP impact. This would use a ratio of 1:1.5. i.e. the time factor = 1.5	Timing would be instantaneous – time factor 1:1
Located appropriately	As offset is dealing with the specific impact the location will already be determined. Ratios for location multiply the predicted output (i.e. kg pollutant/Ml) by the following factors: • Immediate (within 2 km downstream) or upstream location (1:1)	The proposed riparian project is located upstream of the WRP discharge point – use a ratio of 1:1.	Upstream of impact so location factor is 1:1

Offset Criteria	Comment from offset framework	Riparian Revegetation	Removal of cattle from waterway eliminating direct excretion
	• Greater than 2 km from site (1.5:1) • >5 km downstream of impact site (2:1)	i.e. the location factor = 1	
Enforceable	Will need two levels of contract. Exact form will depend on the regulatory/policy driver. 1. Contract between the EPA and the proponent specifying the length of the offset, the business case (as defined by this framework) and the offset action. 2. Contract between the proponent and the delivery of the works (may also include the asset manager if different).	The project will require a contract / memorandum of understanding between Coliban Water / North Central CMA / private landholder.	
Verifiable	Should be verifiable to the satisfaction of both the proponent and the asset owner (CMA / State Govt.). Will be dependent on the actions taken but if possible should be undertaken based on accepted standard. Offset evaluation should be undertaken at the end of the offset period (in preparation for next risk assessment). It should include: • Intent of the action • Success of implementation (for example did the vegetation establish, what was the survival rate) • Cost comparison (capital and ongoing) This information would be compiled and presented as part of the framework evaluation. Offset actions that do not conform to an accepted standard will require a greater degree of monitoring the results. A set of pre-determined KPIs must be identified as part of the offset nomination. These should relate to the implementation of the action (e.g. verify that it is built as planned) and its function (e.g. it worked as designed).	Implement a water quality monitoring program to verify the effectiveness of the riparian zone and cattle exclusion activities. Results will be of interest to other offset managers.	
Socially acceptable	Results are equivalent to the site and nature of the impact so consultation with community may be quite simple compared to other approaches. In some cases, reference to previous consultation (such as that undertaken for a River Health Strategy) will be sufficient. If it occurs consultation is likely to be focussed on informing rather than gathering data to decide on result. The exception to this will be if there are several feasible offset options and there are multiple benefits of each. In this case community preferences should provide extra weight in determining the preferred action.	Landholder consultation had been undertaken by NCCMA and the project is ready to proceed pending funding.	
Life Cycle Cost Analysis	Costing of offset options will largely dictate result - offset should be the least cost for the community that achieves the same result. More complex if there are several offset options with multiple benefits where higher costs may be accepted for other benefits (which possible would attract other contributions).	Life cycle costs for riparian zones revegetation are relatively well defined North Central CMA have costs available.	Life cycle costs for cattle exclusion need to be verified.

9.5 Nutrient loading to the Campaspe River for the baseline scenario and 2022 / 2036 scenarios

A summary of the nutrient loading to the Campaspe River from the Kyneton WRP is presented in Table 75 for each scenario. The baseline scenario (2017-2020 worst case discharge of both BNR and Lagoon 4 discharge) shows an annual nutrient baseline load to the river of 5,056 kg/year for total N and 2,040 kg/year for total P. Loads associated with the 2022 and 2036 scenarios are also presented in Table 75, as well as a comparison to the baseline scenario.

Under the 2022 and 2036 scenarios, there is less nutrient load being released to the Campaspe River than the baseline scenario. This due to the difference in nutrient concentrations and discharge volumes in each scenario, compared to the baseline, and that Lagoon 4 discharge is not included in any of the scenarios, except for the baseline. The key differences are:

– **Total N concentration**: the average value of total N in the combined discharge – i.e. the baseline scenario – was 9.6 mg/L (with a median of 7.8 mg/L), whereas in the BNR only discharge i.e. the 2022 and 2036 scenarios, the average was 6.3 mg/L (with a median of 6.4 mg/L).
– **Total P concentration**: the average value of total P in the combined discharge – i.e. the baseline scenario – was 3.13 mg/L (with a median of 0.35 mg/L), whereas in the BNR only discharge i.e. the 2022 and 2036 scenarios, the average was 0.21 mg/L (with a median of 0.18 mg/L).
– **Under the baseline scenario**, Kyneton WRP typically discharged at a ratio of 5:1 – i.e. 5 parts river flow to one part WRP discharge, with streamflow measured at Redesdale. Under the 2022 and 2036 scenarios, streamflow was determined from the Kyneton gauge, which provides considerably less streamflow than at Redesdale. As such, discharging at various ratios with streamflow measured at Kyneton typically gives a much smaller total discharge volume than that undertaken in the baseline scenario.

Table 75 Nutrient loads to Campaspe River for the baseline, 2022 and 2036 scenarios

Scenario	Discharge			Annual Load to river (kg/year)		Difference from baseline (kg/year)	
		Proportion	Streamflow-to-discharge ratio*	Total N	Total P	Total N	Total P
Baseline	2017-2020 BNR and Lagoon 4 Actual measured discharge volumes			5,056	2,040	-	-
2022	2022 BNR discharge	66.7%	1:2	1,625	52	-3,431	-1,988
2036	2036 BNR discharge	66.7%	1:2	2,349	77	-2,707	-1,963

*Streamflow as measured at Kyneton gauging station

The difference in load between each scenario and the baseline scenario is the additional nutrient load that is required to be offset i.e. the incremental load. However, for the 2022 and 2036 scenarios presented, the nutrient loads to the Campaspe River are lower than the baseline, i.e. there is no incremental load to offset. There is an opportunity, however, to offset all loads from the 2022 and 2036 scenarios.

Calculations for the nutrient loads and the offsets available from Sites A – D are presented in Table 76 for the 2022 scenario and in Table 77 for the 2036 scenario. For the 2022 scenario, results show under a conservative scenario, the amount of load offset is 229% of the required load from the offsets framework for total N and 1058% for total P. With the ‘maximum potential’ scenario, these offset percentage values increase to 248% of the required load from the offsets framework for total N and 1196% for total P. For the 2036 scenario, results show under a conservative scenario, the amount of load offset is 159% of the required load from the offsets framework for total N and 714% for total P. With the ‘maximum potential’ scenario, these offset percentage values increase to 172% of the required load from the offsets framework for total N and 808% for total P.

As such, results of calculations for both the 2022 and 2036 scenarios have offset percentage values greater than 100% for total N and total P – this means all nutrients discharge from the BNR plant have been offset by the cattle exclusion and riparian zone revegetation works.

*Table 76 Calculation of nutrient loads and offsets (Sites A-D) under the 2022 Scenario**

Step in calculation	Note	Unit	Conservative		Maximum potential	
			Total N	Total P	Total N	Total P
Total Load to be offset	A	kg/year	1,625	52	1,625	52
Nutrient generation from cattle directly excreting into waterway	B	kg/year	3538	531	3538	531
Credit toward offset from removal of cattle from waterway (adjusted for uncertainty factor of 1)	C	kg/year	3538	531	3538	531
Resulting load required to be offset by riparian zone revegetation	D	kg/year	-1,913	-479	-1,913	-479
Nutrient generation from agricultural land	E	kg/year	1136.6	113.7	1875.4	341.0
Nutrient removal through riparian zones (50% Conservative, 80% Maximum Potential)	F	kg/year	568.3	56.8	1500.3	272.8
Credit toward offset from riparian revegetation (adjusted for uncertainty factor of 3)	G	kg/year	189	19	500	91
Total Load offset (i.e. cattle removal from waterway credit + riparian revegetation credit)	H	kg/year	3727	550	4038	622
Total Load not offset	I	kg/year	-2,102	-498	-2,413	-570
Total Load offset %	J	%	229%	1058%	248%	1196%

*Offset calculations undertaken using methods set out in Alluvium (2015).

A – Total load to be offset, this value comes from the load identified under the 2022 scenario.

B – The nutrient generation from direct excretion of cattle into waterway (see Table 69).

C – Credit towards offset from removal of cattle from waterway – this value is the total load (B) divided by the uncertainty factor (factor of safety) for direct cattle excretion (a value of 1.)

D - Resulting load required to be offset by riparian zone revegetation – i.e. the total load (A) minus credit towards offset from removal of cattle (C). A negative value means all total loads have been offset by cattle exclusion even before riparian zone revegetation has been investigated.

E – Nutrient generation from agricultural land for both conservative and maximum potential scenarios (see Table 65).

F – Nutrient removal through riparian zones – this is the value from (E) multiplied by conservative value of 50% removal and maximum potential value of 80%.

G - Credit towards offset from riparian revegetation (adjusted for an uncertainty factor of 3 – i.e. the value in (F) is divided by 3) – see Table 74.

H – Total Load offset (i.e. cattle removal from waterway credit + riparian revegetation credit) = (C) + (G)

I – Total load not offset is (A) – (H). A negative value means all loads have been offset.

J –Load offset as a proportion of required load to be offset (H / A) x 100 %. A value greater than 100% means all loads have been offset.

*Table 77 Calculation of nutrient loads and offsets (Sites A-D) under the 2036 Scenario**

Step in calculation	Note	Unit	Conservative		Maximum potential	
			Total N	Total P	Total N	Total P
Total Load to be offset	A	kg/year	2,349	77	2,349	77
Nutrient generation from cattle directly excreting into waterway	B	kg/year	3538	531	3538	531
Credit toward offset from removal of cattle from waterway (adjusted for uncertainty factor of 1)	C	kg/year	3538	531	3538	531
Resulting load required to be offset by riparian zone revegetation	D	kg/year	-1,189	-454	-1,189	-454
Nutrient generation from agricultural land	E	kg/year	1136.6	113.7	1875.4	341.0
Nutrient removal through riparian zones (50% Conservative, 80% Maximum Potential)	F	kg/year	568.3	56.8	1500.3	272.8
Credit toward offset from riparian revegetation (adjusted for uncertainty factor of 3)	G	kg/year	189	19	500	91
Total Load offset (i.e. cattle removal from waterway credit + riparian revegetation credit)	H	kg/year	3727	550	4038	622
Total Load not offset	I	kg/year	-1,378	-473	-1,689	-545
Total Load offset %	J	%	159%	714%	172%	808%

Notes A-J in above table are as per Table 76

9.6 Pathogen load to Campaspe River under baseline, 2022 and 2036 scenarios

Data is presented in this section to estimate the additional pathogen load that would eventuate under the 2022 and 2036 scenarios, compared to the baseline discharge scenario, and the offset potentially available through cattle exclusion and riparian zone revegetation from Sites A-D. Concentrations of four key pathogens in wastewater discharge (*Campylobacter*, *E. coli*, norovirus and *Cryptosporidium*) were obtained either from measured data (*E. coli*) or as an estimate from Table 55 under the median scenario. The discharge volume from Kyneton WRP to the Campaspe River under the current baseline scenario (July 2017- June 2020) is 485 ML/year for the combined domestic and trade waste streams. For the purposes of calculating a pathogen load baseline, it was assumed that 90% of the discharge (436.5 ML/year) was treated domestic water and 10% (48.5 ML/year) was treated trade waste. Pathogen loads are presented in Table 78 and the difference in load from the current baseline is presented in Table 79.

Results show that for both the 2022 and 2036 scenarios there is a lower pathogen load to the Campaspe River, compared to the current baseline scenario i.e. there is no incremental pathogen load under the new scenarios compared to the baseline.

Note pathogen loads presented here are intended to be an indicator of the total number of pathogens entering the waterway over a one year period. This is not intended to be in a ‘QMRA style’, or to replace the QMRA assessment undertaken in pathogen risk assessment section (section 8) of this report.

*Table 78 Pathogen loads to the Campaspe River under baseline, 2022 and 2036 scenarios **

Scenario	Source	Discharge to Campaspe	Concentration (number /L)				Load (numbers / year)			
		ML/year	*Campy lobacter*	*E. coli*	Norovirus	*Crypto-sporidium*	*Campy lobacter*	*E. coli*	Norovirus	*Crypto-sporidium*
Current Baseline (July 2017 – June 2020)	Domestic / BNR	436.5	0.007	20	40	2	3,055,500	8.73E+09	1.75E+10	8.73E+08
	Trade waste	48.5	0.00000022	510	0	0.000001	10.7	2.47E+10	0.00E+00	4.85E+01
	Total	485					3,055,511	3.35E+10	1.75E+10	8.73E+08
2022	Domestic / BNR only	255	0.007	1	40	2	1,785,000	2.55E+08	1.02E+10	5.10E+08
2036	Domestic / BNR only	368	0.007	1	40	2	2,576,000	3.68E+08	1.47E+10	7.36E+08

Pathogen concentrations are from Table 55, except for 2022 and 2036 scenarios in which the *E. coli* median value (post February 2021) was 0 orgs/100 mL. However, because in 35% of data (after Feb 2021) *E. coli* some was detected, a value of 1 org/L is used here estimate loads, rather than a value of 0 which would result in an unrealistic result of zero *E. coli* load to the Campaspe River.

Table 79 Difference in pathogen load compared to the current baseline for 2022 and 2036 scenarios (i.e. incremental pathogen load)

Scenario	Source	Discharge	Difference in load from baseline (numbers / year)			
			Campy lobacter	*E. coli*	Norovirus	*Crypto-sporidium*
2022	Domestic / BNR only	255	-1,270,511	-3.32E+10	-7.3E+09	-3.63E+08
2036	Domestic / BNR only	368	-479,511	-3.31E+10	-2.78E+09	-1.37E+08

9.6.1 Total pathogen load offset

Analyses in the above section showed there to be no incremental pathogen load under the 2022 and 2036 scenarios compared to the baseline scenario. Additional analysis is presented in this section to determine if the total pathogen load could be offset for both the 2022 and 2036 scenarios.

Results are presented in Table 80 for the 2022 scenario and in Table 81 for the 2036 scenario, and both results show that pathogen total loads for all scenarios have been offset from existing Sites A-D – i.e. greater than 100% of the load is offset for *Campylobacter*, *Cryptosporidium* and *E. coli*. Note that no values for norovirus are presented in these tables due to the current lack of reliable data for norovirus in cattle manure.

*Table 80 Calculation of total pathogen loads and offsets (Sites A-D) under the 2022 scenario **

Step in calculation	Note	Unit	Conservative			Maximum Potential		
Pathogen* →			*Campylobacter*	*Cryptosporidium*	*E. coli*	*Campylobacter*	*Cryptosporidium*	*E. coli*
Total Load to be offset	A	No./year	1,785,000	5.10E+08	1.79E+06	1,785,000	5.10E+08	2.55E+08
Nutrient generation from cattle directly excreting into waterway	B	No./year	2.98E+10	2.98E+09	2.98E+13	2.98E+10	2.98E+09	2.98E+13
Credit toward offset from removal of cattle from waterway (adjusted for an uncertainty factor of 1)	C	No./year	2.98E+10	2.98E+09	2.98296E+13	2.983E+10	2.98E+09	2.983E+13
Resulting load required to be offset by riparian zone revegetation	D	No./year	-2.98E+10	-2.47E+09	-2.98E+13	-2.98E+10	-2.47E+09	-2.98E+13
Pathogen generation from agricultural land	E	No./year	2.40E+11	2.40E+10	2.40E+14	2.40E+11	2.40E+10	2.40E+14
Pathogen removal through riparian zones (50% Conservative, 80% Maximum Potential)	F	No./year	1.92E+11	1.92E+10	1.92E+14	2.28E+11	2.28E+10	2.28E+14
Credit towards offset from riparian revegetation (adjusted for an uncertainty factor of 3)	G	No./year	6.39E+10	6.39E+09	6.39E+13	7.59E+10	7.59E+09	7.59E+13
Total Load offset (i.e. cattle removal from waterway credit + riparian revegetation credit)	H	No./year	9.37E+10	9.37E+09	9.37E+13	1.06E+11	1.06E+10	1.06E+14
Total Load not offset	I	No./year	-9.37E+10	-8.86E+09	-9.37E+13	-1.06E+11	-1.01E+10	-1.06E+14
Total Load offset %	J	%	5250203%	1838%	5250514679%	5921299%	2072%	41451549%

Notes A-J in above table are as per Table 76

*Norovirus not included due to lack of reliable data in cattle manure

*Table 81 Calculation of total pathogen loads and offsets (Sites A-D) under the 2036 scenario **

