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Preliminary river outfalls assessment: part of the National Outfall Database project extension

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EXECUTIVE SUMMARY

Effluent from wastewater treatment plants has led to degradation of water quality. This report provides a preliminary data analysis of the river outfalls around the Hawkesbury-Nepean catchment areas, and ranks them according to the total flow volume and nutrient load to determine the potential health and environmental impact. Water quality data were collected from 17 inland outfalls of two water authorities around the Hawkesbury-Nepean river by downloading the water quality data reports directly from water authority (WTA) websites. The pollutant contribution index, based on nitrogen and phosphorous loads, was calculated for each outfall using the Load Calculation Protocol of New South Wales Department of Planning, Industry and Environment. Outfalls were ordered from lowest to highest index value and ranked relative to their pollutant contribution to the riverine environment. The index is based on total nutrient load discharge using the variables of flow, nitrogen and phosphorous.

The results showed that total nutrient load from individual outfall sites around the Hawkesbury-Nepean river ranged from 838 kg to 133,142 kg, with a mean of 47,440 kg. The ranked loads were mapped by quartiles. The general patterns suggested that most of the outfalls are located in the lower catchment areas. Higher nutrient load outfalls tend to group closely, compared to the low nutrient load outfalls. The majority of the outfalls from the 75th and bottom quartiles have larger capacities to discharge their nutrient load into the Hawkesbury-Nepean catchment areas. This generally means that over time more nutrients will be discharged into the river, which will significantly increase the pressure on inland water bodies.

With regards to data availability, within the current dataset it is evident that there is an underlying issue of inconsistency in reporting format across WTAs selected for this preliminary analysis. Compared to other states and territories, the Environmental Protection Authority (EPA) NSW has publication requirements for WTA datasets, however, there is no clear statement in regard to uniform formatting of the data.. Therefore, the WTAs may adopt a data format most convenient to them, leading to inconsistent reporting formats (e.g. frequency of reporting and pollutant type). Both marine and freshwater outfalls have the same issues of data availability, however, EPA NSW publication requirements are somewhat helpful (accessible from websites) for researchers or any relevant stakeholders to access water quality data of wastewater treatment plant (WWTP) outfalls. This may not be the case in other state or territories.

1. INTRODUCTION

Rivers provide a variety of ecosystem services for humans, such as for drinking water and irrigation (Robinson et al., 2019). Due to the complexity of riverine ecosystems, a river is often highly sensitive to changes in water quality and flow. River water quality can be degraded by wastewater treatment plant (WWTP) discharges (Stalter et al., 2013; Karaouzas, 2016; Price et al., 2018). The most common contaminants in WTP effluent include heavy metals (Ashley and Napier, 2005; Zhou et al., 2019), micropollutants (König et al., 2017; Brown et al., 2019), and pathogens (Brown et al., 2019; Rowlands et al., 2019). These contaminants may have impacts on the river ecosystems, leading to for example blue-green algal blooms (Paerl et al., 2018; Cheng et al., 2019), and biodiversity impacts. Changes to river water quality and ecosystems affect provisioning (e.g. drinking water and agricultural) and cultural (e.g. recreation) ecosystem services.

Each state/territory government has established an Environment Protection Authority (EPA) to manage and safeguard inland and coastal waters from the impacts of WWTP discharge. Each EPA acts as an independent environmental protection regulator to prevent and control pollutant impacts to human health and the environments. For example, in Victoria the EPA was established under section 5(1) of the Environmental Protection Act of 1970. In New South Wales, the Protection of the Environment Administration Act (1991) (POEA Act) serves as the mechanism to establish the environmental protection regulator.

