Nutrient Management in the Hawkesbury-Nepean River System

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Abstract

Sydney Water is exploring innovative ways to manage the load of nutrients (nitrogen and phosphorus) in the Hawkesbury-Nepean River (HNR). Over the last few decades, major investments in advanced nutrient removal technology have significantly reduced the load of nutrients discharged from wastewater treatment plants into the HNR. Today, diffuse pollution sources such as agricultural runoff and urban stormwater are the major contributor of nutrients to the HNR. There are significant opportunities for water utilities to invest in projects to reduce diffuse nutrient sources as part of a wholistic approach to manage nutrients and reduce their impact on aquatic ecosystems.

1. INTRODUCTION

1.1. The Hawkesbury-Nepean River and catchment

The Hawkesbury-Nepean River (HNR) is one of the largest coastal river systems in New South Wales (NSW). Its catchment covers approximately 22,000 km^2 with more than half this area being forested. Drinking water catchment areas and large national parks make up much of the forested part of the catchment. The river encircles the Greater Sydney basin and large parts of the catchment in this area have been cleared for extensive agricultural activity, urban development and industrial areas (Sydney Water, 2015).

The HNR and its catchment significantly contribute to the economic value of NSW, particularly for agriculture, providing fisheries as well as much of Sydney's fresh food. Numerous other activities in the catchment include extractive, manufacturing and processing industries (Department of Industry, Planning and Natural Resources (DIPNR), 2004; Department of Environment, Climate Change and Water (DECCW), 2010). The HNR is also highly valued by the public for recreational purposes, aesthetic values, as a tourism destination and for a myriad of environmental benefits (DECCW, 2010).

As a result of cumulative development and population growth over the past 230 years, the HNR has been highly impacted and modified. The regulation of flows through the damming of the Warragamba River and upper Nepean River has resulted in large volumes of water being extracted to supply drinking water to Sydney. The installation of numerous weirs for irrigation and industrial uses has reduced the river flow. In addition, a large number of Wastewater Treatment Plants (WWTPs) and industries located in the catchment discharge into the river, by design or by overflow and via stormwater runoff (Sydney Water, 2015).

As a consequence of this development, the water quality in the HNR declined, resulting in poor ecosystem health. Manifestations of poor water quality and river health included frequent blue-green algal (cyanobacterial) blooms in some sections of the river through the 1980's and early 1990's; and excessive growth of several introduced macrophytes and invasive weed species. In the 1980's and 1990's the environmental health of the river was considered poor (DIPNR, 2004; DECC, 2009).

Over the past few decade, the former Hawkesbury-Nepean Catchment Management Authority (HNCMA), the former Office of the Hawkesbury-Nepean, Office of Environment and Heritage (OEH), NSW Environment Protection Authority (EPA), Water NSW, Sydney Water, local councils, and other community organisations have been involved in developing major river health improvement strategies. In recent years, catchment management authorities have been disbanded and there has been a significant loss of momentum with respect to a 'whole of catchment' improvement program.

Figure 1 shows the HNR catchment in the Sydney region. This part of the catchment, downstream of Sydney's major water storages, is the focus area for this paper.

Figure 1 - Lower Hawkesbury-Nepean catchment (Rural Planning Services (RPS), 2018, p.16)

1.2. Nutrients – The problem with nitrogen and phosphorus

Nutrients such as nitrogen and phosphorus are essential elements for a healthy and productive river system. These nutrients support aquatic plant growth and these plants help to oxygenate the water and provide an important habitat and food source for fish and other aquatic organisms. Aquatic plants and algae can become problematic when their growth becomes excessive. Elevated levels of nutrients, along with other factors, can result in the excessive growth of algae and aquatic plants which can severely constrain recreation and commercial uses of the river, and adversely affect aquatic life.

In the HNR, around 70-80% of the nutrients that enter the river each year come from diffuse sources (DECCW, 2010). These diffuse sources include urban stormwater, agricultural runoff, soil erosion and poorly operating onsite wastewater systems such as septic tanks. Diffuse nutrients enter the HNR mainly during wet weather events. Rainfall across urban catchments generates large volumes of stormwater that is generally released to the river with very little treatment or attenuation. Rainfall across peri-rural parts of the catchment causes fertilisers and manures to be washed into the river.