Step in calculation	Note	Unit	Conservative			Maximum Potential		
Pathogen* →			*Campylobacter*	*Cryptosporidium*	*E. coli*	*Campylobacter*	*Cryptosporidium*	*E. coli*
Total Load to be offset	A	No./year	2,576,000	7.36E+08	2.58E+06	2,576,000	7.36E+08	3.68E+08
Nutrient generation from cattle directly excreting into waterway	B	No./year	2.98E+10	2.98E+09	2.98E+13	2.98E+10	2.98E+09	2.98E+13
Credit toward offset from removal of cattle from waterway (adjusted for an uncertainty factor of 1)	C	No./year	2.98E+10	2.98E+09	2.98296E+13	2.983E+10	2.98E+09	2.983E+13
Resulting load required to be offset by riparian zone revegetation	D	No./year	-2.98E+10	-2.25E+09	-2.98E+13	-2.98E+10	-2.25E+09	-2.98E+13
Pathogen generation from agricultural land	E	No./year	2.40E+11	2.40E+10	2.40E+14	2.40E+11	2.40E+10	2.40E+14
Pathogen removal through riparian zones (50% Conservative, 80% Maximum Potential)	F	No./year	1.92E+11	1.92E+10	1.92E+14	2.28E+11	2.28E+10	2.28E+14
Credit towards offset from riparian revegetation (adjusted for an uncertainty factor of 3)	G	No./year	6.39E+10	6.39E+09	6.39E+13	7.59E+10	7.59E+09	7.59E+13
Total Load offset (i.e. cattle removal from waterway credit + riparian revegetation credit)	H	No./year	9.37E+10	9.37E+09	9.37E+13	1.06E+11	1.06E+10	1.06E+14
Total Load not offset	I	No./year	-9.37E+10	-8.64E+09	-9.37E+13	-1.06E+11	-9.83E+09	-1.06E+14
Total Load offset %	J	%	3638049%	1273%	3638264248%	4103074%	1436%	28723220%

Notes A-J in above table are as per Table 76

*Norovirus not included due to lack of reliable data in cattle manure

9.7 Preferred discharge scenario and licence parameters

The preferred discharge scenario and licence parameters, as proposed by Coliban Water, after initial consultation with EPA, are as the following:

- Discharge to waterway flow proportion of 1:2 (1-part waterway flow to 2-parts discharge); or a 66.7% maximum discharge proportion of streamflow at Wards Lane discharge point.
- Discharge to streamflow proportion to be measured from Campaspe River Gauging Station located at the foot of the Calder Freeway Bridge crossing upstream from the Wards Lane discharge point.
- Discharge water quality to consist solely of BNR treated domestic wastewater.
- EPA Licence parameter concentrations as per Table 82:

Table 82 Preferred discharge scenario EPA licence conditions

Parameter	Measurement	Licence Value
BOD_5	Rolling Annual Median	5 mg/L
Total Suspended Solids	Rolling Annual Median	10 mg/L
Total Dissolved Solids	Rolling Annual Median	1,000 mg/L
pH	Within the range	6 to 9
Ammonia	Rolling 90^{th} percentile	1.4 mg/L
Total Phosphorus	Maximum	1 mg/L
	Rolling Annual Median	0.5 mg/L
Total Nitrogen	Maximum	15 mg/L
	Rolling Annual Median	10 mg/L
E. coli	Maximum	400 orgs/100 mL
	Rolling Annual Median	100 orgs/100 mL
Helminths	Maximum	1 *Taenia* egg/L

10. Snipes Creek Discharge Risk Assessment

Investigations were undertaken for the Kyneton WRP with regards to discharging BNR treated wastewater from the WRP to Snipes Creek, rather than to the Campaspe River. Coliban Water does not have an EPA licence to discharge to Snipes Creek and currently does not consider this a location to discharge. One scenario was investigated in the report: a 6 megalitre/day constant discharge (i.e. discharge could occur at any time even if no streamflow was present in the waterway).

Snipes Creek can be described as being in poor ecological condition. This is typical of nearby waterways in the area, including the Campaspe River, Jews Harp Creek and Pipers Creek, which have been assessed as either poor or very poor in the most recent Index of Stream Condition assessment. Aquatic ecology monitoring of Snipes Creek shows that the waterway is degraded and in poor condition with regards to macroinvertebrate (water bug) populations and diversity, and when compared to environmental reference standards and other sites on the Campaspe River. A desktop biodiversity assessment of Snipes Creek was undertaken using the Victorian Biodiversity Atlas (VBA), which revealed no listed species (i.e. vulnerable, critical or endangered) being recorded in the area.

As for the Campaspe River catchment, land use in the Snipes Creek catchment is likely to influence the condition of the waterway: the upper catchment includes industrial areas, whilst the lower catchment has agricultural and rural residential land use. Snipes Creek is noted to have a lack of riparian vegetation and there is free access to the creek for livestock in the lower catchment.

There was no streamflow data available for Snipes Creek, which is an intermittent stream and typically only flows after rainfall. Streamflow data was estimated for Snipes Creek using the streamflow gauge located on the Campaspe River at Kyneton. Snipes Creek streamflow was estimated to flow on approximately 40% of days, with the majority of flow occurring in winter and spring. Under the discharge scenario of 6 ML/day, streamflow in Snipes Creek would alter to become continuous. This altered flow regime would likely affect in-stream biota in Snipes Creek downstream of the discharge point, although may potentially provide some environmental flow benefits.

Water quality data was available for Snipes Creek upstream and downstream of the discharge point, with a total number of available data points being 1,046. Water quality data was also available for the BNR discharge. Snipes Creek upstream of the proposed discharge point showed highly elevated levels of nutrients, turbidity and *E.coli*.. Snipes Creek downstream of the proposed discharge point had less data available than upstream, but was this section of the creek was noted to be of better quality than upstream for some parameters. Snipes Creek further downstream, at Barbower Road, had lower concentrations for most parameters compared to Snipes Creek upstream and downstream, although it had higher concentrations for electrical conductivity.

From a compliance perspective, Snipes Creek upstream had 86% of ammonia data above the ANZG (2018) guideline of 0.9 mg/L, with the highest reading being 130 mg/L. For Snipes Creek downstream, 41% of data for ammonia was non-compliant with a maximum value of 20 mg/L, and Barbower Rd had 17% of ammonia data non-compliant with a maximum of 4.2 mg/L. These maximum recorded concentrations of ammonia present in Snipes Creek are likely to be toxic to in stream biota. Total nitrogen and total phosphorus values were non-compliant across all sites Snipes Creek sites, and *E. coli* was non-compliant for primary contact recreation with all sites where data was available.

A comparison of the Kyneton BNR discharge and Snipes Creek upstream of the proposed discharge point showed the BNR discharge is, for the most part, better quality than the creek. This is particularly so for BOD, dissolved oxygen, suspended solids, ammonia as N, total N, total P and *E. coli*. For pH the BNR and Snipes Creek were similar and both compliant with ERS (2021) guidelines and for electrical conductivity, Snipes Creek was lower than the BNR discharge, but both the creek and the discharge were well below ERS (2021) guidelines. A discharge that is of better quality than the receiving waters, for most parameters, is unusual for a discharge risk assessment.

A discharge risk assessment was completed for the one scenario – a constant 6 ML/day discharge into Snipes Creek at the proposed discharge point. Key inputs into the discharge risk assessment were the streamflow estimated for Snipes Creek and discharge water quality for the BNR plant based on 2015-2020 data (except *E. coli* which used data post February 2021 – when a new ultraviolet treatment system was commissioned). Snipes Creek upstream water quality data were used and nutrient decay rates available for the Campaspe River were applied.

The discharge risk assessment was undertaken on a daily timestep over a 3 year period from July 2017 to June 2020. A baseline scenario of measured discharge to the Campaspe River over the same 2017-2020 period was available to compare results.

Under the 6 ML/day discharge scenario to Snipes Creek, the average annual discharge volume was 2,192 ML/year, a 450% increase in volume when compared to the baseline scenario in which 485 ML/year was discharged to the Campaspe River. A risk score of the discharge is calculated on every day in the analysis period, based on how high concentrations of key parameters reach in the waterway, compared to upstream concentrations. The risk score for the 6 ML/day discharge was considerably lower (with a risk score of 416, or 0.06 per megalitre) when compared to the risk score of the baseline discharge to the Campaspe River (risk score of 12,141 or 8.34 per megalitre of discharge).

Mixing zones were calculated under the 6 ML/day discharge scenario. For total N the mixing zones were determined to be slightly higher in the 6 ML/day scenario (with a median of 3.75 km) compared to the baseline scenario (median of 3.31 km). Total P mixing zones decreased in the 6 ML/day scenario (with a median of 3.72 km) compared to the baseline scenario (median of 3.72 km).

With regards to total loads to the waterway, under the 6 ML/day scenario discharging to Snipes Creek, there is approximately a 275% increase in average annual load to Snipes Creek for total N compared to the baseline scenario of discharging to the Campaspe River. For total P there is a a decrease in total load (22% of the baseline load) for total P, when compared to the baseline scenario.

Key reasons for these outcomes are as follows:

– The baseline scenario (discharge to the Campaspe River) has considerably higher concentrations of some parameters compared to the future BNR-only discharge used in the 6 ML/day scenario, particularly with regards to total P in which BNR-only discharge is approximately 10% of the concentration of the combined BNR/Lagoon 4 discharge used in the baseline scenario.
– The receiving waters of Snipes Creek are considerably higher in background concentrations for total N and total P compared to the BNR discharge i.e. the discharge is frequently of better quality than the creek. Over the three years of analysis from 2017-2020, for each day that the BNR discharge was of better quality than Snipes Creek, there was no additional increase in risk to the creek, and the mixing zone for that day is calculated as zero.

As such, even though the volume of discharge is considerably higher in the 6 ML/day discharge scenario, the improved quality of an only BNR treated wastewater discharge (particularly for total P and *E. coli*) compared to the baseline scenario, and the considerably poorer water quality present in Snipes Creek upstream of the discharge point results in a relatively low risk discharge.

A pathogen risk assessment for Kyneton WRP discharge to the Snipes Creek was undertaken and for the most part utilised similar methods undertaken for the Campaspe River. The findings from GHD (2022b) were mostly applicable to Snipes Creek, even though there were differences between the scenarios investigated (Snipes Creek is a continuous discharge, whereas the Campaspe River assessment is for an intermittent discharge, and at a streamflow-to-discharge ratio of 1:2), because within the Campaspe River pathogen assessment, both the dilution available in the river and the in-stream die off of pathogens were noted to be relatively small, and not factored into pathogen reduction calculations.

The limitations of the pathogen risk assessment for Snipes Creek are similar to the limitations for pathogen risk assessment in the Campaspe River i.e. a lack of reliable pathogen data to characterise raw and treated wastewater and Snipes Creek water upstream, no accurate information to understand potential diversion frequency from Snipes Creek for gardening or household use and no data on the frequency of recreational use of the creek water. It is noted that there is considerable conservatism in the adopted QMRA approach.

11. Discussion

The receiving waterway for Kyneton WRP discharge is the Campaspe River, part of the Murray-Darling Basin. Land use within the Campaspe River catchment above Lake Eppalock includes agricultural land, urban areas and natural / forested lands. The Campaspe River has been described by a number of studies, including the Sustainable Rivers Audit, which was conducted between 2008-2012 and which classified the ecosystem health of the Campaspe Catchment as very poor (Davies et al., 2012). The Index of Stream Condition report (ISC) (2013) provided a snapshot of the ecological condition the Campaspe River and other waterways across Victoria, scoring against five criteria: hydrology, physical form, streamside zone, water quality and aquatic life. A number of waterways in the upper Campaspe catchment were reported as being in ‘very poor’, ‘poor’ and ‘moderate’ condition, with those waterways in the lower parts of the catchment scoring less well than the upper catchment. Despite the identified degradation in the Campaspe River, many values and important assets exist throughout the waterway. The North Central Catchment Management Authority (NCCMA) has identified the Campaspe River to have notable assets with high community value (NCCMA 2013) and are undertaking an ecological improvement program for the upper Campaspe River, as documented in a stream frontage management plan (SFMP).

Environmental values of the Campaspe River, as outlined in ERS (2021) include: aquatic ecosystems (sightly to moderately modified), primary and secondary recreation, aesthetic enjoyment, indigenous cultural and spiritual values, agriculture and irrigation, human consumption after appropriate treatment and human consumption of fish, crustacea and molluscs.

Existing threats and sources of pollution to the Campaspe River are linked to land use and associated management practices. Key land uses in the catchment include agricultural land, rural residential, urban areas, industrial zones (in particular around Kyneton) and natural / forested lands. Agricultural and urban runoff, along with direct stock access to waterways are noted threats to water quality in the Campaspe River.

The ecological condition of the Campaspe River within the vicinity of the Kyneton WRP discharge point has been monitored over multiple years. A range of results are available for macroinvertebrate monitoring. An overview of the results is that the Campaspe River has macroinvertebrate indices that indicate that stream health is impacted at all sites (both upstream and downstream of the WRP discharge point). In the AQUEST monitoring program, it was noted that the site directly below the WRP discharge point showed more degradation than other sites upstream. This site is downstream of the discharge point and located within known mixing zones of the discharge. Nearby tributaries of Post Office Creek and Snipes Creek show the most degradation, likely to be caused by urban, industrial and agricultural runoff.

A platypus monitoring program was undertaken by Cesar Australia and results showed there is likely to be only a sparse population present in the upper Campaspe River upstream and downstream of the Kyneton WRP discharge point. There was no evidence of negative impacts from the Kyneton WRP discharges on platypus populations, the low numbers are likely a reflection of overall poor habitat condition of the Campaspe River upstream and downstream of the discharge point, and due to the heavily modified catchment areas and seasonal cease-to-flow events.

Streamflow data for the Campaspe River was available for this project via a recently installed gauging station located at Kyneton (much closer to the discharge point than the Redesdale gauge station which was used in previous assessments). A rainfall runoff model was developed for the gauge, allowing streamflow to be extended. A step change in annual streamflow was noted before and after 1997, with considerably lower median annual rainfall after the step change. This post 1997 period was used to represent streamflow at Kyneton. The modelled streamflow was use within the mixing zone assessment and the discharge risk assessment.

Discharge from the Kyneton WRP to the Campaspe River occurred on 52% of days over the three-year assessment period of July 2017 – June 2020, and totalled 1,456 ML (an average of 485 ML/year). On days of discharge, the median value was 2.5 ML/day, and the monthly median was 45.3 ML/month. Streamflow over the same three-year period was 63,890 ML at Redesdale (at which the Kyneton WRP discharge was 2.3% of the total streamflow volume). For the Kyneton streamflow gauge, streamflow over the same three-year period (using modelled and gauged data, where available) was estimated to be 31,600 ML (Kyneton WRP discharge was 4.6% of the streamflow).

Water quality data was available for the Campaspe River upstream and downstream of the discharge point, and for the WRP discharge. The Campaspe River upstream of the discharge point showed that the background water quality was compliant with some, but not all, parameters when compared to guideline values from ERS (2021) and ANZG (2018). Total nitrogen and total phosphorus exceeded ERS (2021) guidelines and *E. coli* data showed that the Campaspe River upstream of the discharge point exceeded the guideline for primary contact recreation (i.e. swimming). Water quality data for the Kyneton WRP discharge (combined BNR and Lagoon 4) made available for this project, showed compliance with all relevant EPA licence limits (although this is not a formal assessment of compliance as per EPA Annual Performance Statements). Results also show that the BNR discharge is of considerably better quality than combined BNR / Lagoon 4 discharge. Water quality data downstream of the discharge point showed exceedances for total N and total P and *E. coli*, during both discharge and non-discharge periods. The effect of WRP discharge on nutrient concentrations in the Campaspe River is consistently noted, however BNR/Lagoon 4 combined treated wastewater concentrations were considerably higher than concentrations in the Campaspe River upstream of the discharge point for these parameters. There is no obvious or consistent effect of the WRP discharge to the Campaspe River with regards to *E. coli* concentrations – the discharge is typically of better quality than the river, particularly after February 2021 when a new UV unit was installed. It was noted that some metals data in the WRP discharge exceeded ANZG (2018) guidelines, including aluminium, copper, silver and zinc. For silver, this was likely to be a 'detection limit' issue in which the laboratory reporting limit is higher than the ANZG (2018) guideline. For aluminium, copper and zinc whilst the WRP discharge was higher than ANZG (2018) for some data, it was noted that these parameters had some data elevated above the guidelines for Redesdale (downstream of the WRP discharge point), even during non-discharge periods, and upstream of the discharge point in the case of aluminium.

Mixing zones were noted for total N and total P (and not consistently, or to any great extent, for any of the other assessed parameters). The 'median conditions' assessment found that mixing zones for total N and total P could go as far, and potentially further, than the final sampling point downstream (CD8a, at 11.5 km downstream of the discharge point). Mixing zones were quantified using the daily risk tool (a more accurate method for determining mixing zones) and found the median mixing zones to be around 3.31 km for total N and 5.29 km for total P. It should be noted mixing zones are only present on days of discharge (approximately 52% of days during 2017 – 2020).

Nutrient decay rates for total N and total P were determined using available water quality data downstream of the discharge point, and the updated streamflow data using the Kyneton gauging station. Decay rates are determined to help assess how quickly the concentration of nutrients decrease in the waterway after discharge via assimilation, dilution and dispersion, and this in turn can be used to determine mixing zones. A median decay rate of -2.354 day^{-1} for total N and -2.571 day^{-1} was determined for the Campaspe River downstream of the discharge point.

A risk assessment of the Kyneton WRP discharge to the identified environmental values of the Campaspe River was undertaken using the EPA Framework (for both high concentration but low frequency risks and low-mid-range concentrations but more frequent risks) and also by using a 'Daily Risk Tool'.