With regards to wastewater effluent each state or territory EPA has a role in regulating WWTP discharges. For example, in New South Wales, the EPA regulates water pollution through the establishing pollutant thresholds on environmental protection licenses. These licenses take into account several factors, such as the community value of a waterway, the community's uses of a waterway and practical measures to prevent deterioration of waterway values and uses (EPA NSW, 2013c). Any activity that may produce a discharge of waste that by reason of volume, location or composition adversely affects the quality of any segment of the environment will require a licence from the Authority (DECC NSW, 2009b). The basic requirement of the licence consists of an explanation of the activity, pollutant loads, and discharge limits. The actual load of a pollutant is the mass (in kilograms) of the pollutant (e.g. nitrogen, phosphorous, total suspended solids, oil and grease) released into the environment from the potential emission sources. Throughout each state and territory, emission sources are required to monitor their discharges and to comply with the conditions set out in their licenses. Each WWTP is required to conduct monitoring within the vicinity of their outfalls, analyse the samples and report the results to the EPA (DECC NSW, 2009b; EPA VIC, 2009).

Clean Ocean Foundation (COF), under the auspice of National Environmental Science Program – Marine Biodiversity Hub, has successfully developed a publicly accessible database of coastal outfall discharges from WWTPs around Australia – the National Outfall Database (NOD) (Gemmill et al., 2019; NOD, 2020). In collaboration with key partner, Dr Ian Wright from the University of Western Sydney the NOD has undertaken a preliminary audit of WWTP discharges into a river ecosystem with a view to expand this further in the future.

The Hawkesbury-Nepean catchment area, which is one of the largest coastal basins in New South Wales, was selected by COF as the preliminary system to study. This catchment area was selected on the basis that; some datasets already exist, its proximity to a large population centre and the familiarity of Dr Wright with this system. The preliminary study system would then ensure the development of a reliable framework for data collection, analysis and public dissemination. The catchment supports agricultural and horticultural industries and is the main source of drinking water for NSW residents (NSW Government, 2013).

In 2011, the NSW government started a recovery program for the Hawkesbury-Nepean region to reduce nutrient pressures on the river system (NSW Government and DECCW, 2010). However, since the recovery program, there have been significant key issues in the system related to water security and environmental impacts in the catchment areas. These include excessive salinity (Belmer and Wright, 2020) and elevated nutrient concentrations (Fairbairn, 2018), which have resulted in excessive aquatic weed growth and algal blooms (Gufu et al., 2018). These impacts are related to WWTPs effluent into the system.

