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Water sensitive urban design mitigation effect on greenfield urbanisation in the Mangakootukutuku catchment: lessons learnt from the first year of stream water quality monitoring

Bénéfices des techniques alternatives d'assainissement des eaux pluviales pour les nouveaux développements urbains du bassin versant Mangakootukutuku : retour d'expérience de la première année de suivi de la qualité des cours d'eau

Karine E. Borne^{1*}, Sharleen Yalden¹, Jennifer Gadd¹, Lucy McKergow¹, Jonathan Moores¹, Neale Hudson¹, Gareth van Assema¹, Margaret Bellingham¹, Jackie Colliar², Andrea Phillips², Nick Young²

1.National Institute of Water & Atmospheric Research Ltd (NIWA)

2.Hamilton City Council (HCC)

*karine.borne@niwa.co.nz

RÉSUMÉ

Du fait de l'augmentation de la demande en logements, de nombreuses zones rurales en périphérie des grandes villes se transforment progressivement en zones urbaines. Les techniques alternatives (TA) d'assainissement des eaux pluviales visent à capter, gérer et traiter les ruissellements urbains pour maintenir une bonne qualité écologique des cours d'eau. La présente étude expérimentale vise à suivre, à long terme (10-15 ans), la qualité des cours d'eau lors de la transformation d'un bassin versant rural en zone urbaine intégrant des TA (Tiireke), par rapport à un bassin versant urbain conventionnel (BUC), i.e. utilisant un réseau d'assainissement enterré (Rukuhia). Les résultats suggèrent que les premiers stades de développement et de terrassement ont entraîné des exports de sédiments légèrement plus élevés que les zones rurales non développées en amont. L'export de sédiments du bassin versant urbain conventionnel voisin était cependant nettement plus important. Bien que l'on s'attende à ce que le BUC contribue à un export de cuivre, ceci a été masqué par les exports élevés du bassin versant rural amont comprenant des tourbières (possible source de cuivre). Un autre bassin versant conventionnel, ne subissant pas l'influence de potentiels exports de contaminants en amont, est actuellement à l'étude pour inclusion dans le programme de suivi. L'analyse préliminaire de l'ensemble des polluants suivis et des activités prévues dans le bassin versant Tiireke aidera à affiner la stratégie de suivi pour les années à venir. Ceci permettra de mieux capturer l'impact des activités de développement et les bénéfices liés à l'utilisation généralisée des TA une fois la zone développée, par rapport à une gestion conventionnelle des eaux pluviales.

ABSTRACT

In a context of increasing housing demand, many greenfield areas at the outskirts of major cities are gradually being turned into urban areas. Green infrastructure systems and/or Water Sensitive Urban Design (WSUD) are alternatives to conventional drainage systems that aim to capture, manage and treat urban runoff to maintain a good ecological health of receiving water bodies. This long-term experimental study, i.e. 10-15 years, aims to track through time, the changes occurring as one catchment (Tiireke) changes from rural to urban land use, integrating WSUD, compared to a conventional (i.e. "Business as usual" (BAU), no WSUD) catchment (Rukuhia). Initial results suggest that early stages of development and earthworks have resulted in slightly higher suspended solids (SS) exports compared to upstream rural undeveloped areas. SS export was however much higher from the nearby conventional urban catchment. Although it is expected that the BAU urban subcatchment contributes to copper export, this was concealed by in-stream attenuation of the high input loads from its upstream rural/peatland subcatchment. An alternative BAU catchment, with no upstream contaminant export influence, is being investigated for the next phase of monitoring. Initial data analysis of the broad list of monitored pollutants and planned activities in the Tiireke catchment will help refine the monitoring strategy for future years to better capture the impact of development activities and the benefits provided by the widespread use of WSUD once developed, when compared to a conventional urban catchment.