With regards to the assessment of high concentration but low frequency risks, an investigation of maximum recorded concentrations within the BNR discharge was undertaken for ammonia as N (ammonia) and biological oxygen demand (BOD) for the discharge scenario at a ratio of 1:2, using the risk methodology set out in EPA guideline 1287. An assessment of the 'pre-control risk' (inherent risk) for ammonia and BOD resulted in a 'medium' risk being determined for these parameters to the Campaspe River at the discharge point. However, once controls are put in place for ammonia ('interlock' devices that divert out-of-specification discharge water to storage rather than the Campaspe River), the 'post controlled risk' (residual risk) for ammonia shows considerably lower concentrations for ammonia, and then once discharged to the Campaspe River, it results in as 'low' risk to the receiving environment (reduced down from a 'medium' risk in the pre controlled risk assessment).

With respect to BOD, whilst an interlock arrangement is not feasible, using the dissolved oxygen sensor in the BNR plant, high risk releases with respect to BOD could be identified and appropriately managed.

For the low-mid concentration but higher frequency risks, a method following the EPA framework and guided by a threat/consequence process derived from the 'AVIRA' publication for assessing risks to waterways (Riverness (2013)) was adopted. With regards to risks to aquatic ecology, most parameters showed low risks associated with them for both summer and winter discharges. Exceptions were total N and total P which had high risks to the Campaspe River, and this is in the form of eutrophication of the waterway (i.e. a secondary effect rather than direct toxicity). These elevated nutrient concentrations in the Campaspe River as a result of the WRP are contained within a mixing zone (i.e. a distance downstream at which the concentrations return to upstream or ERS guideline limits). Risks from ammonia in the discharge to aquatic ecology of the Campaspe River are calculated as being low, mainly due to low frequency of the BNR discharge (prior to mixing with the river) exceeding guidelines (one sample in 327 during 2015-2021 was above USEPA (2013) guidelines, which takes into account the effects of pH and temperature on the toxicity level). After mixing with the Campaspe River concentrations of ammonia and therefore the risks associated with it reduce even further.

For primary and secondary contact, the risk assessment showed that there were low risks from the WRP discharge associated with *E. coli* in the Campaspe River, given that the concentrations of the discharge (post March 2021) are lower than the river.

For irrigation, there were some medium risks associated with total P, however, the consequences of this are considered to be low – the elevated total P would be confined to the mixing zone only. A low risk in with *E. coli* was identified for Class B recycled water (i.e. median < 100 orgs/mL), however, the discharge is currently of better quality than Class B recycled water and meets Class A recycled water criterion for *E. coli* (< 10 orgs/mL).

For stock watering, results for all parameters showed that there was low risk, including *E. coli*.

A 'Daily Risk Tool' was used to assess the current baseline (BNR and Lagoon 4 combined discharge from July 2017 – June 2020) and for other scenarios that included 2022 and predicted 2036 inflows into the BNR plant.

The 2022 and 2036 scenarios used a streamflow-to-discharge ratios of 1:2 (also termed as a 'proportion' of 66.7% – i.e. 2 ML of discharge, 1 ML of streamflow (upstream) so the proportion of discharge downstream is 1:2 (66.7%)). Streamflow was modelled (or gauged, where available) at the discharge point at Wards Lane using data from the Kyneton gauge.

A daily risk assessment was undertaken for the 2022 and 2036 scenarios. The risk assessment included consideration of the water quality impact of the Kyneton WRP discharge on the values of the Campaspe River (aquatic ecology, primary and secondary contact, irrigation and stock watering). For each the 2022 and 2036 scenarios, only BNR discharges were considered (no Lagoon 4 discharges). The discharge to the Campaspe River was that determined from the water balance modelling component of this project.

ERS (2021) guidelines, including guidelines for nutrients and *E. coli* for primary and secondary contact, stock watering and irrigation were used (see section 4.1). The BNR discharge quality used within the 2022 and 2036 scenarios were characterised by 2015-2020 data (except for *E. coli* in which post March 2021 data was used), and the Campaspe River water quality was characterised by 2007-2020 data.

The risk scores, nutrient mixing zones and nutrient and pathogen loads for each of the scenarios was determined and compared to the baseline scenario. Key results of the risk assessment are summarised below.

– The baseline scenario had a discharge of 1,456 ML to the Campaspe River over July 2017 to June 2020 (average 485 ML/year), with a total risk score of 12,141 (or 8.34 ML^{-1}). A median mixing zone of 3.31 km for total N, and 5.29 km for total P, was noted, as was an average annual load of 5,056 kg/year for total N and 2,040 kg/year for total P.
– Highest risks were associated with total N and total P to aquatic ecology values in the receiving waters (in the form of eutrophication of the waterway). Total N and total P risks were also associated with irrigation (bio-clogging of irrigation equipment), although the consequences of these risks are deemed low given the asset life of most irrigation equipment.
– Heavy metals may be a risk (aluminium, copper, silver and zinc) during some discharge scenarios; however, not a lot of data is available for the Campaspe River near the WRP discharge point which would help put any risks into context with background conditions. It is noted that the Campaspe River has elevated concentrations of these identified metals downstream of the discharge point, even on non-discharge days. As such, the risks associated with these metals within the BNR discharge on the Campaspe River are considered to be low. This can be confirmed with additional data for heavy metals, particularly dissolved copper and zinc.
– An assessment of *E. coli* data available for the Campaspe River upstream and downstream of the discharge point, showed that all sites are in Category D (using ERS (2021) methodology) and, therefore, suitable for secondary recreation only (not primary contact, such as swimming). The BNR discharge is typically of

considerably better quality than the Campaspe River with regards to *E. coli* concentrations, and post February 2021 the discharge would be considered Category A (suitable for primary recreation).

– Risk results show that for discharge of the same quality, the higher the proportion of discharge in the streamflow, the higher the total risk, mixing zones and loads to the waterway. Predicted discharges in 2036 provide higher discharge volumes and, therefore, higher total risk scores, mixing zone distances and loads compared to the 2022 scenario.
– Mixing zones for the 2022 scenarios for total N were 0.88 km (median value) and 4.57 km (90th percentile), and for the 2036 scenario for total N 1.28 km (median value) 6.07 km (90th percentile), compared to a baseline of 3.31 km (median) and 13.21 km (90th percentile). That is, there were decreases in the mixing zone in comparison to the current baseline, for the 2022 and 2036 scenarios.
– Mixing zones for the 2022 scenario for total P ranged from 0.28 km (median value) and 1.8 km (90th percentile), and for the 2036 scenario for total P 0.44 km (median) and 2.45 km (90th percentile) compared to the baseline of 5.29 km (median) and 30.6 km (90th percentile). As for total N, there were decreases in mixing zone distances for the 2022 and 2036 scenarios when compared to the baseline.
– There is a considerable reduction in risk scores, mixing zone distances and loads of total N and total P to the river for the 2022 and 2036 scenarios, when compared to the baseline scenario. This is due mainly to the improved quality of BNR discharge compared to the combined BNR/Lagoon 4 discharge that is used in the current baseline scenario.
– Under both the 2022 and 2036 scenarios, there was compliance with all current EPA licensed parameters. The BNR discharge is compliant with the current EPA licence conditions, so any discharge scenario with just BNR discharge will remain compliant, as long as the plant continues to perform as it has during the 2017-2020 period.
– A pathogen risk assessment, using a QMRA methodology, showed potential risks from *Cryptosporidium*, Rotavirus and *Campylobacter* to identified beneficial uses downstream. However, confidence in this style of risk assessment is relatively low given the lack of measured data available for log reduction values for pathogens through the BNR plant and that no data was available for the Campaspe River upstream of the discharge point to validate existing risks to the identified beneficial uses of the waterway.
– Under normal operating conditions, the upgraded UV unit at the Kyneton WRP is likely to result in significant inactivation of a range of human infectious viruses and other pathogens. It was estimated that the pathogen risks from primary contact recreation are being managed to an acceptable level, due to the small exposure volumes associated with recreation, and because discharges to the river do not normally occur at times when recreation is likely to also be occurring. Signage downstream of the discharge to warn any swimmers of potential risks is also an appropriate risk reduction method.
– An ‘infected traveller’ scenario was investigated to assist in answering questions about the risk of helminths to the Campaspe River (and then cattle drinking that water), should an infected person arrive in Kyneton. Key questions in the scenario included: what is the number of ova in the influent into Kyneton WRP every day whilst the infected traveller is in town, what is Kyneton WRP’s current ability to remove the helminth ova and what is the expected concentration in the discharge to the Campaspe River, what concentration in the discharge to the creek would result in an unacceptable risk to cattle downstream and what is the number of concurrent infected travellers arriving and staying in Kyneton that would result in the risk to cattle downstream of the discharge point becoming unacceptable?
– Results from the scenario include that the risk to cattle is the highest during periods when the WRP inflow is at its lowest, as this results in the least dilution of any (rare) shedding cases in the sewerage catchment population. The conservative estimated waterway concentration of helminth eggs (HE) during worst-case conditions (2022 inflow, with the lowest treatment scenario for helminths with 1.5 LRV) was 0.0114 HE/L, resulting from one infected person in the sewerage catchment, which is below the WHO guideline of 0.1 HE/L, and a more conservative threshold of 0.0167 HE/L. The risk threshold of 0.0167 HE/L will be exceeded when two, or more than two, people in the township are infected, under the 2022 scenario with 1.5 LRV at the WRP. However, this assessment is conservative: risks were determined as if the Kyneton WRP discharge would occur every day (this would not occur in reality) and the higher end of pathogen concentrations (i.e. 95th percentile values) were typically used for the assessment, and whilst this is accepted QMRA methodology, it may be considered overly conservative.

- An assessment of nutrient loads discharged to the Campaspe River for each scenario was undertaken and compared to loads from the baseline scenario (i.e. the difference being the 'incremental' load). For the 2022 and 2036 scenarios, loads for total N and total P were lower than the baseline load. As such, neither the 2022 or 2036 scenarios showed any incremental increase in nutrient load.
- Pathogen loads within the discharge for the 2022 and 2036 scenarios were calculated using concentration data or estimated values from literature, and compared to pathogen loads within the baseline scenario. There were no increases in loads for *Campylobacter*, Rotavirus and *Cryptosporidium* for the 2022 and 2036 scenarios i.e. there were no incremental increases in pathogen load.
- Total nutrient and pathogen loads would be offset by the existing land management sites A-D (568 hectares of grazing land, with cattle exclusion and riparian revegetation), for both the 2022 and 2036 scenarios.
- Assumptions made in the offset calculations (e.g. nutrient generation, and efficacy of riparian zones for nutrient capture), can be tested once field monitoring data is analysed over a number of years.
- The ANZG (2018) Water Quality Guidelines recommend the use of additional indicators to give greater weight (or certainty) to assessment conclusions, rather than only relying on water quality results. Additional monitoring for indicators such as macroinvertebrates, fish and other aquatic species in the Campaspe River (as per Aquest) continues to provide helpful additional lines of evidence of any effects of future discharge.

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Appendix A

Additional information on modelled streamflow data for Kyneton

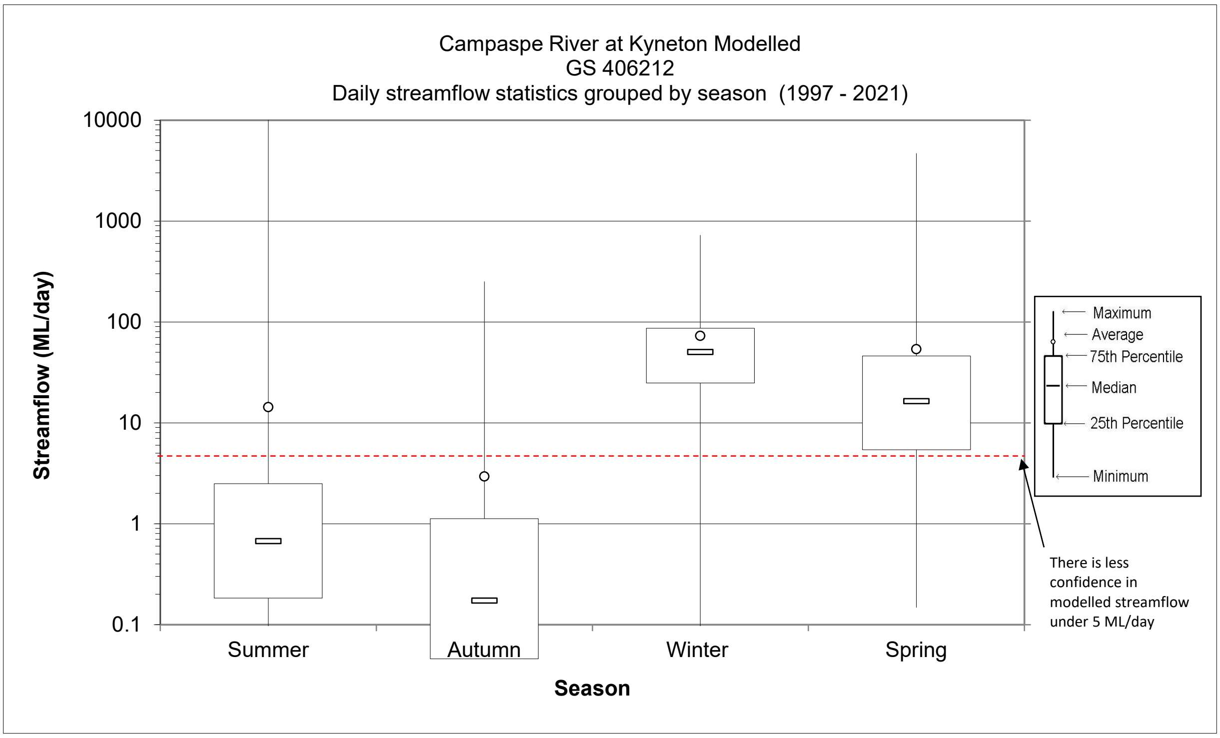


Figure A.1 ***Daily streamflow statistics grouped by season for the Campaspe River at Kyneton (1997 – 2021)***

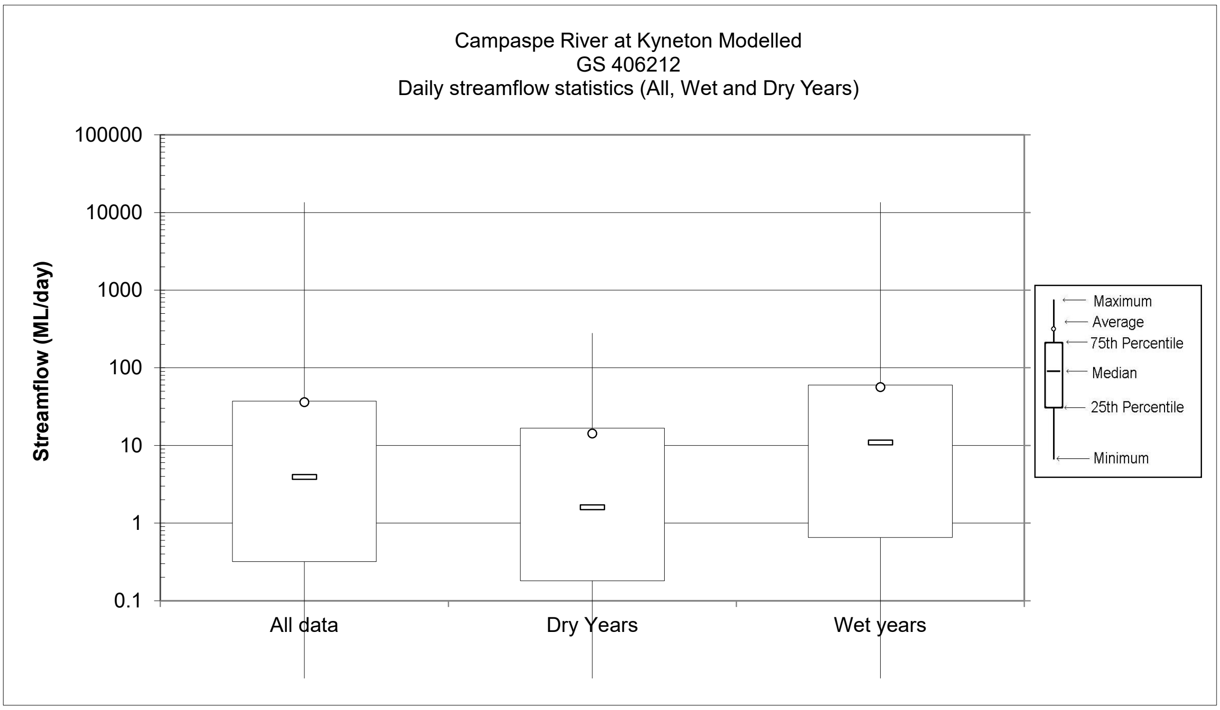


Figure A.2 ***Daily streamflow statistics grouped by all, dry and wet years for the Campaspe River at Kyneton (1997 – 2021)***

Appendix B

Additional Pathogen Removal Literature

Indicative log reductions values of enteric pathogens and indicator organisms (Source: Table 3.4 NRMMC et al., 2006) are presented in Table B1.