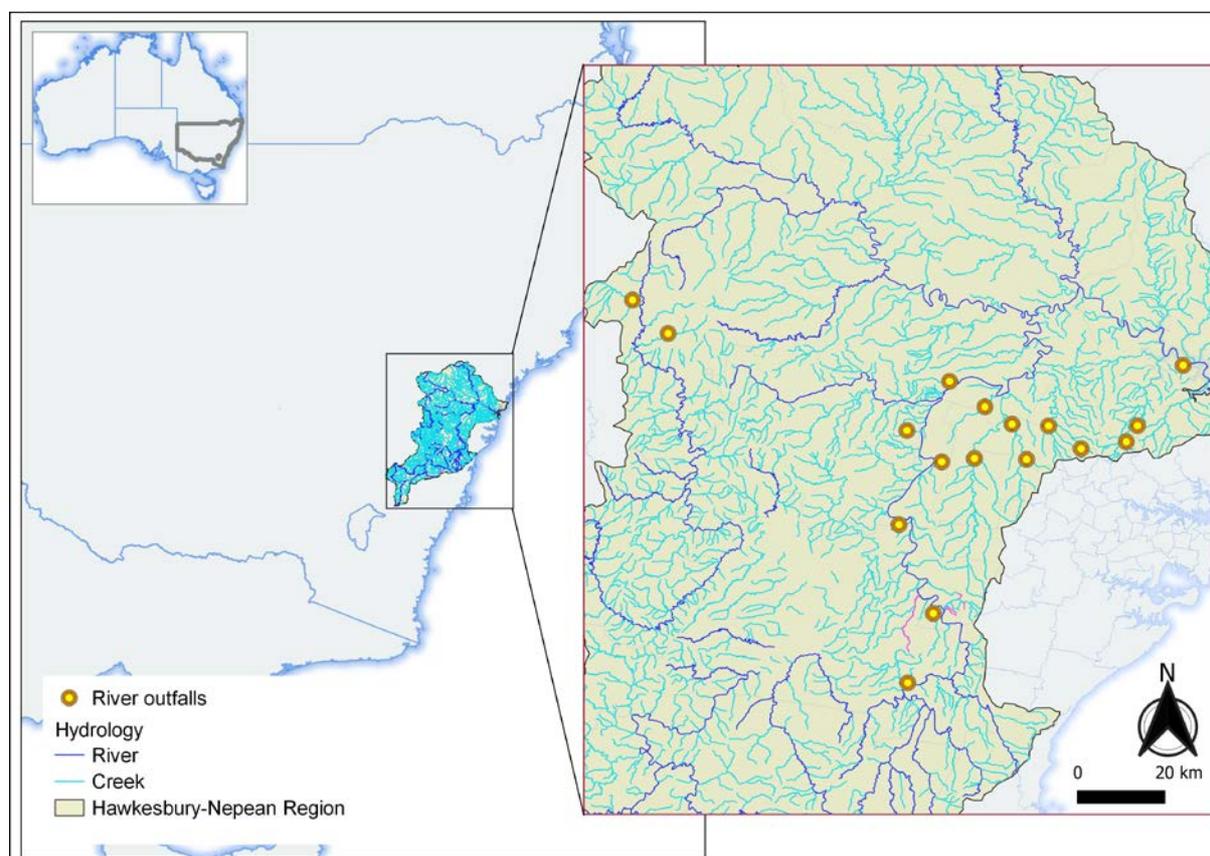
This report aims to assess effluent monitoring data between 2017-2018 from river outfalls around the Hawkesbury-Nepean catchment areas to determine whether the potential water and financial benefits demonstrated for water treatment plants outputting to the marine environment apply also to freshwater systems. It also investigates the amount of nitrogen and phosphorus loads along the streams and ranks them. The outcomes of this report would be useful to identify potential impacts of inland outfalls on riverine biodiversity as well as human health risks. The results of this analysis may help the relevant stakeholders, policy makers and managers to prioritise the outfall infrastructure reform and wastewater recycling initiatives. Furthermore, it may also contribute to develop a strategy of natural resources management of riverine ecosystem health around Australia.

2. METHODS

2.1 Data collection

In this preliminary river study, water quality data were collected from 17 inland outfalls of two water authorities around the Hawkesbury-Nepean river by downloading the water quality data reports directly from water authorities (WTA) websites (Table 1 and Figure 1). Both websites have published four years of effluent monitoring data as required by the local EPA (EPA NSW, 2013a). WTA monitoring requirements varied depending on EPA license requirements. Therefore, the type of pollutant monitored varied across all outfall locations. Due to consistency, this report specifically chose and analysed 2017-2018 calendar year data for a pilot study. This report assessed only nitrogen, phosphorus and flow volume (Table 2), as these three indicators were commonly measured across all WTAs. Hydrology and Hawkesbury-Nepean catchment areas layers were downloaded from Geoscience Australia (Stein et al., 2011) and NSW Office of Water (2012), respectively.

Figure 1. Pilot study outfall locations across Hawkesbury-Nepean Region, New South Wales.



2.2 Data analysis

The pollutant contribution index, based on nitrogen and phosphorous loads, was calculated for each outfall (Figure 1). Outfalls were ordered from lowest to highest index value to rank them according to their relative pollutant contribution to the river environment. The index is based on a total nutrient load discharge (see below) using the variables of flow, and nitrogen and phosphorous concentrations.