KEYWORDS

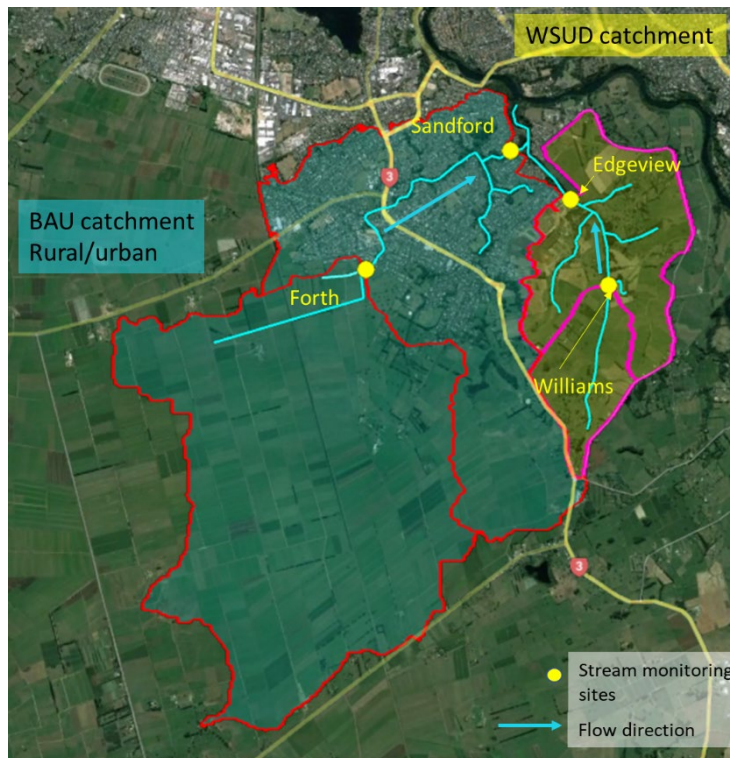
WSUD, catchment scale, stream water quality, suspended solids, copper

1 INTRODUCTION

Worldwide, urbanisation has led to increased imperviousness, and associated runoff and pollutant exports impacting the ecological health of receiving water bodies. Aotearoa New Zealand is no exception, with clear evidence of the effects of urban land use on freshwater ecosystems (Larned et al., 2020). In a context of increasing housing demand, many greenfield areas at the outskirts of major cities are being gradually turned into urban areas. This is the case in Hamilton, the largest inland city of New Zealand, which is located on the banks of the Waikato River. Hamilton City Council (HCC)'s obligation is to protect and enhance the health and wellbeing of the Waikato River. This is partly achieved through inclusion of green infrastructure systems or Water Sensitive Urban Design (WSUD) in new developments, as an alternative to the conventional drainage system. WSUD helps to capture, manage and treat urban runoff to maintain a good ecological health of receiving water bodies. Aspects of WSUD have been studied at a local/system scale over many years however the impact of WSUD at a catchment scale is still not fully understood (Wild et al., 2020). The aim of the present project is to assess and better understand the change in land use - stream health relationships, at a catchment scale, through the transition from rural to urban development, and to evaluate the benefits of WSUD to mitigate adverse impacts on the hydrology, water quality and freshwater ecological systems. This will inform improved approaches to urbanisation that meet HCC's overarching objective "to restore the health and wellbeing of the Waikato River".

2 METHODS

2.1 Catchment description



The study area is located south of Hamilton, New Zealand, and referred to as the Mangakootukutuku catchment. This catchment is divided into 2 smaller catchments: Tiireke ("WSUD" catchment) and Rukuhia (control or "Business as usual" (BAU) catchment) (Fig. 1). Tiireke (4.9 km²) is a greenfield being turned into urban land through the "Peacocke" development which started in 2017 with expected completion within the next 15-20 years. The stormwater management system of the Peacocke development will mainly rely on WSUD and will comprise mainly wetlands and some swales and rain gardens. Rukuhia is a mix of rural (15.6 km²) and conventional urban development (6 km²) from the 1950s (mainly residential with low-density single dwellings, small areas of commercial land (neighbourhood shopping centres), schools and parks).

Figure 1 Business as usual (BAU in blue) and WSUD (yellow) catchments, stream sampling sites and their respective subcatchments (delineated in red for BAU, and pink for WSUD catchments)

2.2 Monitoring and data analysis

This is a long-term experimental study, i.e. 10-15 years, that will track through time, the changes occurring as one catchment (Tiireke) changes from rural land use to urban land use, with best practice environmental protection and mitigation applied during the development and construction phase, and WSUD incorporated in the developed phase, compared to a conventional (i.e. no WSUD) catchment (Rukuhia). Four stream monitoring sites (Fig 1) were installed in 2019 where 5 min-interval flow and physico-chemical (4 sites only) data are collected, as well as discrete water quality samples during baseflow (grab samples) and storm events (using ISCO samplers) and fish and invertebrate (annual surveys).