Table B.1 Indicative Log Reductions Values (LRV) of enteric pathogens and indicator organisms (Source: Table 3.4 NRMMC et al., 2006)

Treatment	*E. coli*	Bacteria (incl. *Campylobacter*)	Viruses (incl. adenoviruses, rotaviruses and enteroviruses)	Phage	*Giardia*	*Cryptosporidium*	Helminths	*C. perfringens*
Primary treatment	0-0.5	0-0.5	0-0.1	N/A	0.5-1.0	0-0.5	0-2.0	0-0.5
Secondary treatment	1.0-3.0	1.0-3.0	0.5-2.0	0.5-2.5	0.5-1.5	0.5-1.0	0-2.0	0.5-1.0
Dual media filtration with coagulation	0-1.0	0-1.0	0.5-3.0	1.0-4.0	1.0-3.0	1.5-2.5	2.0-3.0	0-1.0
Membrane filtration	3.5->6.0	3.5->6.0	2.5->6.0	3->6.0	>6.0	>6.0	>6.0	>6.0
Reverse osmosis	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0
Lagoon storage	1.0-5.0	1.0-5.0	1.0-4.0	1.0-4.0	3.0-4.0	1.0-3.5	1.5-3.0	N/A
Chlorination	2.0-6.0	2.0-6.0	1.0-3.0	0-2.5	0.5-1.5	0-0.5	0-1.0	1.0-2.0
Ozonation	2.0-6.0	2.0-6.0	3.0-6.0	2.0-6.0	N/A	N/A	N/A	0-0.5
UV light	2.0->4.0	2.0->4.0	>1.0 adenovirus >3.0 enterovirus and Hepatitis A	3.0-6.0	>3.0	>3.0	N/A	N/A
Wetlands – surface flow	1.5-2.5	1.0	N/A	1.5-2.0	0.5-1.5	0.5-1.0	0-2.0	1.5
Wetlands – subsurface flow	0.5-3.0	1.0-3.0	N/A	1.5-2.0	1.5-2.0	0.5-1.0	N/A	1.0-3.0

N/A = not available, UV = ultraviolet. Reductions depend on specific features of the process, including retention times, pore size, filter depths, disinfectant.

A range of other references for pathogen removal are presented below for various treatment processes present in the Kyneton WRP.

Helminth reduction through activated sludge plants

Helminth egg removal from sewage effluent, via activated sludge plants, is examined by Stevens et al. (2017), based on available literature values. Nine literature LRVs were regarded as suitable, and these ranged between <0.2 and 2.6 for helminth removal. A significant relationship was found between the Hydraulic Retention Time (HRT) of the plant and the LRVs of helminths calculated from treatment; however, the data was noted as limited and demonstrating a high degree of variability. The removal of suspended solids through activated sludge plants was expected to be associated with the concomitant removal of helminth eggs, citing the stickiness of the eggs and their frequent attachment to suspended solids. The WHO (2006) guidelines indicate that activated sludge and secondary sedimentation can achieve a 1 to <2 LRV for helminths.

Helminth inactivation with UV

Brownell and Nelson (2006) examined the inactivation of the helminth Ascaris using UV treatment, and estimated the following mean log inactivation for different UV fluences, this has been reproduced in Table B2.

Table B.2 LRVs from experimental Ascaris treatment with UV (from Brownell and Nelson, 2006)

UV fluence (J/m^2)	Log inactivation (mean)	95% confidence interval
500	0.44	0.20
1,000	1.00	0.06
2,000	1.56	0.11
3,000	1.91	0.28
4,000	2.23	0.43
5,000	>2.53	

Simhon et al (2019) undertook an investigation to determine the effectiveness of ultraviolet light (30-40 mJ/cm^2) and chlorination (3.1 mg/L – 7.3 mg/L with contact time between 10 – 15 minutes) has on the removal of viruses (enteroviruses and noroviruses), coliphage and *E. coli* in wastewater in several treatment plants in Ontario, Canada. They reported modest LR values for viruses (0.3 – 1.3 for enterovirus and 0.5-0.8 for norovirus), and higher LR values for coliphage (0.8 – 3) and E. coli (2.5). They noted that coliphage appear to be a good indicator of viruses and are far easier to enumerate in a wastewater sample than viruses. Sand filtering was noted to be much more effective at virus removal than chlorination or UV.

Appendix C

Further information on virus removal using the Quantitative Microbial Risk Assessment (QMRA) method

<u>Note the information below has essentially been provided by David Sheehan at Coliban Water, with some editing and assistance from GHD.</u>

Background

Additional information is provided in this appendix has been prepared in response to a meeting between Coliban Water, EPA and GHD, that was held on Monday 7 March 2022. The key topic of discussion is with respect to likely virus log removal values (LRVs) for discharges from the Kyneton Water Reclamation Plant (WRP) to the Campaspe River, and the impact that the assessed LRVs may have on downstream beneficial uses. A key area for discussion is that microbial risk to downstream users should be equivalent to 1 x 10^{-6} DALY per person per year (i.e. 1µDALY pppy).

Acceptable microbial risk

The World Health Organisation (WHO) has set the level of acceptable microbial risk associated with the consumption of drinking water at 1µDALY pppy. This level of risk also appears in guideline documents for potable reuse, which makes sense as the exposure pathway (i.e. exposure through the consumption of treated water) is the same.

The usefulness of the 1µDALY pppy is that, by defining the level of acceptable risk, it can be used to define treatment requirements to achieve the desired outcome. For example, WHO's 2017 document Potable reuse: Guidance for producing safe drinking-water specifies the follow log reduction values for potable reuse.

Table 5.1 Performance targets calculated from default concentrations of pathogens

	Pathogens		
	Enteric bacteria (*Campylobacter*)	Enteric viruses (noroviruses)	Enteric protozoa (*Cryptosporidium*)
Default concentration (per litre) in source wastewater	7000	20 000	2700
Log reductions[a]	8.5	9.5	8.5

[a] Rounded to nearest 0.5 log.

The first thing that needs to be noted is units attached to the 1µDALY – per person per year; that is, the 1µDALY is an annualised risk based on a yearly, or annual, exposure scenario.

The second thing that needs to be noted is the annual exposure scenario. In the Australian context, when calculating the DALYs associated with a particular pathogen of interest for the consumption of water used as drinking water, the exposure scenario is the consumption of 2 litres of treated water per day; that gives an annual exposure figure of 730 litres per year.

If a microbial risk level of 1µDALY pppy is going to be applied to recreational activity downstream of the discharge point, then the annual exposure scenario needs to be determined. A number of literature estimates of the exposure volume resulting from primary contact recreation have been examined to form this scenario.

- NHMRC's 2008 Guidelines for Managing Risks in Recreational Waters suggests an exposure volume of 200 mL per day from recreational contact with water, based on the assumption that recreational water consumption is equivalent to 10% of drinking water consumption, which is assumed to be 2 L per day.
- WHO's 2021 Guidelines on Recreational Water Quality - Volume 1 - Coastal and Fresh Waters suggests an exposure volume during primary contact recreation is 30 mL.
- Suppes et al (2014) examined pathogen exposure through primary contact recreation in swimming pools. These authors estimated an ingested volume of 100 mL per exposure event, as a conservative estimate. The cited pool water ingestion rates ranged from 0.9 to 105.5 mL per hour of recreation, with 25 of 38 swimmers ingesting some pool water.

- In 2013, RMIT and Monash University, on behalf of Water Quality Research Australia (now WaterRA), undertook a study to determine the volume of water ingested during swimming, using the tracer cyanuric acid (https://www.waterra.com.au/project-details/39). In this study, it was estimated that somewhere between 0.08 and 0.20 mL of water was ingested during a typical period of swimming, based on experimental data from three test subjects in their 40's. It could be assumed that consumption rates would be substantially greater amongst some recreators, particularly children.
- EPA Victoria (2021) published a study examining the recreational water quality risks in Port Phillip Bay. The exposure assessment included an estimation of the volumes of water ingested during primary and secondary contact recreation, using distributions fitted to the datasets from two previous cited studies of water ingestion during recreation. The 95th percentile ingestion volumes from these datasets were 80.6 mL for primary contact recreation, and 17.1 mL for secondary contact (per event).

Based on the literature estimates above, someone undertakes primary contact recreation 50 times a year, depending on the estimate chosen, could consume somewhere between 6 litres and 6 mL of river water over the course of the year, which is well below the 730 litres per year assumed for potable reuse. Using the estimate of 50 exposure events per year as an upper bound, and the 95th percentile estimates of volume ingested per event from EPA (2021) of 80.6 mL for primary contact and 17.1 mL for secondary contact, the estimated exposure per annum can be calculated as 4.03 L/annum for primary contact, and 0.855 L/annum for secondary contact.

Using the inputs defined above (WHO 2017, Table 5.1 performance targets for water treatment), the consumption of 1 litre per year would require log(($10^{8.5}$)/730) LRVs, or 5.6 LRVs, for bacteria and protozoa; and log(($10^{9.5}$)/730) LRVS, or 6.6 LRVs, for viruses. The LRVs required for various annual consumption volumes, including the primary and secondary contact recreation estimates defined above, are summarised in Table C1.

Table C.1 LRVs required under various annual consumption estimates

Annual Consumption	Bacteria	Viruses	Protozoa
0.006 L/annum	3.4 LRV	4.4 LRV	3.4 LRV
0.855 L/annum	5.6 LRV	6.6 LRV	5.6 LRV
1 L/annum	5.6 LRV	6.6 LRV	5.6 LRV
4.03 L/annum	6.2 LRV	7.2 LRV	6.2 LRV
6 L/annum	6.4 LRV	7.4 LRV	6.4 LRV
730 L/annum	8.5 LRV	9.5 LRV	8.5 LRV

The challenge with working out exposures and treatment removal efficiencies for human infectious viruses is that there is very limited information on this class of pathogens.

The KWR publication *Elimination of micro-organisms by water treatment processes – 3rd edition (2010)* provides LRVs for a range of culturable viruses, which are reproduced in Table C2 below. This information also appears in Hijnen et al (2006) Inactivation credit of UV radiation for viruses, bacteria and protozoan (oo)cysts in water: A review can be found in (doi:10.1016/j.watres.2005.10.030).

The upgraded UV system at the Kyneton WRP is rated at 35 mJ/cm^2. The shaded cells in Table C2 are below 35 mJ/cm^2 value.

Table C.2 Virus LRVs for UV treatment (based on Hijnen et al (2006))

Virus	UV dose in mJ/cm^2 required to achieve listed LRVs			
	1	**2**	**3**	**4**
Adenovirus type 40	56	111	167	-
Adenovirus type 2, 15,40,41	42	83	125	-
Adenovirus (not type 40)	25	50	-	-

Virus	UV dose in mJ/cm² required to achieve listed LRVs			
Calicivirus canine^	10	21	31	41
Rotavirus SA-11	10	20	29	39
Calicivirus feline^	9	19	28	38
Coxsackie virus B5	8	17	25	34
Poliovirus Type 2	7	15	22	30
Hepatitis A	6	11	17	22
Calicivirus bovine^	5	11	16	21

^ Norovirus is the reference pathogen, but it is not easy to culture, so various caliciviruses are used instead.

Except for Adenoviruses, most other classes of viruses will be inactivated to a satisfactory degree by the upgraded UV system, based on these published values.

Recreational guidelines are not generally based on quantified risks (DALYs) from viral pathogen hazards. This can be attributed to the uncertainties associated with the analytical measurement of reference viruses, as well as those associated with some of the assessment inputs (such as other pathogen inputs, for example, other swimmers and/or other sources of pathogens upstream and downstream of a discharge point). However, it is reasonable to prepare a QMRA around *Cryptosporidium*, given that there is a detailed evidence base for this particular pathogen. This is not to dismiss the significance of virus hazards, which can of course be greater than those presented by protozoa, but is to instead provide some context as to what the quantified risk presented by recreational waters elsewhere can be.

If it is assumed that a hypothetical recreational water contains 0.1 *Cryptosporidium* oocysts per litre (a reasonable estimate based on literature values), then the associated risk for a single swimming event could be calculated as 1.92×10^{-6} DALYs/event, as detailed in Table C3 below.

Table C.3 Cryptosporidium QMRA for bathing in freshwater

Line	Description	Calculation	Cryptosporidium	Comment
i	Pathogen concentration recreational water (org/L)		0.1	Assumed concentration
j	Bather exposure per event (L)		0.0806	EPA Victoria (2021)
k	Dose per event (organisms)	i*j	0.01	
l	Number of events		1	Single swimming event
m	Probability of infection per organism		0.2	AGWR (2020)
n	Proportion of infection leading to illness		0.7	AGWR (2020)
o	DALYs per case		0.0017	AGWR (2020)
p	Proportion of population susceptible to illness		1	WHO (2011)
q	Recreational water DALYs per person per event	k*l*m*n*o*p	1.92E-06	

If this is adjusted to a risk per annum, with the assumption of 50 swimming events, that would translate to 9.59×10^{-5} DALYs/annum.

Given that there are likely to be numerous other sources of human infectious *Cryptosporidium* in the catchment of the Campaspe River, and that it is not known what *Cryptosporidium* and other pathogen risks are presented from these other sources, the relevance of this DALY figure to discharges from the Kyneton WRP is uncertain.

Lastly, as was mentioned at the 7 March 2022 meeting, discharges from the Kyneton WRP to the Campaspe River typically occur in the colder months of the year when primary contact recreation is unlikely to occur, lessening the exposure risk.

As a point of comparison, Table 25 below, from EPA Publication 1911.2, provides exposure volumes for various uses, which puts the primary contact recreation exposure values into context.

Table 25 – Recycled water intended uses and exposure grouped by major exposure categories

Use	L/event	Events/year	L/year	L/day	mL/day
Drinking water	2	365	730	2	2000
Commercial lettuce	0.005	70	0.35	9.59×10^{-4}	0.96
Commercial other	0.001	140	0.14	3.84×10^{-4}	0.38
Total commercial			0.49	1.34×10^{-3}	1.34
Garden sprays	0.0001	90	0.009	2.47×10^{-5}	0.02
Garden ingest	0.001	90	0.09	2.47×10^{-4}	0.25
Garden accident	0.1	1	0.1	2.74×10^{-4}	0.27
Home lettuce	0.005	7	0.035	9.59×10^{-5}	0.1
Home other	0.001	50	0.05	1.37×10^{-4}	0.14
Total garden			0.284	7.78×10^{-4}	0.78
Toilet flushing	0.00001	1100	0.011	3.01×10^{-5}	0.03
Washing machine	0.00001	100	0.001	2.74×10^{-6}	0
Cross connection	1	0.365	0.365	1.00×10^{-3}	1
Total internal			0.377	1.03×10^{-3}	1.03
Total residential (garden + internal)			0.661	1.81×10^{-3}	1.81
Municipal irrigation	0.001	50	0.05	1.37×10^{-4}	0.14
Total residential + municipal			0.711	1.95×10^{-3}	1.95
Fire fighting	0.02	50	1	2.74×10^{-3}	2.74

Source: Derived from Table 3.7 of AGWR, Phase 1, page 100; NRMMC et al. 2006).

It should be noted that given the discharge occurs into an untreated river, at a proposed maximum dilution ratio of 66.7%, where there are a range microbial of inputs, both above and below the discharge point, Coliban Water cannot warrant the microbial quality of the instream water below the discharge point.

QMRA

A QMRA using standard literature inputs and the estimates of the WRP pathogen removal efficacy (Table 54, Table 55) can be performed on the Kyneton WRP discharge. The approach taken in Table 55 was to estimate pathogen LRVs based on efficacy described in a number of sources, to arrive at “Minimum LRV” and “Median LRV” estimates for each of the reference pathogens.

QMRAs have been performed, examining primary and secondary contact recreational risks from pathogens, with assumed WRP removal with “Minimum LRV” and “Median LRV” estimates. These QMRAs are presented from Table C4 to Tabe C7. The outputs of the QMRAs include the annual risk from 50 exposure events, expressed as DALYs per person per annum. These estimates include only the risks from WRP discharge. The risks from other contaminant sources are not quantified, and the discharge may have an insignificant or beneficial effect if the risks from other sources are particularly elevated.