Extensive land clearing has led to significant erosion problems across much of Western Sydney, with tonnes of soil washed into the river during wet weather. The banks of the river and many of its tributaries are also in poor condition and suffer from extensive bank erosion. Bank erosion can occur in dry weather due to wakes from powerboats. High stream and river flows due to rainfall and urban stormwater have caused significant bank erosion. Bank erosion not only contributes tonnes of sediment to the river each year, but also makes access to the river difficult and promotes the spread of

invasive weed species that opportunistically take hold along these damaged banks in place of native vegetation.

The remaining 20-30% of nutrients enter the river system from wastewater treatment plants that discharge treated wastewater to the river (DECCW, 2010). Wastewater generated by residential, commercial and industrial premises across the HNR catchment is collected and treated at one of seventeen major wastewater treatment plants. Sydney Water owns and operates 15 of these treatment plants, with the other two plants being owned and operated by Hawkesbury City Council. The load of nutrients discharged the river from wastewater treatment plants is reasonably constant during the year.

1.3. Nutrient management and regulation

Nutrients discharged to the HNR from licensed wastewater treatment plants are regulated by the NSW Environmental Protection Authority (EPA). Environment Protection Licenses (EPLs) specify the limits and conditions that apply to these discharges, including monitoring and reporting requirements. This includes concentration and load limits for total nitrogen and total phosphorus.

Other sources of nutrients that enter the river system are not regulated. Nutrients from diffuse pollution sources are not typically monitored and there are no concentration or load limits that apply as agricultural runoff or urban stormwater are not subject to licensing by the EPA. While some investment has occurred over the last few decades to reduce diffuse nutrient pollution, most notably through the River Recovery Program, there is no regulatory pressure for councils or landholders to adopt better nutrient management practices.

Wastewater treatment plants were a much larger contributor of nutrients to the river during the 1980's and 1990's as most of the plants used basic treatment technology with poor nutrient removal capability. Over the last few decades, significant investment in advanced nutrient removal technology at most of the HNR treatment plants has seen a dramatic reduction in the loads of nitrogen and phosphorus discharged to the river. Most of the wastewater treatment plants are very highly performing with limited scope for further affordable process improvements (AAJV, 2017).

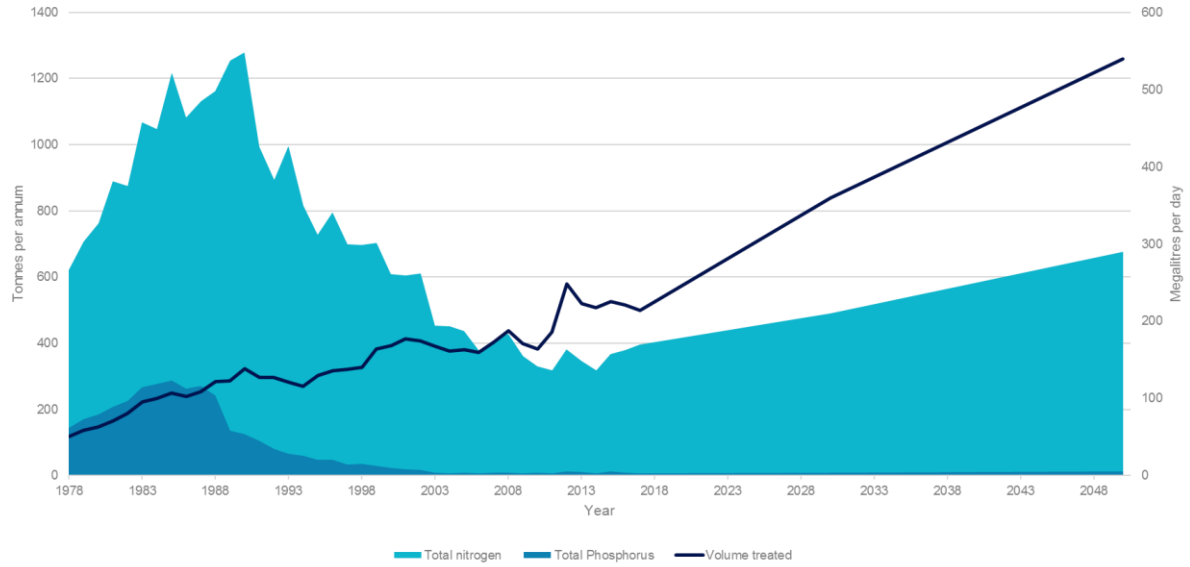

Figure 2 - Nutrients and flow contributed to the HNR from Sydney Water treatment plants