Nitrogen and phosphorous (nutrient) load was calculated based on the Load Calculation Protocol (DECC NSW, 2009b) using

$$N_l = \sum_{n,p} \frac{Tf * N_a}{1000}. (1)$$

where, N_l is the total nutrient load in tonnes, calculated for nitrogen and phosphorous individually, Tf is the total monthly flow from each outfall in megalitres (ML) and N_a is the monthly average nutrient concentration in mg/L. Nitrogen and phosphorous loads were summed to provide the total nutrient load. Values were sorted and ranked for each outfall location for 17 outfall locations and grouped into quartiles. All sites have the same complete data of nitrogen, phosphorus and flow volumes.

3. RESULTS

3.1 Summary statistics

Summary statistics of the assessed parameters are presented in table 1. Total nitrogen varied between 0.06 and 38.5 mg/L, with an average of 6.54 mg/L. The mean value of total phosphorus was 0.17 and standard deviation values of 0.92 mg/L. Flow volume tended to have a wide range of values between 0 to 251,370 kL/day, with a mean of 12,895 kL/day.

Table 1. Summary statistics of the river outfalls dataset between 2017-2018 calendar year. In bold is the assessed parameter in this report.

Parameter	Unit	N	Min	Max	Mean	SD	SE
Ammonia	mg/L	2285	0	27.4	0.33	1.20	0.0005
Faecal coliforms	cfu/100mL	2249	0	720,000	1,150.28	24,815.33	11.0339
Oil and grease	mg/L	657	0	7	0.04	0.52	0.0008
pH	pH	91	6.1	8.3	7.30	0.40	0.0044
Total Nitrogen	mg/L	2357	0.06	38.5	6.54	4.41	0.0019
Total Phosphorus	mg/L	2357	0	26.6	0.17	0.92	0.0004
Total Suspended Solids	mg/L	2358	0	85	1.68	4.13	0.0018
Biochemical Oxygen Demand – 5 days	mg/L	2358	0	75	0.50	2.53	0.0011
Aluminium	mg/L	85	0.05	2.93	0.49	0.40	0.0047
Flow volume	kL/day	13761	0	251,370	12,895	15,812	1.1491

The outfalls ranking is divided into four quartiles, top 25% (green), 50th (amber), 75th (yellow), and the bottom 25% (red), which represent the nutrient load from low to high values (Table 2). Total nutrient load from individual outfall sites ranged from 838 to 133,142 kg, with a mean of 47,440 kg. There are five outfalls (Brooklyn, Wallacia, Wallerawang, Picton and North Richmond) representing the top quartiles, while the remaining were each represented by four outfalls. The top quartile has a minimum of 838 kg with the maximum of 4,527 kg nutrients load. The bottom quartile, on the other hand, has a high range of nutrient load between 80,289 and 133,142 kg, which was represented by Rouse Hill, Winmalee, St Marys and Quakers Hill WWTPs. There is significant variability between nutrient load values in the 50th quartile, which ranged from 5,142 to 47,650 kg.

Figure 2 shows that the top quartile outfalls (green dots) are located far from each other. The 50th, 75th and bottom quartiles (amber, yellow and red, respectively), on the other hand, tend to group closely together. While most of the top quartiles discharge closely or directly into the Hawkesbury river, the 50th, 75th and bottom quartiles seem to use local creeks as their main discharge point.