Table C.4 Primary recreation QMRA, using "Minimum LRVs" estimate

Line	Description	Calculation	Cryptosporidium	Norovirus	Campylobacter	Comment
a	Pathogen concentration sewage (org/L)		2000	8000	7000	AGWR (2020)
b	Pathogen LRV from RWP (log)		0.5	1	3	Table 48, "Minimum LRVs"
c	Pathogen concentration discharge (org/L)	a/10^b	632	800	7	
d	Discharge proportion of streamflow (%)		66.7	66.7	66.7	Table 39, 1:2 Streamflow:Discharge
e	Pathogen concentration creek (org/L)	c*d/100	422	534	5	
f	Bather exposure per event (L)		0.0806	0.0806	0.0806	EPA Victoria, 2021
g	Dose per event (organisms)	e*f	34	43	0.38	
h	Number of events per year		50	50	50	EPA Victoria, 2021
i	Annual exposure (organisms/year)	g*h	1700.046795	2150.408	18.81607	
j	Probability of infection per organism		0.2	0.69	0.019	AGWR (2020)
k	Proportion of infection leading to illness		0.7	0.7	0.3	AGWR (2020)
l	DALYs per case		0.0017	0.0005	0.024	AGWR (2020)
m	Proportion of population susceptible to illness		1	1	1	
n	Recreational water DALYs per person per annum	i*j*k*l*m	4.05E-01	5.19E-01	2.57E-03	

Table C.5 Primary recreation QMRA, using "Median LRVs" estimate

Line	Description	Calculation	Cryptosporidium	Norovirus	Campylobacter	Comment
a	Pathogen concentration sewage (org/L)		2000	8000	7000	AGWR (2020)
b	Pathogen LRV from RWP (log)		3	2.3	6	Table 48, "Median LRVs"
c	Pathogen concentration discharge (org/L)	a/10^b	2	40	0	
d	Discharge proportion of streamflow (%)		66.7	66.7	66.7	Table 39, 1:2 Streamflow:Discharge
e	Pathogen concentration creek (org/L)	c*d/100	1	27	0	
f	Bather exposure per event (L)		0.0806	0.0806	0.0806	EPA Victoria, 2021
g	Dose per event (organisms)	e*f	0	2	0.00	
h	Number of events per year		50	50	50	EPA Victoria, 2021
i	Annual exposure (organisms/year)	g*h	5.37602	107.7757	0.01881607	
j	Probability of infection per organism		0.2	0.69	0.019	AGWR (2020)
k	Proportion of infection leading to illness		0.7	0.7	0.3	AGWR (2020)
l	DALYs per case		0.0017	0.0005	0.024	AGWR (2020)
m	Proportion of population susceptible to illness		1	1	1	
n	Recreational water DALYs per person per annum	i*j*k*l*m	1.28E-03	2.60E-02	2.57E-06	

Table C.6 Secondary recreation QMRA, using "Minimum LRVs" estimate

Line	Description	Calculation	Cryptosporidium	Norovirus	Campylobacter	Comment
a	Pathogen concentration sewage (org/L)		2000	8000	7000	AGWR (2020)
b	Pathogen LRV from RWP (log)		0.5	1	3	Table 48, "Minimum LRVs"
c	Pathogen concentration discharge (org/L)	a/10^b	632	800	7	
d	Discharge proportion of streamflow (%)		66.7	66.7	66.7	Table 39, 1:2 Streamflow:Discharge
e	Pathogen concentration creek (org/L)	c*d/100	422	534	5	
f	Bather exposure per event (L)		0.0171	0.0171	0.0171	EPA Victoria, 2021
g	Dose per event (organisms)	e*f	7	9	0.08	
h	Number of events per year		50	50	50	EPA Victoria, 2021
i	Annual exposure (organisms/year)	g*h	360.6799031	456.228	3.991995	
j	Probability of infection per organism		0.2	0.69	0.019	AGWR (2020)
k	Proportion of infection leading to illness		0.7	0.7	0.3	AGWR (2020)
l	DALYs per case		0.0017	0.0005	0.024	AGWR (2020)
m	Proportion of population susceptible to illness		1	1	1	
n	Recreational water DALYs per person per annum	i*j*k*l*m	8.58E-02	1.10E-01	5.46E-04	

Table C.7 Secondary recreation QMRA, using "Median LRVs" estimate

Line	Description	Calculation	Cryptosporidium	Norovirus	Campylobacter	Comment
a	Pathogen concentration sewage (org/L)		2000	8000	7000	AGWR (2020)
b	Pathogen LRV from RWP (log)		3	2.3	6	Table 48, "Median LRVs"
c	Pathogen concentration discharge (org/L)	a/10^b	2	40	0	
d	Discharge proportion of streamflow (%)		66.7	66.7	66.7	Table 39, 1:2 Streamflow:Discharge
e	Pathogen concentration creek (org/L)	c*d/100	1	27	0	
f	Bather exposure per event (L)		0.0171	0.0171	0.0171	EPA Victoria, 2021
g	Dose per event (organisms)	e*f	0	0	0.00	
h	Number of events per year		50	50	50	EPA Victoria, 2021
i	Annual exposure (organisms/year)	g*h	1.14057	22.86556	0.003991995	
j	Probability of infection per organism		0.2	0.69	0.019	AGWR (2020)
k	Proportion of infection leading to illness		0.7	0.7	0.3	AGWR (2020)
l	DALYs per case		0.0017	0.0005	0.024	AGWR (2020)
m	Proportion of population susceptible to illness		1	1	1	
n	Recreational water DALYs per person per annum	i*j*k*l*m	2.71E-04	5.52E-03	5.46E-07	

Beneficial uses

As was mentioned at the 7 March 2022 meeting, the treated wastewater that will be discharged to the river under this proposal is the same treated wastewater that is currently classified as Class B recycled water, and is used to irrigate the Kyneton Racecourse, the Kyneton Botanic Gardens, and various sports fields in the Kyneton township.

The quality requirements for Class B recycled water, as specified in Table 1 or EPA Publication 1910.2 (2021) are:

– Secondary treatment and pathogen (including helminth reduction for cattle grazing) reduction (as per EPA Publication 730, published in 2002)
– *E. coli* - <100 orgs/100 mL (based on an annual median value)
– pH between 6 and 9 (based on 90th percentile value)
– BOD_5 - <20 mg/L (based on an annual median value)
– Suspended Solids - < 30 mg/L (based on an annual median value)

If these criteria are met, then, as per Table 26 in EPA Publication 1911.2 (2021), reproduced below, there are a range of uses that the treated wastewater can be put to, with no further treatment.

With respect to discharge to the river, it is assumed that, at the point of discharge, the uses listed in Table 26 are not compromised.

As was noted in the preceding section, it should be noted that given the discharge occurs into an untreated river, at a proposed maximum dilution ratio of 66.7%, where there are a range of microbial and chemical inputs, both above and below the discharge point, Coliban Water cannot warrant the quality of the instream water below the discharge point, and whether it is still suitable for Class B uses.

The river health monitoring program that is being undertaken by AQUEST, in association with the environmental offsets program, provides evidence on some these inputs. The available reports from this monitoring program can be found here: https://connect.coliban.com.au/kyneton-offsets-project.

Table 26 – Acceptable uses and irrigation methods to use as preventive measures

Recycled water use category or exposure	Acceptable Classes			Irrigation controls	Withholding period controls		Helminth controls
	A	B	C	B and C	4 hrs	5 days	
Urban and industrial uses							
Residential, unrestricted public access, open industrial systems	Y	N	N	None	None	None	Y
Restricted public access, closed industrial systems	Y	Y	Y	Withholding periods	Y	None	N
Agricultural uses (non-livestock)							
Raw human food crops exposed to recycled water	Y	N	N	None	None	None	Y
Crops grown over 1 metre above the ground and eaten raw (for example apples, pears, apricots, table grapes, olives)	Y	Y	Y	No food contact with recycled water via irrigation method[C], dropped product not to be harvested	None	None	N
Crops which are skinned,	Y	Y	Y	As above, and not to be wet from	None	None	N

Recycled water use category or exposure	Acceptable Classes			Irrigation controls	Withholding period controls		Helminth controls
	A	B	C	B and C	4 hrs	5 days	
peeled or shelled before consumption (for example lemons, limes, nuts, watermelons, rockmelons)				recycled water when harvested.			
Crops to be cooked (>70°C for 2 minutes) or processed before sale to consumers[A] (for example wheat, wine grapes)	Y	Y	Y	None	None	None	N
Cooked or processed human food crops not directly exposed to recycled water[E]	Y	Y	Y	None	None	None	N
Non-food crops, woodlots, turf, flowers	Y	Y	Y	None	None	None	N
Livestock uses and exposure (pasture use refers to dry or ensile fodder)					**Pasture use (Class B and C)**		**Helminth controls**
Livestock (drinking) water[B]	Y	Y	N	None	N	N	Y
Washdown water for dairy sheds (NOT milking machinery)	Y	Y	N	None	N	N	Y
Irrigation of pasture and fodder for dairy animals (to minimise udder and milk exposure)	Y	Y	N	Withholding periods	Y	N	Y
	Y	Y	Y	Withholding periods	N	Y	Y
Irrigation of pasture and fodder for beef cattle	Y	Y	Y	Withholding periods	Y	N	Y
Irrigation of pasture and fodder for sheep, goats, horses	Y	Y	Y	None	N	N	N
Change in land use post recycled water use without helminth controls							
Exposure of cattle or pigs to grazing area where helminth reduction not implemented	Y	Y	Y	None	2 years		Based on above uses post 2 years, no pig exposure[D]

[A] Crops that are cooked prior to consumption can be sold uncooked to consumers provided the safety of the practice (such as considering the irrigation steps, preparation prior to sale and domestic cooking) can be demonstrated to the satisfaction of EPA.

[B] Includes sheep, goats, cattle, horses, and poultry. Excludes pigs.

[C] Flood, furrow, drip, sub-surface.

[D] If wastewater source contains human faecal material.

[E] For example, crops irrigated via subsurface irrigation only where only the above ground portion is harvested.

Note that using recycled water for livestock water could potentially increase livestock exposure to pathogens and other contaminants. If there are sources of livestock pathogens (greater than an arbitrary 1 per cent of the flow) in the wastewater resource used to produce the recycled water, monitor stock health closely. Preventative measures to lower this risk are to not use recycled water for livestock or use class A recycled water.

Y = yes, N = no. Y indicates that recycled water of this quality is generally acceptable for the corresponding uses, however, additional preventive measures may be required.

Recreational water guidelines

<u>Discussion on the use of a 1µDALY pppy microbial risk standard for recreational waters.</u>

In preparing this document, relevant recreational water guideline documents were reviewed. In 2021, WHO released their *Guidelines on Recreational Water Quality - Volume 1 - Coastal and Fresh Waters*. These guidelines do not specify any virus-related guidelines values, nor does it suggest a microbial risk target of 1µDALY pppy.

The relevant guideline values from the WHO document are presented in the table below, and are based on the concentration of intestinal enterococci.

Table 0.1
Guideline values for microbial quality of coastal and freshwater recreational waters

Intestinal enterococci (95th percentile value per 100 mL [rounded values])	Basis of derivation	Estimated risk per exposure
≤40 A	This range is below the NOAEL in most epidemiological studies. Low risk or low probability of adverse effects.	• <1% GI illness risk. • <0.3% AFRI risk. • The upper 95th percentile value relates to an average probability of less than 1 case of gastroenteritis in every 100 exposures. The AFRI burden would be negligible.
41–200 B	The 200/100 mL value is above the threshold of illness transmission reported in most epidemiological studies that have attempted to define a NOAEL or LOAEL for GI illness and AFRI.	• 1–5% GI illness risk. • 0.3–1.9% AFRI risk. • The upper 95th percentile value relates to an average probability of 1 case of gastroenteritis in 20 exposures. The AFRI illness rate at this upper value would be less than 19 per 1000 exposures, or less than approximately 1 in 50 exposures.
201–500 C	This range represents a substantial elevation in the probability of all adverse health outcomes for which dose–response data are available.	• 5–10% GI illness risk. • 1.9–3.9% AFRI risk. • This range of 95th percentiles represents a probability of 1 in 10 to 1 in 20 of gastroenteritis for a single exposure. Exposures in this category also suggest a risk of AFRI of 19–39 per 1000 exposures, or approximately 1 in 50 to 1 in 25 exposures.
>500 D	Above this level, there may be significant risk of high levels of minor illness transmission.	• >10% GI illness risk. • >3.9% AFRI risk. • There is a greater than 10% chance of gastroenteritis per single exposure. The AFRI illness rate at the 95th percentile value of >500/100 mL would be greater than 39 per 1000 exposures, or greater than approximately 1 in 25 exposures.

A–D: microbial water quality assessment categories (refer to section 4.3) used in the classification procedure; AFRI: acute febrile respiratory illness; GI: gastrointestinal; LOAEL: lowest-observed-adverse-effect level; NOAEL: no-observed-adverse-effect level.

These intestinal enterococci values appear in NHMRC's 2008 *Guidelines for Managing Risks in Recreational* and in Victoria's Environmental Reference Standard (2021), reproduced below.

In addition to intestinal enterococci, EPA have also provided *E. coli* values in the ERS for primary contact recreation at freshwater (also reproduced below). Like the WHO and NHMRC documents, the ERS does not specify a microbial risk target, nor does it give any direct guidance as to how to handle virus data in relation to human health risk associated with primary contact recreation.

Based on the *E. coli* values listed in the ERS, the proposed discharge from the Kyneton WRP would not compromise primary contact recreation.

Table 5.19: Water-based recreation – Classification matrix for long-term microbial indicators and objectives

<table>
<tr><th colspan="2"></th><th colspan="5">Microbial Assessment Category
(95th percentile (Hazen method))</th></tr>
<tr><th colspan="2"></th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th></tr>
<tr><td colspan="2">Freshwater</td><td>≤ 130 E. coli/100 mL</td><td>130 – 260 E. coli/100 mL</td><td>261 – 550 E. coli/100 mL</td><td>551 – 5500 E. coli/100 mL</td><td>> 5500 E. coli/100 mL</td></tr>
<tr><td colspan="2">Freshwater, Marine, Estuarine</td><td>≤ 40 enterococci/ 100 mL</td><td>40 – 200 enterococci/ 100 mL</td><td>201 – 500 enterococci/ 100 mL</td><td>501 – 5000 enterococci/ 100 mL</td><td>> 5000 enterococci/ 100 mL</td></tr>
<tr><td rowspan="5">Sanitary Inspection Category</td><td>Very Low</td><td>Very Good</td><td>Very Good</td><td>Follow-up</td><td>Follow-up</td><td rowspan="5">Follow-up</td></tr>
<tr><td>Low</td><td>Very Good</td><td>Good</td><td>Follow-up</td><td>Follow-up</td></tr>
<tr><td>Moderate</td><td>Good</td><td>Good</td><td>Poor</td><td>Poor</td></tr>
<tr><td>High</td><td>Good</td><td>Fair</td><td>Poor</td><td>Very Poor</td></tr>
<tr><td>Very High</td><td>Follow-up</td><td>Follow-up</td><td>Poor</td><td>Very Poor</td></tr>
</table>

Notes

1. For long term assessment for water-based recreation (primary contact and secondary contact), a rolling water quality data set with a minimum number of 60 samples must be developed and maintained. The microbial assessment category must be assessed in both general weather (a range of weather conditions) and dry weather conditions
2. For long term assessment for primary contact water-based recreation, data must be collected during periods of high recreational use and a sanitary inspection at a site is required.
3. Site-specific microbial long term objectives may be used if a 'follow-up', 'poor' or 'very poor' long term water quality grade is determined. Site-specific objectives must be derived from a risk assessment approach, following industry best practice and guidance published or approved by EPA.

Table 5.20: Water-based recreation – Short term indicators and objectives

E. coli **(orgs/100mL)** **Freshwater**	**Enterococci (orgs/100mL)** **Marine, estuarine and freshwater**
Consecutive sample: ≤ 260	Consecutive sample: ≤ 200
Single sample: ≤ 550	Single sample: ≤ 500

Notes

1. For short term assessment for primary contact water-based recreation, data must be single samples regularly collected during periods of high recreational use.
2. Microbial water quality objectives must be assessed against only dry weather water quality data if warning about risk to water quality from stormwater pollution following rain is communicated to the public by –
   (i) daily water quality forecasting; and
   (ii) permanent signs warning of risk after stormwater pollution.
3. Site-specific short term objectives may be derived from a risk assessment approach, following industry best practice and guidance published or approved by EPA to reflect potential health outcomes.

It is recognised that both the NHMRC and WHO guidance documents make the point that a microbial risk assessment should be undertaken with respect to primary contact recreation, but given the high level of uncertainty associated with the behaviour of human infectious viruses in aquatic environments, and the lack of published dose-response models for most of the viruses, it is difficult to propose definitive log reduction values.

A recent journal article*, Human Health Risks Associated with Recreational Waters: Preliminary Approach of Integrating Quantitative Microbial Risk Assessment with Microbial Source Tracking* (Gitter et al 2020) attempted to look at this issue. The authors did not land on a model for viruses, and article is being provided as background information.

Summary statement

Under normal operating conditions, the upgraded UV unit at the Kyneton WRP is likely to result in significant inactivation of a range of human infectious viruses.

An additional level of protection is provided by the fact that discharges to the waterway do not normally occur at times when primary contact recreation is most likely to occur along the river.

Pathogen risk estimates from highly repeated exposure (i.e. 50 events per year) recreation were made for the receiving waterway. These estimates are summarised in Table C8, and are expressed as DALYs per person per year.