Figure 2 shows that the annual loads of nitrogen and phosphorus from Sydney Water's wastewater treatment plants peaked in the 1980's. At that time, Sydney Water discharged over 1,200 tonnes of total nitrogen and over 250 tonnes of total phosphorus to the river. During the 1990's and 2000's, significant investments were made to improve nutrient removal at Sydney Water's treatment plants. Many poorly performing plants were shut down, with wastewater being transferred to larger plants with advanced nutrient removal processes (Sydney Water, 2015).

Currently Sydney Water treatment plants release around 400 tonnes of total nitrogen and 10 tonnes of total phosphorus to the river each year. Sydney Water is now achieving world's best practice for phosphorus removal. Wastewater treatment plants still contribute a significant amount of nitrogen to the HNR system and there are limited affordable treatment solutions available to further improve nitrogen removal (AAJV, 2017).

1.4. Driver for regulatory change

The health of the HNR is critically important to both Sydney Water and the EPA. Both organisations have concerns regarding the long-term health of the river system, particularly with the increased pressures from new development across Greater Sydney. The fastest population growth is expected within the HNR catchment, where population is projected to grow from 740,000 in 2016 to well over 1.5 million in 2056 (Greater Sydney Commission, 2018)

The volumes of wastewater generated across the catchment will increase in line with population growth. As rural parts of the catchment are developed into new housing areas, the volumes of urban stormwater will substantially increase, adding pollutants to local waterways and compounding existing erosion issues.

In response to these risks to the health of the river, the EPA established a project to review the regulatory framework and licensing arrangement for nutrients that are discharged from licensed wastewater treatment plants across the catchment. The project was supported by the Office of Environment and Heritage (OEH) and the two major wastewater service providers in the catchment, Sydney Water and Hawkesbury City Council (HCC). There was already consensus that most of the nutrient load limits in wastewater EPLs were too high. The EPA planned to reduce these license limits to effectively cap the contribution of nutrients from wastewater treatment plants at current levels.

1.5. Objectives

The principal objective of the regulatory review project led by the EPA was to establish a regulatory framework for wastewater treatment plant discharges that allows for nutrient levels in the HNR to be managed in a way that maintains a healthy river in a growing city at a reasonable cost to the community. The concept of nutrient offsets was included in the scope of the review to enable treatment plant operators to invest in the most efficient nutrient reduction projects, even if these projects were targeting diffuse pollution sources.

Sydney Water began its own project to support the EPA in their regulatory review and to consider how this regulatory change may impact wastewater servicing strategies across the catchment. Sydney Water considered a catchment-wide approach to the management of nutrients in the river system, seeking to balance environmental, social and economic benefits to the people of Sydney.

A critical objective for Sydney Water was to have clarity regarding the future environmental regulatory requirements that would apply to its wastewater treatment plants. This would enable the most effective servicing strategies to be developed and allow the long-term funding needs for the implementation of these strategies to be determined.

Sydney Water is subject to economic regulation by the Independent Pricing and Regulatory Tribunal (IPART). As part of this economic regulation, Sydney Water is required to supply medium to long-term investment plans to IPART as part of each pricing submission. The next pricing submission is due to IPART in June 2019 and therefore the details of the regulatory framework were required by mid-2018 to inform planning activities.

2. METHODOLOGY

Sydney Water appointed a dedicated Program Manager in 2016 to deliver the HNR nutrient management project. Funding for the project was secured for three years from 2016 until 2019. It was essential that Sydney Water's strategies to manage nutrients were underpinned by the best available science, supported by the community and were able to be implemented in a cost-effective way. To enable this project, a series of parallel workstreams were developed as described below in Figure 3.