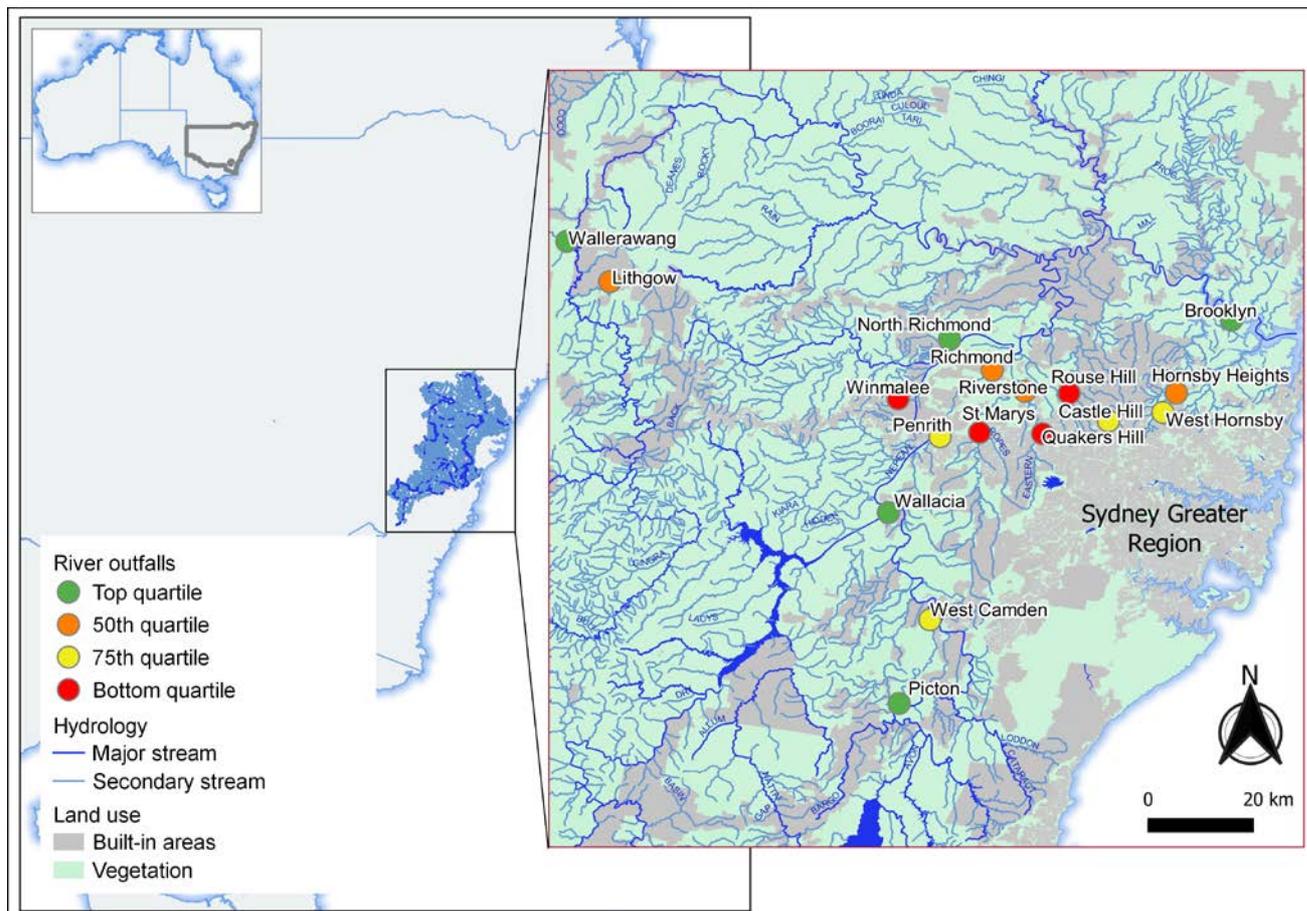
Table 2. Pilot study outfalls ranking around Nepean-Hawkesbury catchment areas.

Rank	State	Outfall	Authority	Nutrient Load (kg)
1	New South Wales	Brooklyn	Sydney Water	838
2	New South Wales	Wallacia	Sydney Water	1,848
3	New South Wales	Wallerawang	City of Lithgow Council	1,968
4	New South Wales	Picton	Sydney Water	2,740
5	New South Wales	North Richmond	Sydney Water	4,527
6	New South Wales	Richmond	Sydney Water	5,142
7	New South Wales	Lithgow	City of Lithgow Council	14,343
8	New South Wales	Hornsby Heights	Sydney Water	17,630
9	New South Wales	Riverstone	Sydney Water	47,650
10	New South Wales	West Hornsby	Sydney Water	50,642
11	New South Wales	Penrith	Sydney Water	74,910
12	New South Wales	West Camden	Sydney Water	76,897
13	New South Wales	Castle Hill	Sydney Water	79,740
14	New South Wales	Rouse Hill	Sydney Water	80,289
15	New South Wales	Winmalee	Sydney Water	94,946
16	New South Wales	St Marys	Sydney Water	119,236
17	New South Wales	Quakers Hill	Sydney Water	133,142