Table C.8 ***Pathogen risks for highly repeated exposure from recreation (DALYs/person/year)***

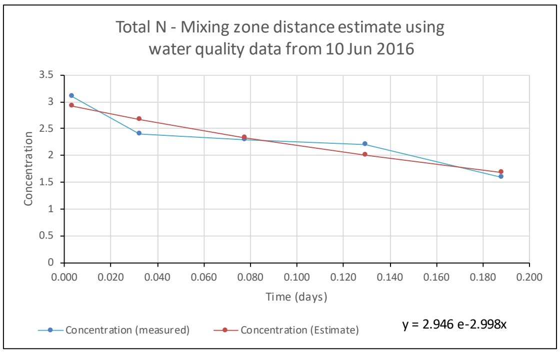
	Protozoa	Virus	Bacteria
Primary contact recreation, “minimum LRVs” from treatment	4.05E-01	5.19E-01	2.57E-03
Primary contact recreation, “median LRVs” from treatment	1.28E-03	2.60E-02	2.57E-06
Secondary contact recreation, “minimum LRVs” from treatment	8.58E-02	1.10E-01	5.46E-04
Secondary contact recreation, “median LRVs” from treatment	2.71E-04	5.52E-03	5.46E-07

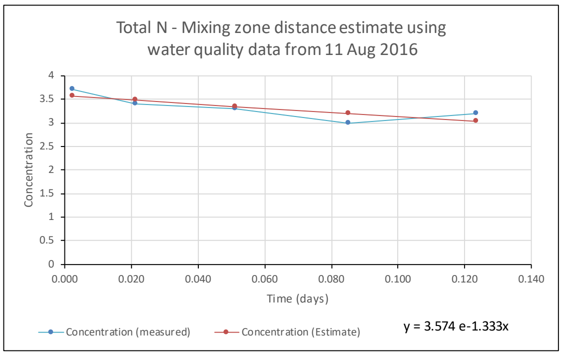
Appendix D

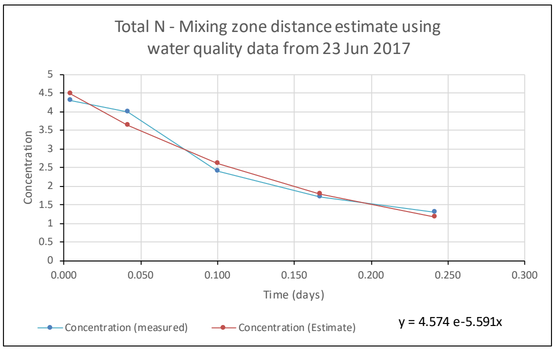
Nutrient Decay Rate Determinations

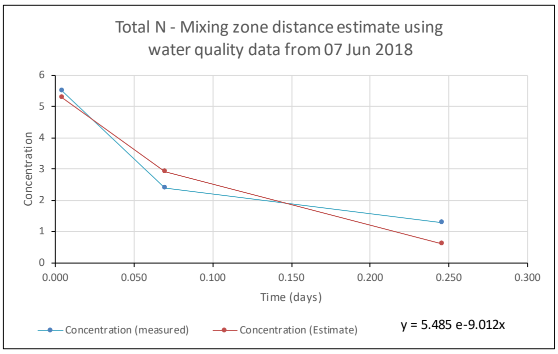
Updated decay rates for the Campaspe River were determined using new streamflow data and available nitrogen and phosphorus data downstream of the discharge point.

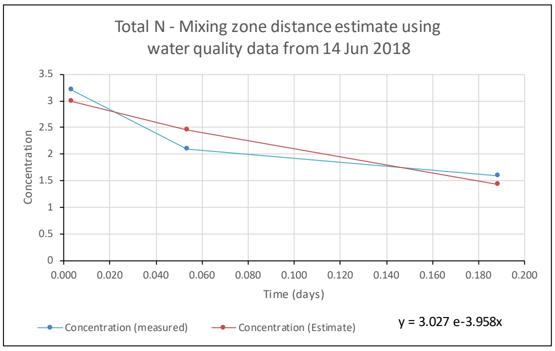
Total N decay rate estimation:

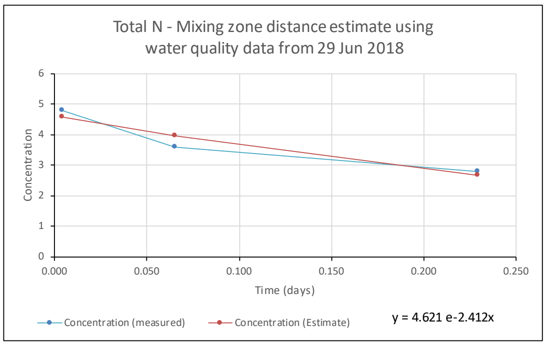


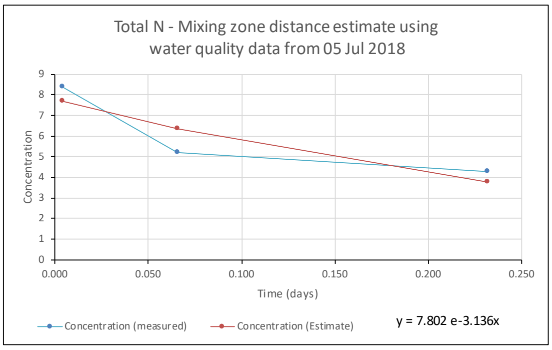


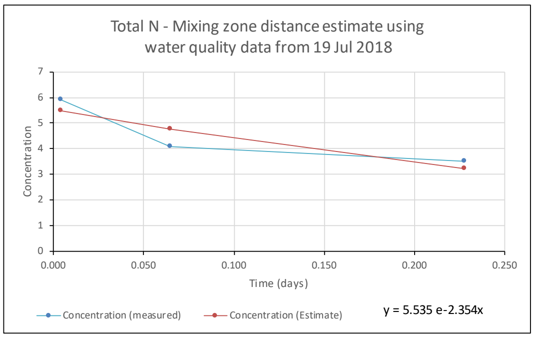


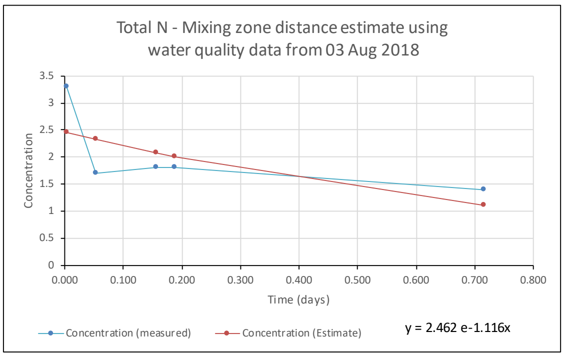


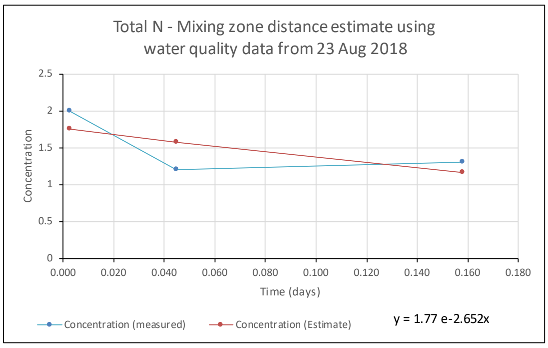









Total N - Mixing zone distance estimate using water quality data from 03 Aug 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.462 e-1.116x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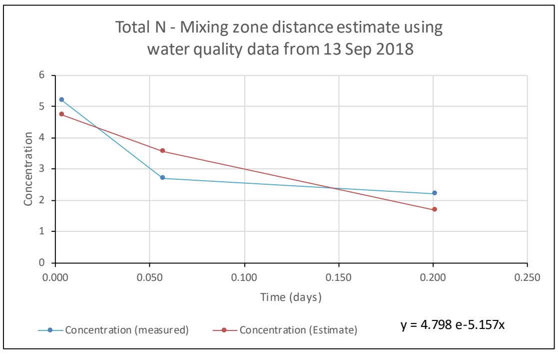
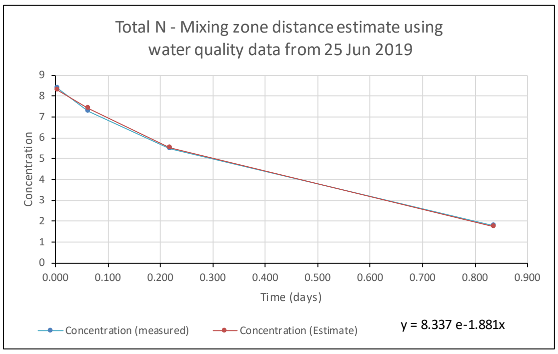
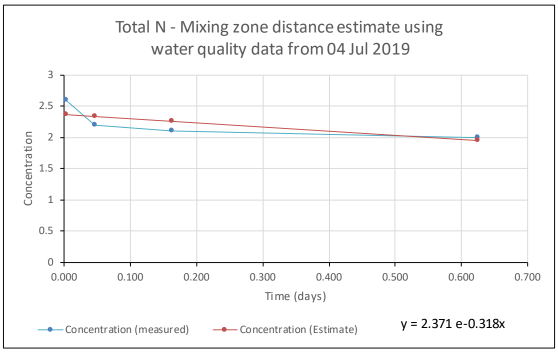
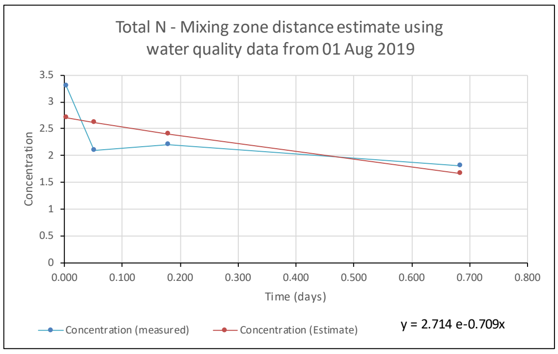
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.77 e-2.652x


Total N - Mixing zone distance estimate using water quality data from 13 Sep 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 4.798 e-5.157x


Total N - Mixing zone distance estimate using water quality data from 25 Jun 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 8.337 e-1.881x


Total N - Mixing zone distance estimate using water quality data from 04 Jul 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.371 e-0.318x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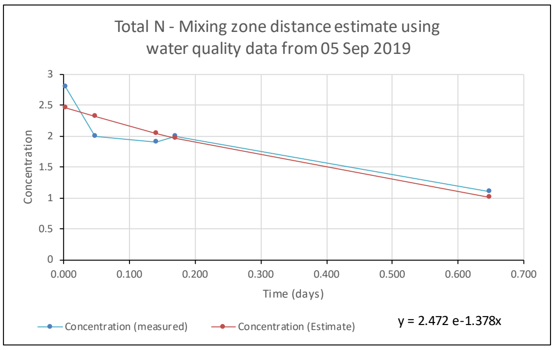
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.714 e-0.709x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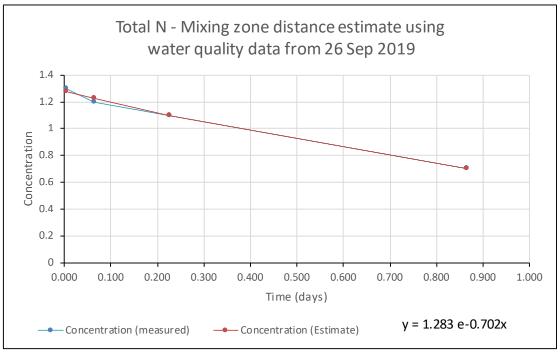
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.472 e-1.378x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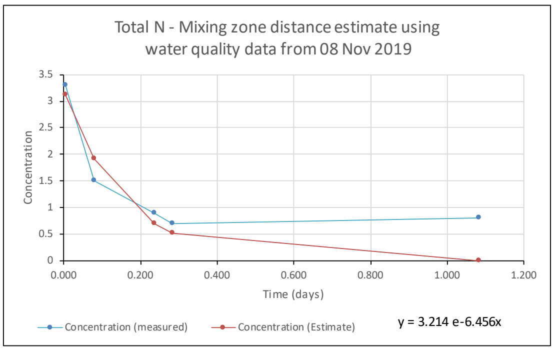
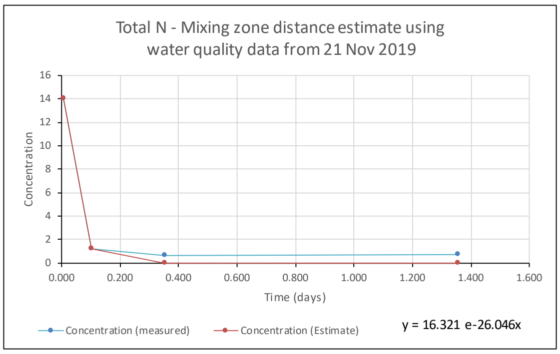
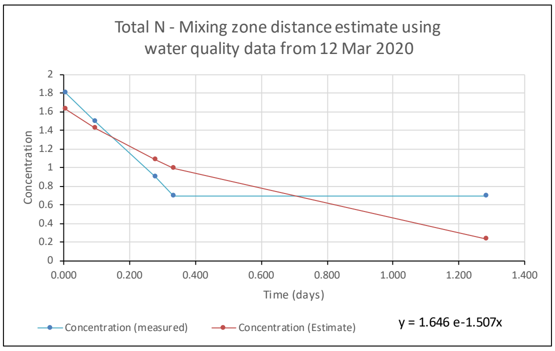
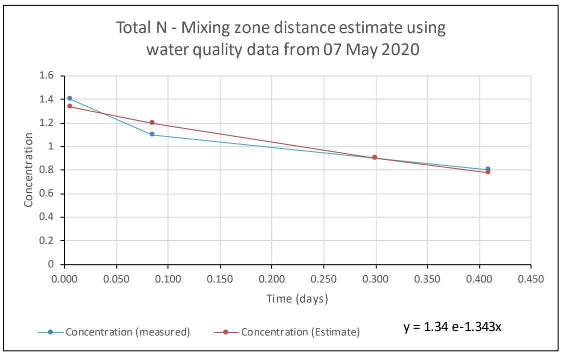
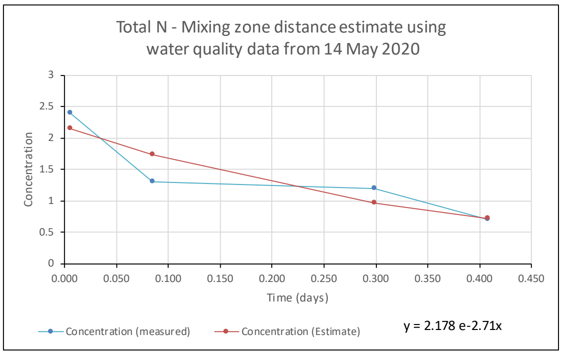
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.283 e-0.702x

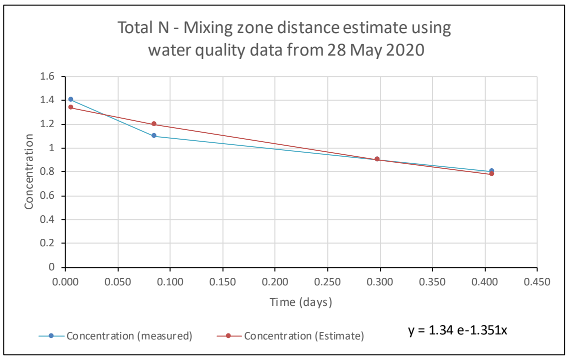

Total N - Mixing zone distance estimate using
water quality data from 08 Nov 2019
Concentration
3.5
3
2.5
2
1.5
1
0.5
0
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 3.214 e-6.456x

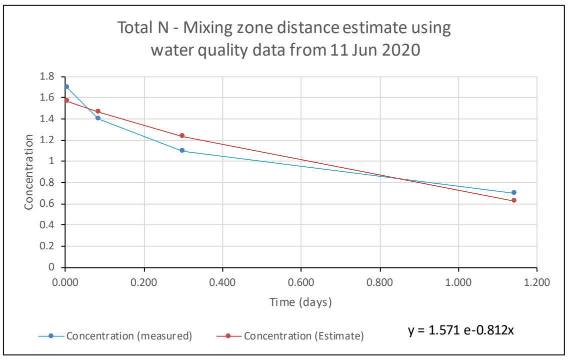

Total N - Mixing zone distance estimate using
water quality data from 21 Nov 2019
Concentration
16
14
12
10
8
6
4
2
0
0.000
0.200
0.400
0.600
0.800
1.000
1.200
1.400
1.600
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 16.321 e-26.046x

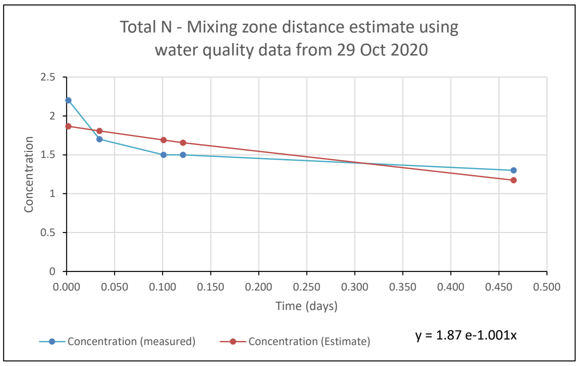

Total N - Mixing zone distance estimate using
water quality data from 12 Mar 2020
Concentration
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000
0.200
0.400
0.600
0.800
1.000
1.200
1.400
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.646 e-1.507x

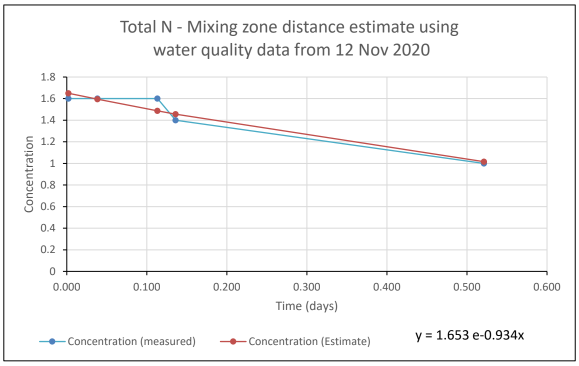

Total N - Mixing zone distance estimate using
water quality data from 07 May 2020
Concentration
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.34 e-1.343x