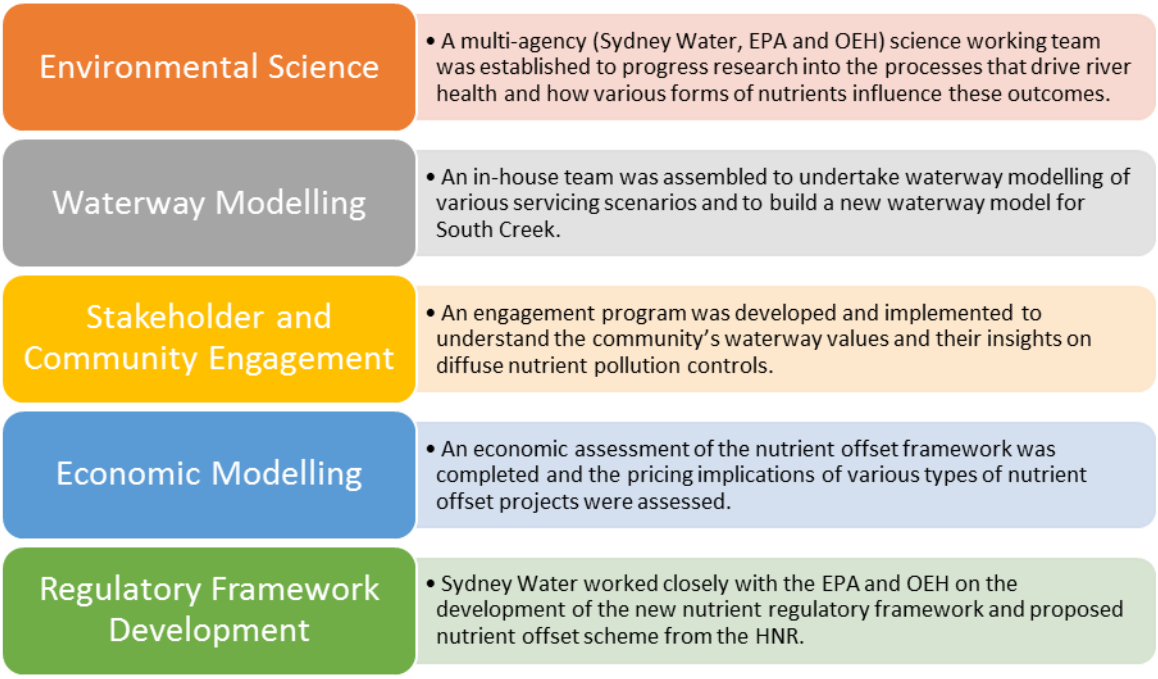

Figure 3 - HNR nutrient project workstreams

Together, these sub-projects provided a clear direction for Sydney Water's wastewater servicing strategies in the catchment. Each workstream was led by a subject matter expert that provided advice to the Program Manager. The following sections describe the workstreams in more detail.

2.1. Environmental science and waterway modelling

To ensure that environmental science work was well coordinated, a multiagency (Sydney Water, EPA and OEH) science working group was formed in early 2017. The purpose of this group is to share existing data and information on the HNR and through constructive discussions, improve the collective understanding of the complex aquatic processes that govern the health of the river system.

Three clear issues emerged that warranted further action and investigation:

1. The South Creek sub-catchment is critically important to the management of sustainable development in the HNR system. The impact of new stormwater and wastewater flows to South Creek will be significant and required a dedicated South Creek hydrodynamic waterway model to be constructed by Sydney Water.
2. A baseline dataset was required for dry and wet weather period to quantify the current state of the river system. This required monitoring campaigns to the conducted along the main stem of the river and within many of the tributaries.
3. The relative contribution of point and diffuse nutrient sources was poorly understood. This goes beyond their annual mass loadings and considers how the aquatic environment is impacted by different forms of nutrients and how nutrients transform and interact with each other in the river system. Further research was required in this area.

2.2. Stakeholder and community consultation

Sydney Water engaged Rural Planning Services (RPS) to deliver community and stakeholder engagement to inform decision-making about nutrient management in the HNR catchment area. This project comprised three stages: a HNR catchment social analysis, a community and stakeholder engagement strategy and community and stakeholder engagement research.

The overall strategy was informed by four foundation topics which arose during the initial social

analysis and were used to focus community and stakeholder engagement, enabling a deep and thorough understanding of core issues during the project. Social, economic and environmental values the community has for the river system and their expectations for river health were explored. Subsequently, consideration was given to how best these values should be addressed in early planning and decision-making, and how nutrients should be managed to ensure river health outcomes are delivered at the least cost to the community (RPS, 2018)

The HNR catchment nutrient management research project was designed to hear the views and perspectives of key stakeholders, community organisations and individuals across the catchment. It provided the community and stakeholders with numerous ways to participate.