The first year of storm event water quality sampling occurred in 2021-2022, at which time part of the Tiireke catchment had already been partly developed and earthworks for road network and water services was occurring in the downstream part of the catchment (i.e. within the Edgeview subcatchment). Over that period of time, a total of 426 samples were analysed for suspended sediment concentration (SSC), total and dissolved copper (Cu) and zinc, nitrogen, phosphorus, and the faecal indicator bacteria *E. coli* and total coliforms. Only SSC and Cu data collected during storm events are presented in this abstract. 74 to 119 samples were collected at each site during storm events (11 events in total from May 2021 to February 2022) and covered at least the rising limb of the hydrograph and peak flow. Data were used to compute 2 types of metrics:

- a) In-stream event pollutant loads - when field samples covered at least 80% of the event flow volume, which was the case for 2 to 5 events at each site over the 11 sampled.
- b) In-stream modelled event pollutant loads - using flow data and modelled concentrations computed from regression equations ($r^2=0.80-0.97$) including a combination of the predictor variables: flow, antecedent dry days, 7 days antecedent rainfall, season. This allowed us to calculate modelled pollutant loads for 25 to 27 events at each site over the monitoring period.

Field (a) and modelled (b) loads were compared to inform on the most suited approach for event-based assessment of pollutant export at a catchment scale.

For easiest comparison between sites and catchments all event load data are reported relative to the monitoring site's contributing catchment area and event rainfall depth (i.e. g/km² of contributing catchment/ mm of rainfall).

3 RESULTS

Initial results suggest that modelled data (Fig 2-b, 3-b, 4-b) allowed a greater variability and magnitude of event pollutant loads to be captured, at each site, compared to those derived exclusively from field data (Fig 2-a, 3-a, 4-a). Although field data covered all seasons, most of the event loads that could be calculated from field data meeting the criteria stipulated in a) above, were over summer and autumn. Computed field event loads therefore captured a narrower variability than loads calculated from modelled data that covered all seasons. Discrepancy between field and modelled pollutant loads was particularly visible at Forth, where median modelled event pollutant loads were 9.5 to 16.5 times higher than field data, compared to 2 to 5.7 times higher for the other sites. The low number of field event pollutant loads that could be calculated at Forth (only 2 out of 7 collected events at that site met the requirements of 80% of event flow volume sampled) compared to 3-5 events at the other sites, might have also reduced the chance to capture the full range of possible event pollutant loads. Given the logistical difficulties of simultaneously sampling multiple sites with various hydrological responses (flashy and intense response at downstream urban sites versus lagging and slower at the upstream rural sites), thereby reducing the number of field event load calculations possible, we consider an approach that combines discrete sampling during storm event with modelling to be essential in understanding event loads.

The downstream site of the BAU catchment (Sandford site) exhibited higher modelled SS event pollutant loads (relative to area and rainfall) with a 4.7 times higher median than its upstream site Forth (Fig 2-b). A relatively smaller increase of Cu loads was noticed from upstream to downstream in this catchment, as shown by overlapping box plots in Fig 3-b and 4-b. This suggests markedly greater input of sediments from the urban part of the BAU catchment (Rukuhia) while this phenomenon was relatively smaller for copper. Although it is expected that the urban part of the BAU catchment contributes to copper export, it is partly concealed by the high upstream loads from Forth, and the possible attenuation mechanisms occurring between both monitoring sites (Forth and Sandford). The Forth subcatchment is primarily rural (mainly dairy farming) but includes some drained peatlands which are thought to generate high concentration of copper in the stream during rainfall events and this contributes to about 0.4 g of TCu/km²/mm of rainfall (Fig 3-b). While the Sandford subcatchment appears to be an appropriate control catchment (as conventional urban catchment) for SS, its upstream rural subcatchment has impeded accurate assessment of metals export.

A slight increase of SS loads was observed at the downstream site of the WSUD catchment (compared to the upstream site Williams) and no increase was detected for Cu (Fig 2-b, 3-b and 4-b). Higher SS loads at Edgeview than Williams (median of 8,900 versus 4,900 g/km²/mm) could be explained by inputs from the already developed urban area and from ongoing construction activities close to the Edgeview sampling site, which together represented about 10 % of Edgeview subcatchment area. These exports were however substantially lower than from the BAU catchment exhibiting a median SS load of 20,800 g/km²/mm (modelled data at Sandford, Fig2-b).

In recognition of excessive influence of rural inputs in the control urban catchment, an entirely urban control catchment with no upstream rural influence, is being investigated for the next phase of monitoring. Initial data analyses of the broad list of monitored pollutants (zinc, nitrogen, phosphorus, faecal indicator bacteria) and of the planned activities in the WSUD catchment will help refine the monitoring strategy for the next years to better capture the impact of development activities and the benefits provided by the widespread use of WSUD once developed, when compared to a conventional urban catchment.