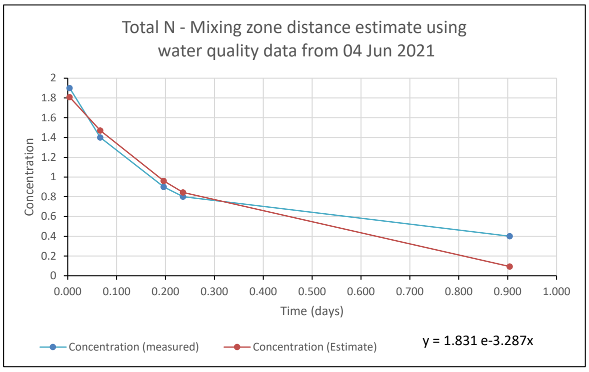

Total N - Mixing zone distance estimate using
water quality data from 14 May 2020
Concentration
3
2.5
2
1.5
1
0.5
0
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.178 e-2.71x

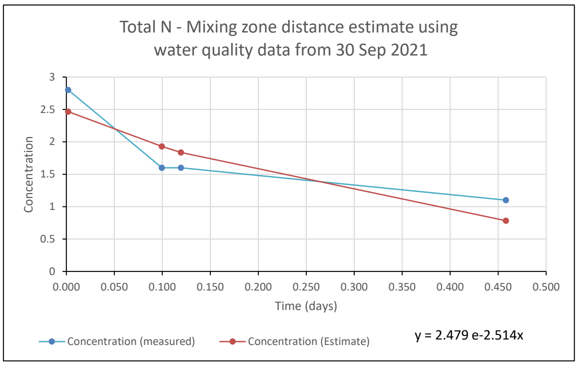

Total N - Mixing zone distance estimate using
water quality data from 28 May 2020
Concentration
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000
0.050
0.100
0.150
0.200
0.250
0.300
0.350
0.400
0.450
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.34 e-1.351x


Total N - Mixing zone distance estimate using
water quality data from 11 Jun 2020
Concentration
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000
0.200
0.400
0.600
0.800
1.000
1.200
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.571 e-0.812x

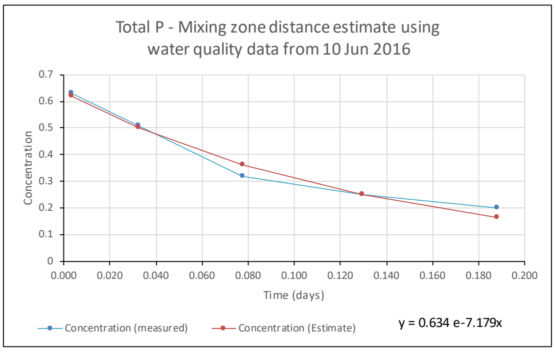

Total N - Mixing zone distance estimate using water quality data from 29 Oct 2020
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.87 e-1.001x

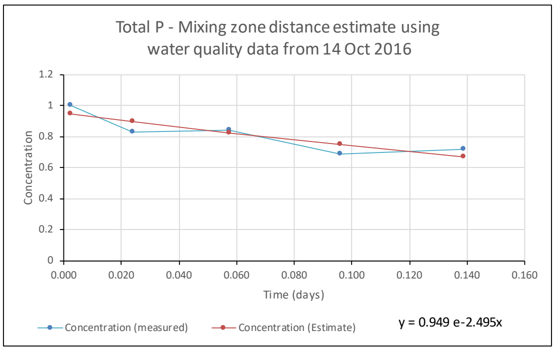

Total N - Mixing zone distance estimate using water quality data from 12 Nov 2020
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.653 e-0.934x

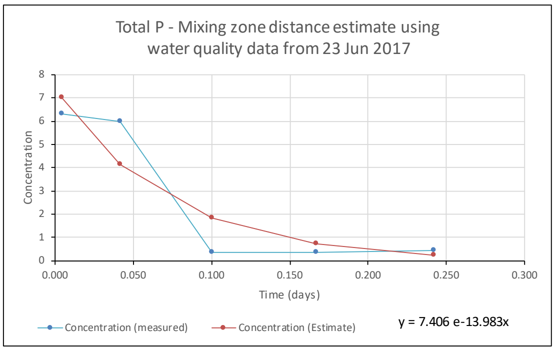

Total N - Mixing zone distance estimate using water quality data from 04 Jun 2021
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.831 e-3.287x

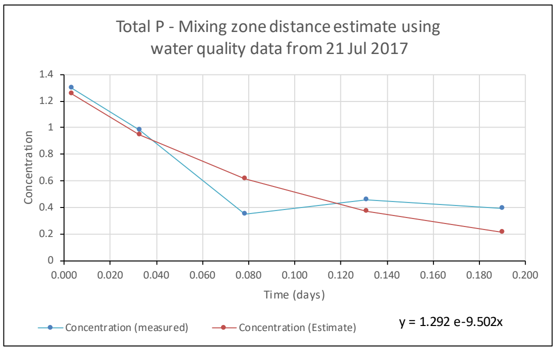

Total N - Mixing zone distance estimate using water quality data from 30 Sep 2021
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.479 e-2.514x

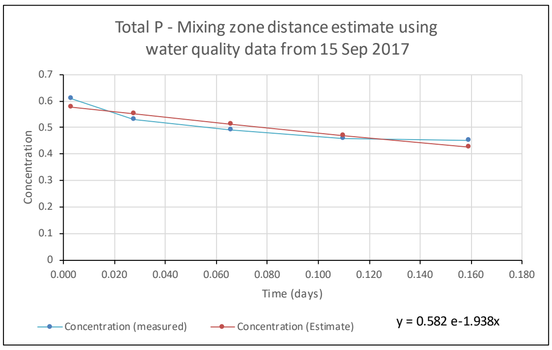
Total P decay rate estimation:

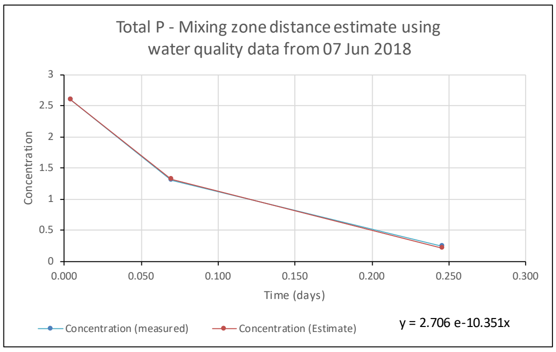


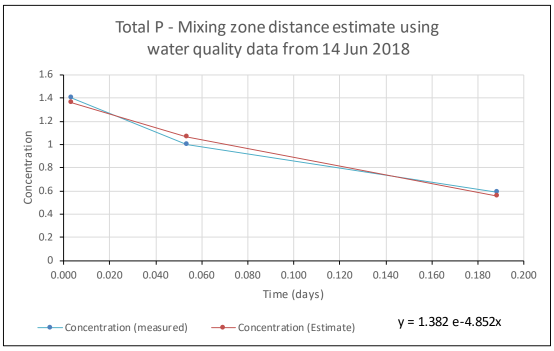


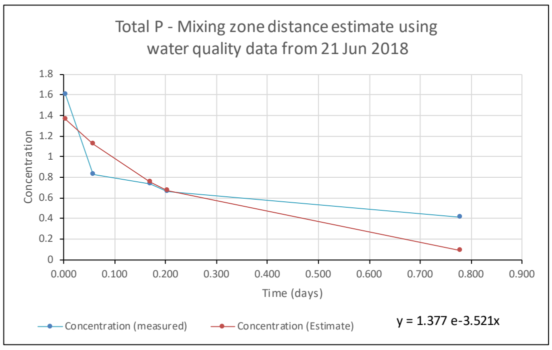


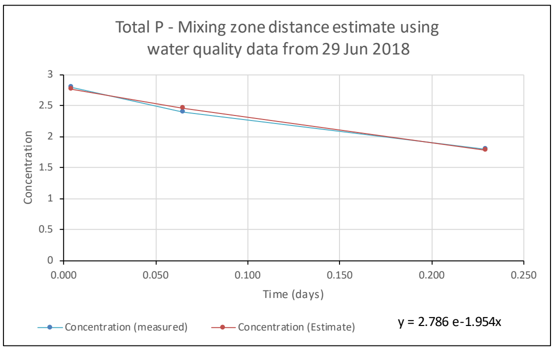


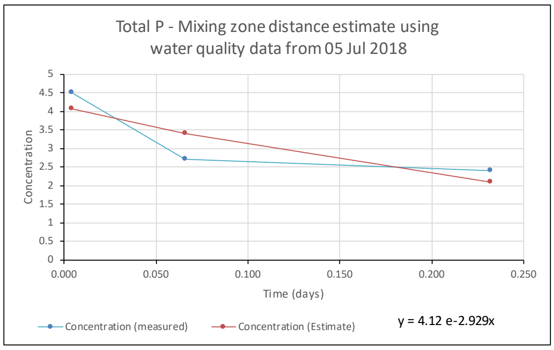


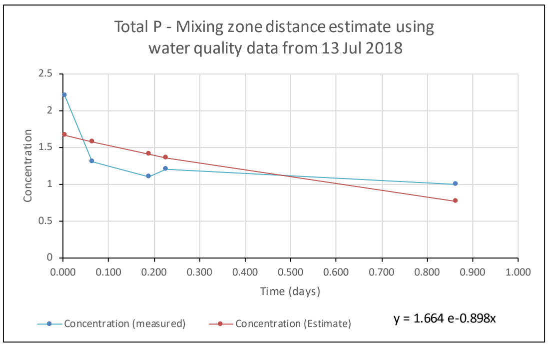


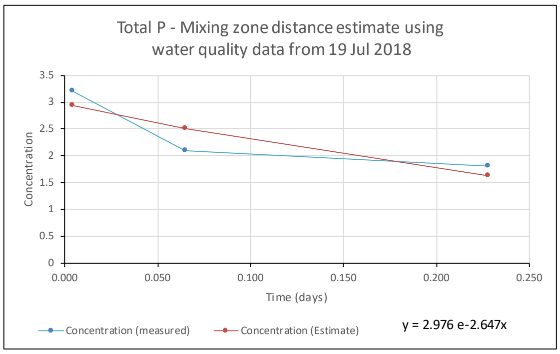


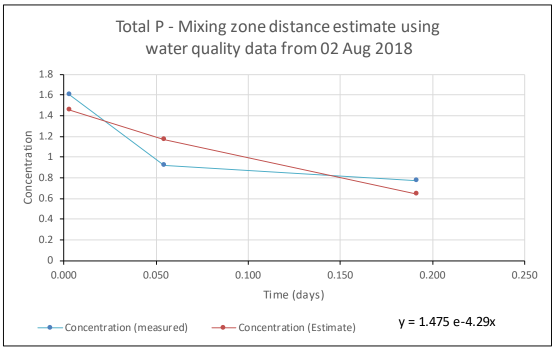


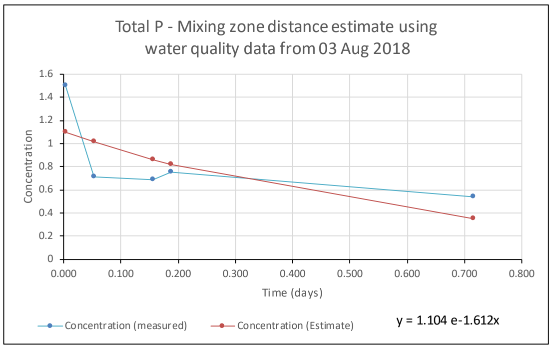

Total P - Mixing zone distance estimate using
water quality data from 29 Jun 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.786 e-1.954x

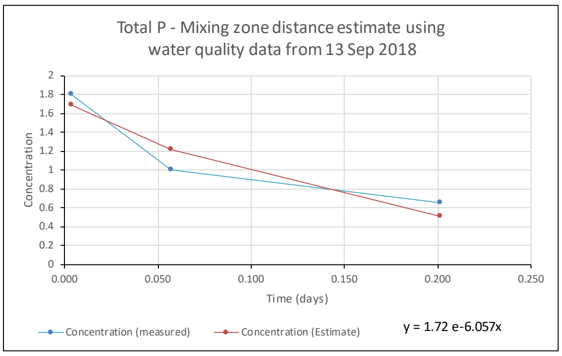

Total P - Mixing zone distance estimate using
water quality data from 05 Jul 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 4.12 e-2.929x

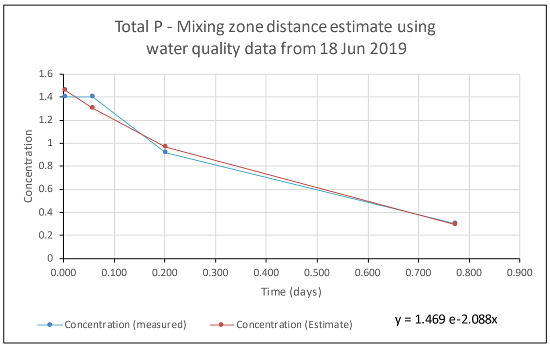

Total P - Mixing zone distance estimate using
water quality data from 13 Jul 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.664 e-0.898x

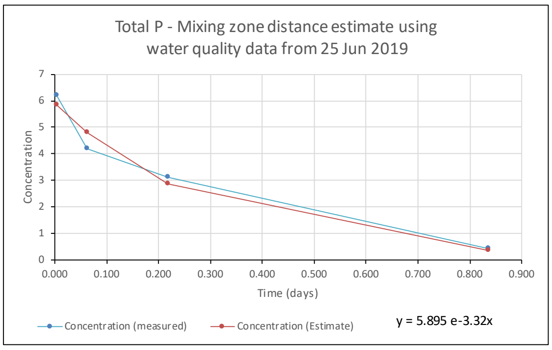

Total P - Mixing zone distance estimate using
water quality data from 19 Jul 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.976 e-2.647x

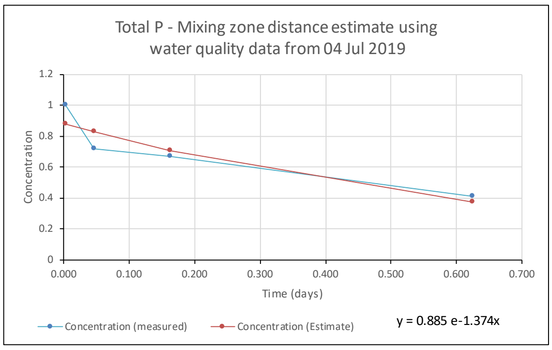

Total P - Mixing zone distance estimate using
water quality data from 02 Aug 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.475 e-4.29x

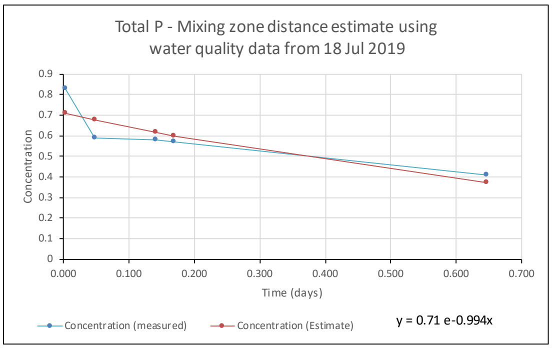

Total P - Mixing zone distance estimate using
water quality data from 03 Aug 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.104 e-1.612x

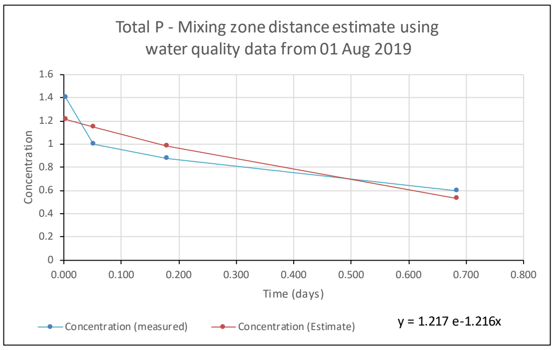

Total P - Mixing zone distance estimate using
water quality data from 13 Sep 2018
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.72 e-6.057x

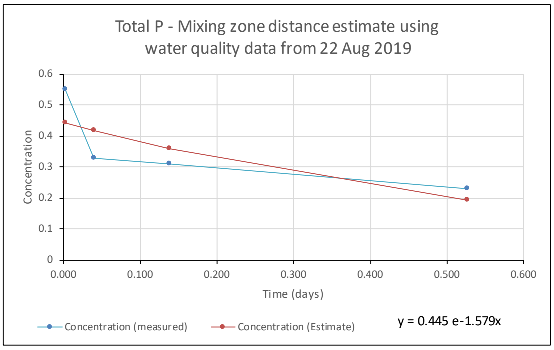

Total P - Mixing zone distance estimate using
water quality data from 18 Jun 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.469 e-2.088x