A variety of face-to-face, telephone and online engagement tools were used to inform stakeholders and the community about the project and engagement activities and to facilitate the expression of their opinions, experiences and ideas. The research was conducted between December 2017 and June 2018. An overview of the methods, target audience and reach are provided in Table 1 below.

Table 1 – Multi-faceted design of the engagement program (RPS, 2018)

Method	Target Audience	Reach
Phase 1		
Intercept survey	• Users and visitors to the waterway	• 168 participants
Phase 2		
Community reference group (CRG) series	• Local residents • Community groups • Regular waterway visitors or users • Local council representatives	• 26 participants across • 5 groups
Facilitated meetings	• Local council representatives • Office of Environment and Heritage (OEH)	• 3 meetings • 9 councils and OEH • 35 participants (excluding project team)
	• Developers working within the catchment	• 2 participants
	• Local Aboriginal Land Councils	• 1 Local Aboriginal Land Council
Phase 3		
Telephone survey	• Local residents within the catchment • Residents across the Sydney Water area of operation	• 300 participants • 300 participants
Concurrent activities		
Sydney Water Talk project webpage	• Interested community members • Sydney Water customers • Users and visitors to the waterway • Community Reference Group participants	• 1286 visitors ▪ 829 aware visitors ▪ 409 informed visitors ▪ 48 engaged visitors
Places you value interactive map	• Interested community members • Sydney Water customers • Users and visitors to the waterway • Community Reference Group (CRG) participants	• 33 people placed 184 pins on interactive map: ▪ 34 comments for environmental value ▪ 29 comments for social value ▪ 67 comments for water-based recreational value

Method	Target Audience	Reach
		▪ 42 comments for land-based recreational value ▪ 12 comments for economic value
Social media	• Facebook, LinkedIn and Instagram users	• 58,110 total impressions: ▪ 42,004 on LinkedIn ▪ 12,344 on Facebook ▪ 3,762 on Instagram • 325 likes on Instagram

2.3. Economic modelling

The cost of capping nutrient loads from wastewater treatment plants into the HNR will substantially increase Sydney Water's wastewater servicing costs due to the need to absorb the impacts of unprecedented population growth. This was recognised by the EPA and was a driver behind the development of a nutrient trading and offset protocol. This offset protocol would allow treatment plant operators to comply with the nutrient load limits through investment in the reduction of diffuse nutrient pollution in the catchment. These offset projects would generate credits that would be used to offset nutrient loads discharged from wastewater treatment plants.

Work was required to quantify the financial impact of the capping of nutrient loads under two scenarios.

1. Current state – where growth would require the management of nutrient loads through treatment plant upgrades, the transfer of wastewater to the ocean or expansive residential and industrial recycled water schemes.
2. Nutrient offsets – where investments are directed to reducing nutrient pollution from other sources and therefore generate nutrient offset credits to ensure ongoing compliance with EPL load limits.

Sydney Water engaged Sapere Research Group to provide advice on the economic risks and implications of nutrient offset projects and the complexities of how these investments could be accounted for within IPARTs pricing regulation.

3. RESULTS

The HNR has been studied for many decades by Sydney Water and other agencies. There is an extensive temporal and spatial dataset of water quality information for the river system and Sydney Water has a sophisticated hydrodynamic model of the main stem of the river. This model has provided some great insights into the potential impact of development on the health of the river.

In other areas such as community engagement, Sydney Water has not been as active. These elements of the project required significant effort from the project team. Economic modelling was the last part of the project to commence as it relied on inputs from the other workstreams. This economic work is still being finalised at the time of writing.

The following sections document some of the key results from each project workstream.

3.1. Environmental science and waterway modelling

The science working group initiated a series of campaign monitoring programs across the river system. The most significant of these was undertaken during May 2017. Over 140 sites were sampled along the river and its major tributaries for a myriad of parameters and pollutants. Although this sampling was conducted in dry weather, it became clear that the river was still recovering from the effects of wet weather that had occurred many weeks earlier.