Note:

	= Top quartile
	= 50 th quartile
	= 75 th quartile
	= Bottom quartile

Figure 2. Pilot study outfalls ranked by quartiles for 2017-2018 calendar data.



4. DISCUSSION

Nutrient concentration and discharge flow data were collected from seventeen outfalls around the Hawkesbury-Nepean catchment areas. These outfalls were ranked according to their combined nutrient load (nitrogen and phosphorus). According to the current dataset, the general patterns (Figure 2) suggest that most of the outfalls are located in the lower catchment areas servicing urban areas on the outskirts of the Sydney metropolitan area. Higher nutrient load outfalls reflect the larger population services in the western Sydney and Blue Mountains area and tend to group closely, compare to the low nutrients load outfalls that serve smaller populations.

In the top quartile, despite having low nutrient load values, Brooklyn and Wallerawang WWTPs do not have stated nutrient load limits in their licenses, which could enable them to discharge substantial nutrient loads to the environment. The Wallerawang WWTP contributes nutrients to the upper Cocks River, a major tributary to Sydney's main water supply (Warragamba Dam). The rest of the top quartile outfalls have both nitrogen and phosphorus load limits stated in their licenses. In terms of nutrients load, Wallacia and North Richmond did not exceed their load limits, except Picton WWTP which slightly exceeded its nutrient load. The Picton WWTP uses most of its effluent to irrigate crops, and its licence (EPA NSW, 2020) specifies that the discharge of treated sewage wastes can only occur when the volume released is less than 25% of daily creek flow (Stonequarry Creek). As for 50th, 75th and bottom quartiles, all the outfalls discharged both nitrogen and phosphorus within their acceptable load limits.

The majority of the outfalls from the 75th and bottom quartiles service growing urban populations on the outskirts of the Sydney metropolitan area and discharge their nutrient load into tributaries within the lower reaches of the Hawkesbury-Nepean river system (Sydney Water, 2018). Without upgrades to wastewater treatment, over time the growing urban population and wastewater volumes can cause more nutrients to be discharged into the river, significantly increasing pressure in the inland water bodies. However, major upgrades to WWTPs has resulted in falling nutrient loads (Sydney Water, 2018). Without careful management, the pressure of increased populations can cause eutrophication due to algal blooms and raise the human health risks as well as affecting aquatic biodiversity (NSW Government, 2013; Paserl et al., 2018).

Improved Australia-wide inland outfalls monitoring is needed to identify the extent outfalls impact on water quality and riverine ecosystem. This preliminary analysis has given at least an estimation that river outfall monitoring in other states or territories might experience the same issues. Despite there being a concern of emerging pollutants, several studies confirmed that traditional pollutant (e.g. heavy metals (Zhou et al., 2019) and nutrients (Carey and Migliaccio, 2009)) have substantial impacts towards the river environment. However, there are relatively few studies which focus on traditional pollutants on Australian freshwater ecosystem.

Although this study used a limited number of outfalls, in the current dataset it can be seen that there are complex underlying issues of nutrient discharges and inconsistency in

reporting format across WTAs within one state. Compared to other states and territories, NSW has a regulation towards the WTAs in terms of data access. However, there is no clear statement in regard to uniform formatting of the data (EPA NSW, 2013b). Therefore, the WTAs may format data according to their convenience, which also leads to dataset inconsistency within the state. Both marine and freshwater outfalls have similar issues with regards to data availability, however, EPA NSW publication requirements are somewhat helpful for researchers or any relevant stakeholders to access water quality data of WWTP outfalls.

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