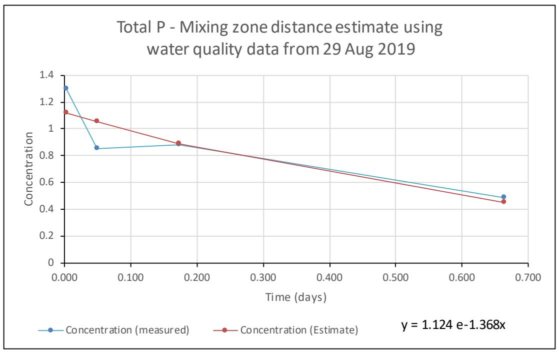

Total P - Mixing zone distance estimate using water quality data from 25 Jun 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 5.895 e-3.32x

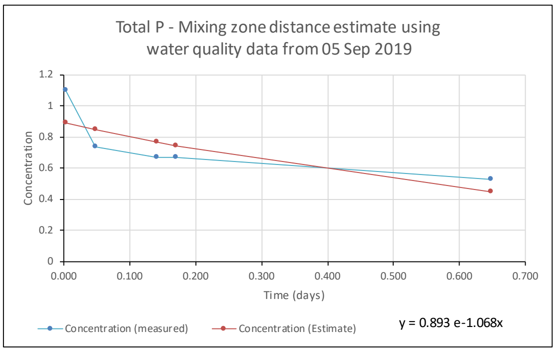

Total P - Mixing zone distance estimate using water quality data from 04 Jul 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.885 e-1.374x

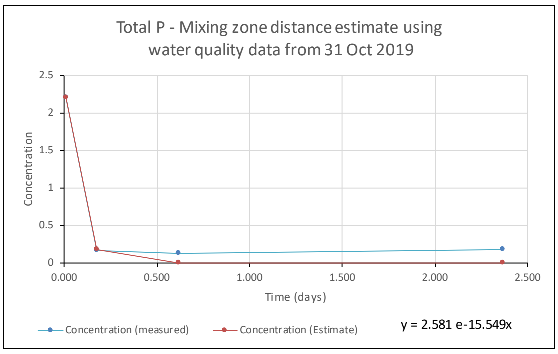

Total P - Mixing zone distance estimate using water quality data from 18 Jul 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.71 e-0.994x

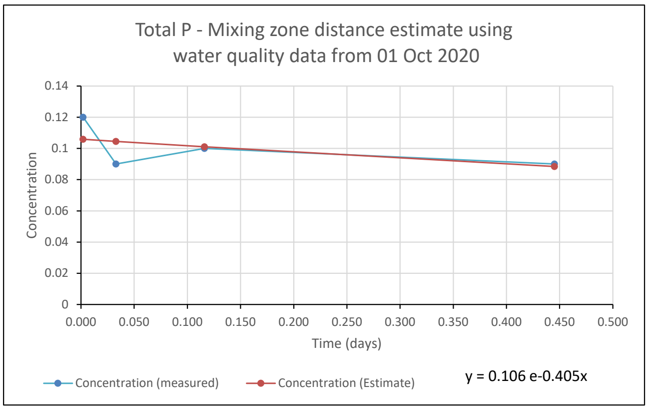

Total P - Mixing zone distance estimate using water quality data from 01 Aug 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.217 e-1.216x

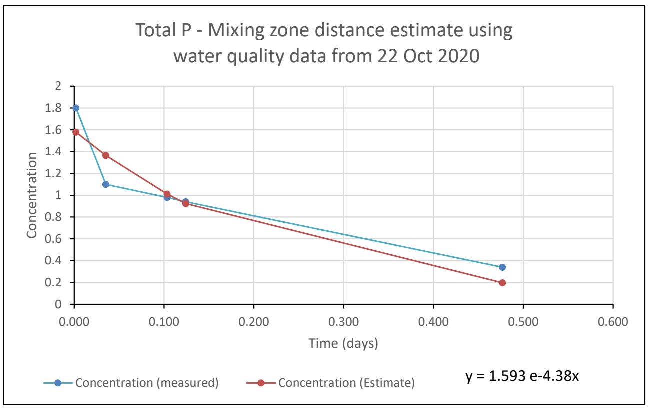

Total P - Mixing zone distance estimate using water quality data from 22 Aug 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.445 e-1.579x

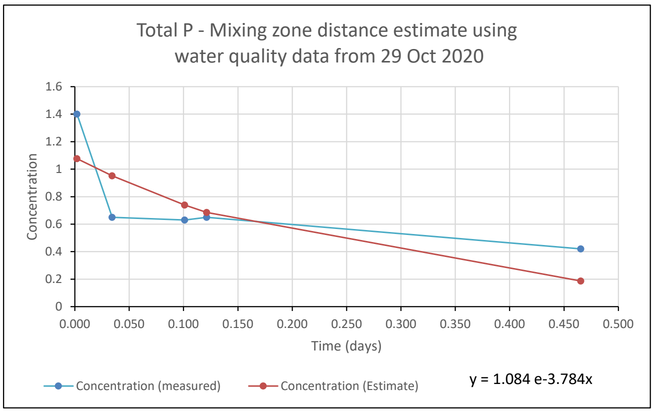

Total P - Mixing zone distance estimate using water quality data from 29 Aug 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.124 e-1.368x

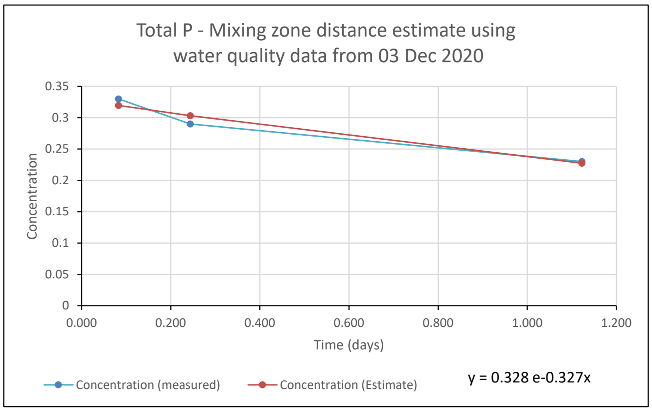

Total P - Mixing zone distance estimate using water quality data from 05 Sep 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.893 e-1.068x

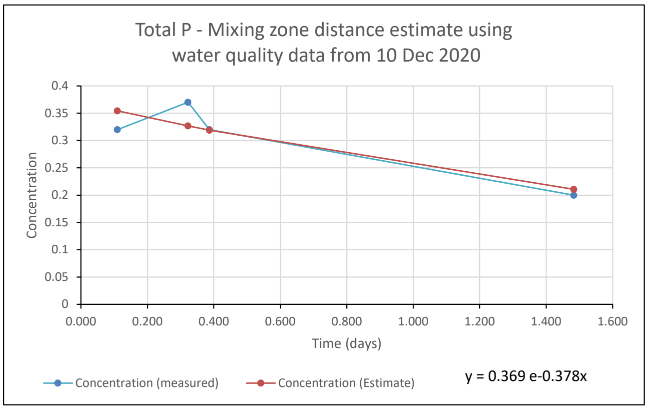

Total P - Mixing zone distance estimate using water quality data from 31 Oct 2019
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 2.581 e-15.549x

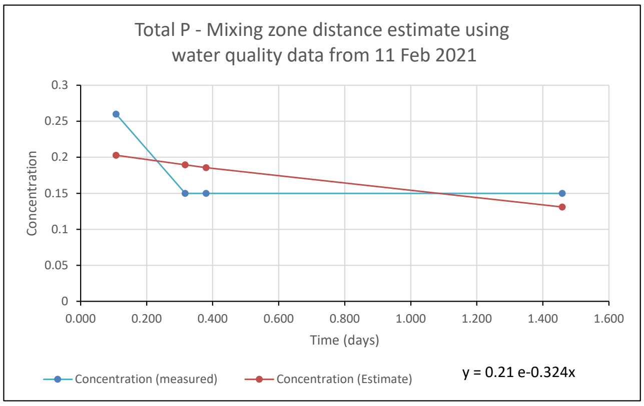

Total P - Mixing zone distance estimate using
water quality data from 01 Oct 2020
Concentration
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.000 0.050 0.100 0.150 0.200 0.250 0.300 0.350 0.400 0.450 0.500
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.106 e-0.405x

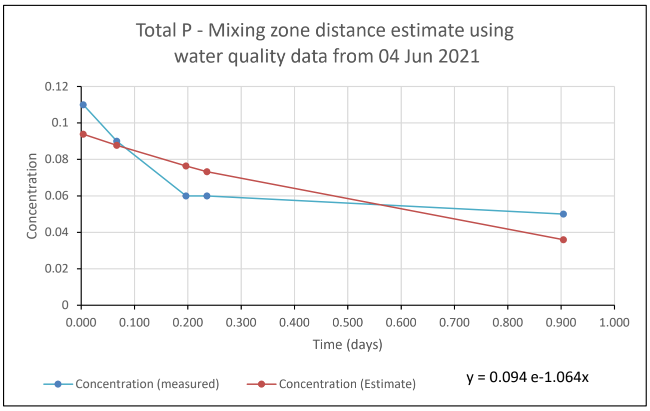

Total P - Mixing zone distance estimate using
water quality data from 22 Oct 2020
Concentration
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000 0.100 0.200 0.300 0.400 0.500 0.600
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.593 e-4.38x

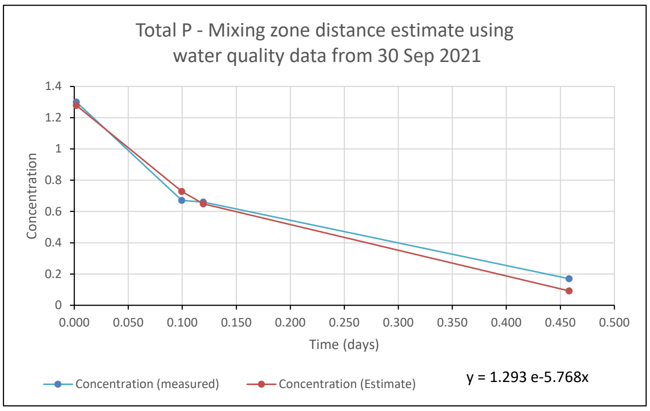

Total P - Mixing zone distance estimate using
water quality data from 29 Oct 2020
Concentration
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000 0.050 0.100 0.150 0.200 0.250 0.300 0.350 0.400 0.450 0.500
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.084 e-3.784x

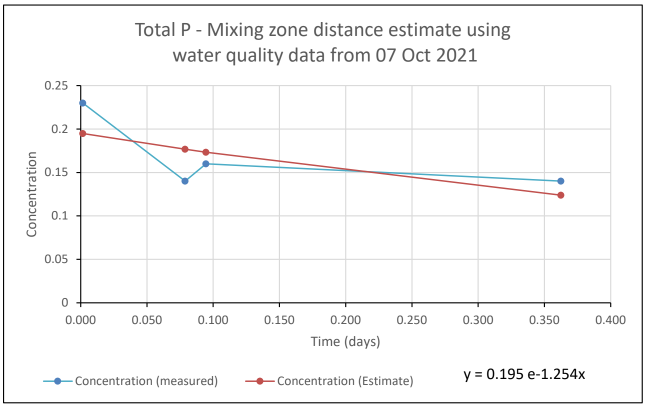

Total P - Mixing zone distance estimate using
water quality data from 03 Dec 2020
Concentration
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.000 0.200 0.400 0.600 0.800 1.000 1.200
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.328 e-0.327x

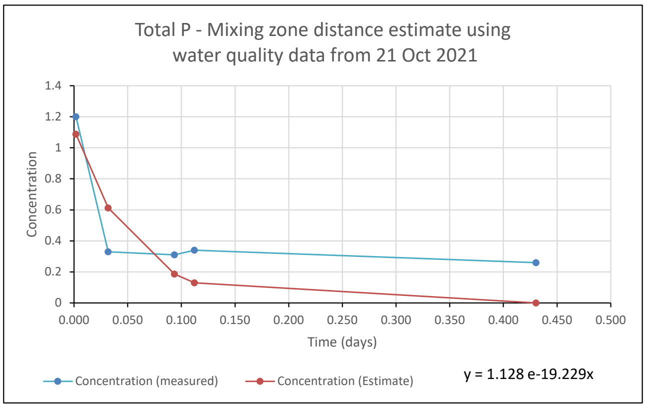

Total P - Mixing zone distance estimate using
water quality data from 10 Dec 2020
Concentration
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.000 0.200 0.400 0.600 0.800 1.000 1.200 1.400 1.600
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.369 e-0.378x

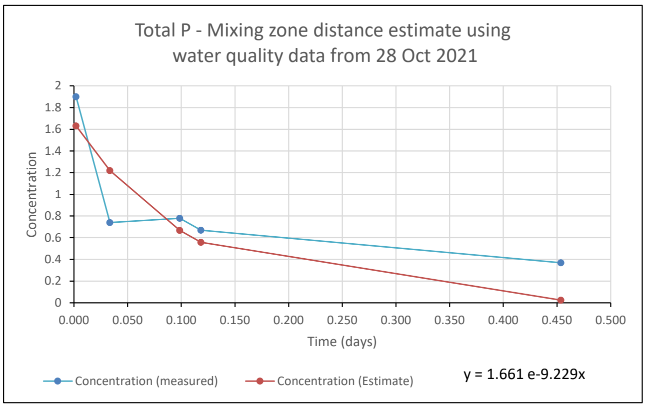

Total P - Mixing zone distance estimate using
water quality data from 11 Feb 2021
Concentration
0.3
0.25
0.2
0.15
0.1
0.05
0
0.000 0.200 0.400 0.600 0.800 1.000 1.200 1.400 1.600
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.21 e-0.324x


Total P - Mixing zone distance estimate using
water quality data from 04 Jun 2021
Concentration
0.12
0.1
0.08
0.06
0.04
0.02
0
0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 1.000
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.094 e-1.064x


Total P - Mixing zone distance estimate using
water quality data from 30 Sep 2021
Concentration
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.000 0.050 0.100 0.150 0.200 0.250 0.300 0.350 0.400 0.450 0.500
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.293 e-5.768x


Total P - Mixing zone distance estimate using water quality data from 07 Oct 2021
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 0.195 e-1.254x


Total P - Mixing zone distance estimate using water quality data from 21 Oct 2021
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.128 e-19.229x


Total P - Mixing zone distance estimate using water quality data from 28 Oct 2021
Concentration
Time (days)
Concentration (measured)
Concentration (Estimate)
y = 1.661 e-9.229x

Appendix E

Daily Risk Tool – Method Overview

The risk analysis assumes that the higher the concentration of a parameter above the guideline value, the higher the risk (with a linear response). The rules to calculate a risk score based on concentration relative to a guideline value is as follows:

When the concentration is above the guideline then:

Risk score = (concentration – guideline value) / (guideline value)

= (concentration / guideline value) - 1

When the concentration is equal to or less than the guideline:

Risk score = 0

An example calculation of risk score for a total N value of 2.7 mg/L with a guideline of 0.6 mg/L is as follows:

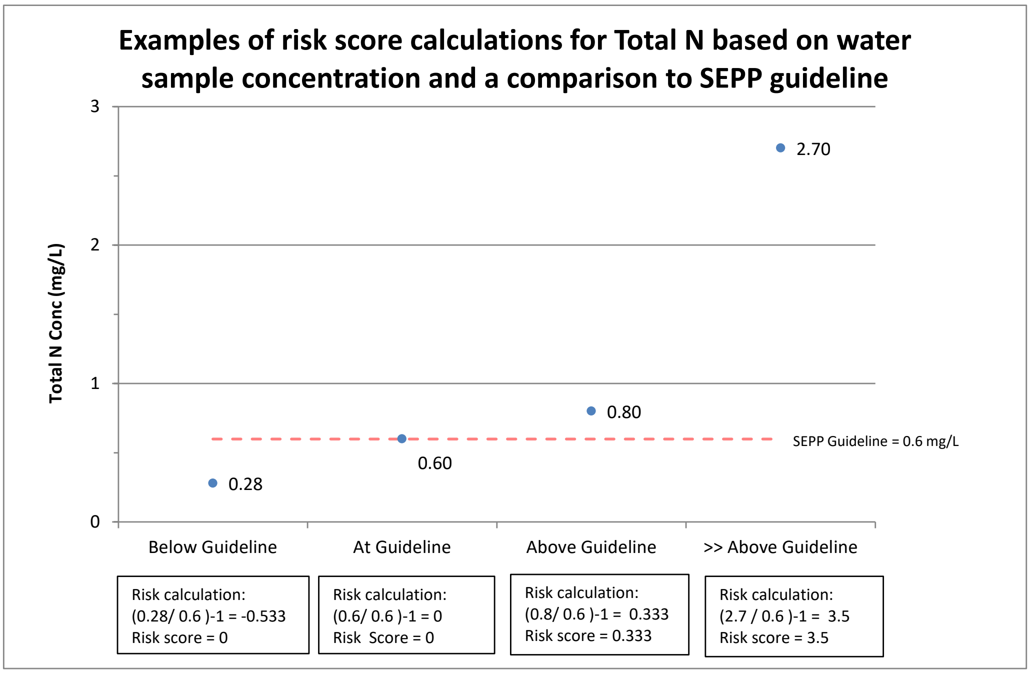
Risk score = (2.7 – 0.6) / 0.6

= (2.7 / 0.6) – 1

= 4.5 -1

=3.5

A number of example calculations of risk score for total N are presented below.



The guideline values used in the risk assessment were ERS (2021) and ANZG (2018) limits.

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