This campaign was organised by OEH and Sydney Water. Due to the large scale of the exercise, it attracted the interest of other national and international aquatic science groups. During the exercise, scientists from the Sydney Institute of Marine Science, Macquarie University, University of Canberra and the University of Wisconsin/Milwaukee also participated in collecting samples. Additional samples were also taken to support some of their own specific research programs.

In September 2017 and January 2018, further sampling campaigns were completed that better represented dry conditions. Due to the persistent dry weather, it was impossible to undertake river sampling during a significant wet weather event. Sydney Water will conduct this wet weather monitoring during the next major rainfall event.

The river monitoring campaigns produced some results that were unexpected and will drive scientists to develop a new conceptual model for aquatic processes within the river system. The major findings were:

- Most of the sections of the HNR and its tributaries do not meet the water quality objectives set by the Health Rivers Commission (HRC) or the Australian and New Zealand Environment Conservation Council (ANZECC).
- The river is impacted for several months following heavy rainfall. This is due to its extensive catchment area and the enormous loads of pollutants that are washed into the river during these events.
- Most of the pollutants that enter the river system are retained within the river in some form. Only very large flood events cause an export of nutrients and sediment to the ocean. These events occur very infrequently.
- The 'artificial' flows that are created by wastewater treatment plant discharges have a positive impact on river health as they reduce the residence time in the river, provide additional water for licensed extraction and often dilute the background levels of phosphorus. Increasing treatment plant discharges reduces the risk of algal blooms.
- The majority of phosphorus in the river is derived from diffuse nutrient inputs. Treatment plant phosphorus has been reduced to very low levels and is therefore a minor contributor.
- The treatment plants have a negative impact on the river in terms of macrophyte growth. This is due to the nitrogen that the treatment plants discharge to the river. Unlike algae, macrophyte growth is not abated by reduced residence times. Macrophytes can also utilise phosphorus in sediments in combination with instream nitrogen to enable their growth.
- Sediment appears to play a far more active role in river health than previously thought. The traditional understanding was that sediment formed deep inactive layers on the riverbed in areas such as Sackville where the velocity of the river reduces. Sampling results show that the opposite is true in areas impacted by the influence of tides. The sediment in the section of river between Windsor and Wisemans Ferry is generally held in suspension by tidal flows. Some minor sedimentation occurs at the change of tides, but this is quickly resuspended again. Rather than being inactive, this sediment plays a much more active role in eutrophication events.

Waterway modelling is also being progressed using a hydrodynamic model of the HNR. This model was built by Sydney Water for the use of the NSW state government. A supplementary model is also being built for the South Creek sub-catchment as this part of the HNR system will be the location of most greenfield urban development over the next few decades. Together, these models will provide insights into the water quality and river health outcomes of various servicing pathways. This includes the relative benefit of catchment work to reduce diffuse sources of nutrients as well as more traditional wastewater treatment plant upgrades.

3.2. Stakeholder and community consultation

The following key themes and findings emerged from the community and stakeholder engagement process.

Table 2 - Key themes and findings from Community Engagement (RPS, 2018)

Key theme	Key findings

Community values held for the Hawkesbury-Nepean waterways	• The community recognise the importance of protecting the river and hold the expectation that river health will be maintained
	• The waterways are valued for the recreational activities they afford
	• The intrinsic environmental values of the waterways are appreciated by the community
	• The community recognise the economic value of the waterways in contributing to tourism and agricultural industries
	• Barriers to the enjoyment of the waterways include:
	  ◦ Lack of access, amenities and facilities.
	  ◦ Poor water quality affecting the ability to swim in some parts of the river.

Population growth in the catchment	• Unprecedented population growth in Western Sydney is compromising the environment and negatively impacting on water quality • Stakeholders agreed that more should be done to address poor development practices impacting on the environment • Population growth is placing greater pressure on existing wastewater treatment plants and stormwater infrastructure.
Stormwater infrastructure and management	• Existing basic stormwater design in established areas influences the effectiveness of stormwater management • Water sensitive urban design (WSUD) is generally considered as an effective approach to stormwater management • Maintenance of stormwater infrastructure is a key issue facing local councils
Barriers to effective nutrient management	• Poor governance of waterway management in NSW, as waterway health outcomes can only be achieved through a coordinated, catchment-wide management approach. • Achieving a holistic understanding of the impacts of nutrient pollution on the Hawkesbury-Nepean waterways requires catchment level data • Insufficient funding and resourcing impacts councils' ability to effectively manage their part of the catchment and the impacts of new development on the river system
Environmental awareness and community education	• Educating the community on urban water management practices and their impact on river health is required • Greater emphasis needs to be placed on informing the residents of Sydney on the impacts of growth on water quality • Environmental education for children and youth required greater attention • Opportunities are present for the sharing of Aboriginal and European natural resource management practices
Increased awareness of diffuse pollution in the Hawkesbury-Nepean Catchment	• There are varying levels of awareness across the community of the sources and impacts of diffuse pollution on waterway health • Poor agricultural practices can result in an increase of nutrients entering the waterways • Regular maintenance of onsite wastewater systems can reduce nutrient pollution • Soil erosion and poor sediment controls have significant impacts on the health of the waterways • Urban stormwater presents significant challenges to waterway health.
Increased awareness of wastewater	• There are varying levels of awareness among stakeholders and the community regarding wastewater treatment and nutrients entering the waterways

Key theme	Key findings
treatment in the HNR Catchment	• The health and dynamics of the waterways are impacted by the release of treated wastewater with nutrients and flow playing a role.
Managing nutrients in the Hawkesbury-Nepean Rivers	• There was general support from stakeholders and community members for Sydney Water to focus attention on diffuse pollution to protect the river • Nutrients entering the waterways through urban stormwater and soil erosion should be prioritised.

Caring for the waterways through the implementation of the Hawkesbury-Nepean Nutrient Management Framework	• The implementation a nutrient offsetting program is widely supported by key stakeholders and the community
	• The upgrade of existing wastewater treatment plants is the least preferred option for nutrient management within the catchment
	• Community engagement and partnerships can lead to better outcomes for the environment and individuals involved
	• Some concerns about a nutrient offsetting program were noted:
	  ◦ Some stakeholders and community members were concerned with the naming of the project
	  ◦ The commitment of long-term funding for nutrient management is required to ensure community trust is sustained
	  ◦ Additional information on how a nutrient offsetting program would work was requested by key stakeholders and community members
	  ◦ The ownership of land was considered as a potential challenge to the effectiveness of nutrient offsetting projects.

Nutrient offsetting projects to improve the health of the Hawkesbury-Nepean Rivers	• Nutrient offset projects preferred by CRG members include bank stabilisation and bank renewal, constructed wetlands, riparian restoration, water sensitive urban design projects, cultural burning, efficient irrigation and pollution reduction. • Complementing nutrient offsetting projects with educational programs is encouraged by community members.

3.3. Economic modelling and pricing implications

Nutrient offset projects are expected to be far cheaper than traditional wastewater treatment solutions, particularly when the wastewater plants are already providing best-practice treatment. Recent offset projects undertaken by Queensland Urban Utilities (QUU) have shown that investments in bank stabilisation to reduce erosion are around 10 times cheaper than treatment plant upgrades yet achieve the equivalent reduction in nutrient loads (Water Services Association Australia (WSAA), 2017).

IPART assesses the financial needs of Sydney Water and sets the maximum prices that Sydney Water can charge customers for a standard set of core water services. The core services are drinking water supply, wastewater services and stormwater drainage. Many forms of nutrient offset projects do not neatly fit into this suite of core services and therefore the pricing implications of nutrient offset investments must be carefully considered.

For example, Sydney Water provides stormwater drainage services in some parts of Sydney and therefore charges customers in those areas a stormwater fee. For the majority of the HNR catchment, Sydney Water does not manage stormwater. Rather, local councils provide stormwater services and they charge their rate payers a stormwater service levy. If Sydney Water partners with a local council in the HNR catchment to deliver a project to reduce nutrients in stormwater, how should this investment be treated by IPART? Should it be treated as a stormwater project and have the costs reflected in the Sydney Water stormwater fee even if the residents who pay the Sydney Water fee live in other parts of the city? What if Sydney Water pays for an asset (e.g. a constructed wetland) that is situated on land owned by a local council? Who is responsible for this asset, who maintains it and how is depreciation handled?

Sydney Water is considering various nutrient offset project options and how each of these investments would best be considered in terms of economics, pricing considerations, asset management arrangements and taxation treatments. Early results of this work indicate that Sydney Water could treat most nutrient offset projects as wastewater servicing investments, irrespective of the nature of the actual offset project type. This is because the inherent reason behind the investment is to manage compliance with wastewater license requirements (Sapere, 2018).

4. DISCUSSION

The key to the success of nutrient offset projects is to ensure that the receiving waterways benefit from this wholistic approach to nutrient management. Like most river catchments, the HNR receives nutrients from a variety of sources. Each source contributes different forms of nitrogen and phosphorus at different times and in different circumstances.

Highly bioavailable forms of nutrients are readily utilised by aquatic plants to fuel their growth. Nutrients from wastewater treatment plants are in forms that tend to be more bioavailable than nutrients that are found in urban stormwater or in eroded sediments. Agricultural runoff can be highly bioavailable if that runoff contains manures or commercial fertilisers that are specifically designed to generate rapid plant growth.

Emerging research is showing that the bioavailability of nutrients changes once they enter a waterway. The nutrients can transform to more bioavailable forms as a freshwater river transitions to salt water, as it enters the estuary. In the HNR, this transition in bioavailability is likely to occur between Windsor and Wisemans Ferry which represents around 80kms of the rivers length. It is also likely to impact the lower tidal section of South Creek. This section of the river has experienced the worst algal blooms, including regular blue green algal blooms in the 1980's and 1990's.

Sydney Water is planning to further this research through a partnership with Griffith University, the Queensland Department of Environment and Science as well as Queensland Urban Utilities. Like Sydney Water, Queensland Urban Utilities is also interested in understanding and quantifying the processes that influence the bioavailability of nutrients within the environment and how this information can be used to better guide nutrient offset projects and their regulation.

5. CONCLUSION

From the multifaceted work program that has been implemented, it has become clear that there are opportunities for water service providers to explore alternative and innovative ways to manage the impacts of nutrients on local water bodies. As wastewater treatment plants are upgraded to provide more advanced nutrient removal, their relative contribution to the overall catchment nutrient load reduces. There are marginal benefits to be realised from investment in costly processes to reduce nutrient concentrations to very low levels, particularly in catchments with high diffuse nutrient loads.

New research is showing that while diffuse nutrients enter the HNR in major spikes during rain events, the nutrients play an active role in the health of the river all year round. Recent sampling by OEH and Sydney Water has challenged the accepted conceptual model for the river system. The sampling showed that in the Windsor to Wisemans Ferry reach, sediments generally stay in suspension, even during dry weather. The residence time in this part of the river is deep and wide (partly due to sand and gravel mining activities). The sediments, organic material and nutrients do not settle forming a largely inactive layer on the river bed. Rather, the energy supplied by tidal action keeps this material in suspension, ensuring it plays an active role in water quality and river health all year round. This new information strengthens the case for investments that seek to reduce diffuse sources of nutrients.

The community and environmental interest groups are very supportive of investments seeking to improve the water quality and health of the HNR. While the community still have some concerns regarding the discharge of treated wastewater into the river system, there is a greater acceptance that the treatment plants are very highly performing and that there are limited affordable options to further improve their nutrient removal performance.

Local communities and councils have strongly supported a HNR nutrient management strategy where Sydney Water takes a more active role in the reduction of nutrient pollution from diffuse sources that currently receive inadequate attention, investment and regulation. These diffuse offset projects can also provide additional social and community benefits such as improvements to safe river access, more appealing river frontage and the attraction of more wildlife into the local area. This provides a stronger and more valued connection between the local community and their waterways which will further reinforce a willingness to pay for ongoing investments to protect and enhance the health of the Hawkesbury-Nepean River system for future generations to enjoy.

6. ACKNOWLEDGMENTS

This work has been progressed through the support of many passionate staff from Sydney Water, EPA, OEH and partnering consultants from AAJV, RPS and Sapere Research Group. I would particularly like to thank Jenny Rogers who has provided tremendous support to the project team and to me personally.

I look forward to continuing this work alongside our current project team and with additional research partners in Queensland. Through the implementation of pilot nutrient offset projects across the HNR catchment, I am confident that these and future similar investments will form a valuable contribution to the ongoing challenge of population growth and nutrient management in the Hawkesbury-Nepean River catchment.

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