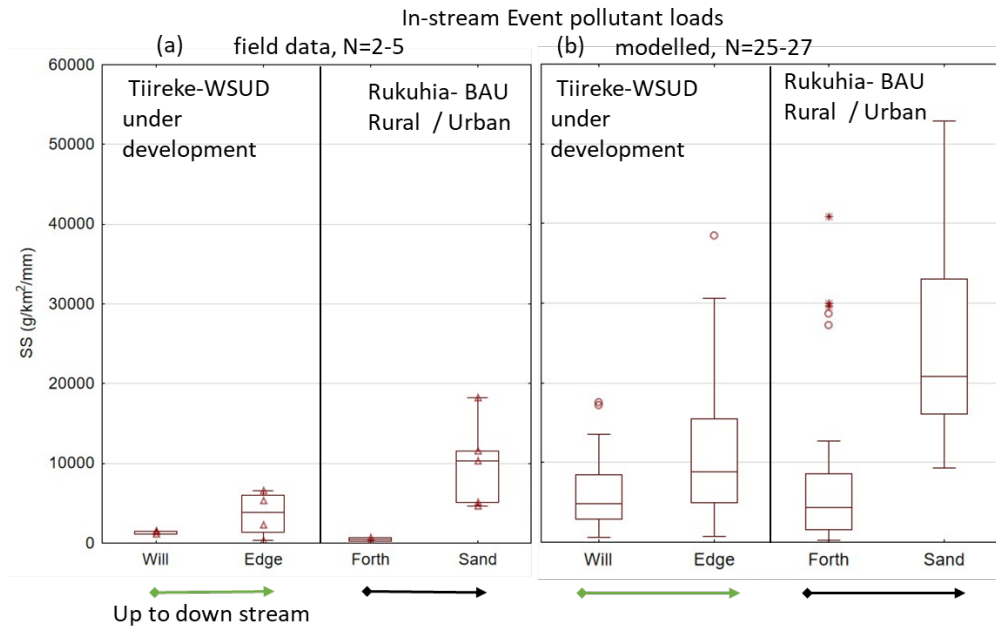


Figure 2 Stream Suspended Sediment event loads at each site per km² of contributing catchment per mm of rainfall, (a) field data, (b) modelled data. Will=Williams, Edge=Edgeview, Sand=Sandford. 1 extreme not shown for (b) Sand. Triangles represent individual field event loads.

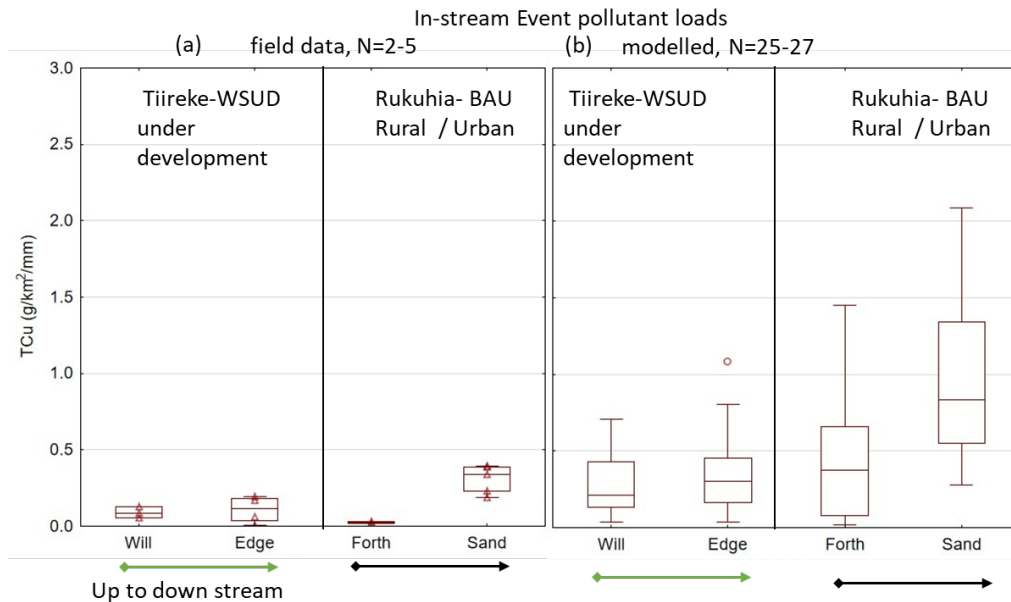


Figure 3 Total copper event loads at each site per km² of catchment per mm of rainfall, (a) field data, (b) modelled data. Will=Williams, Edge=Edgeview, Sand=Sandford. 1 outlier not shown for (b) Sand. Triangles represent individual field event loads.

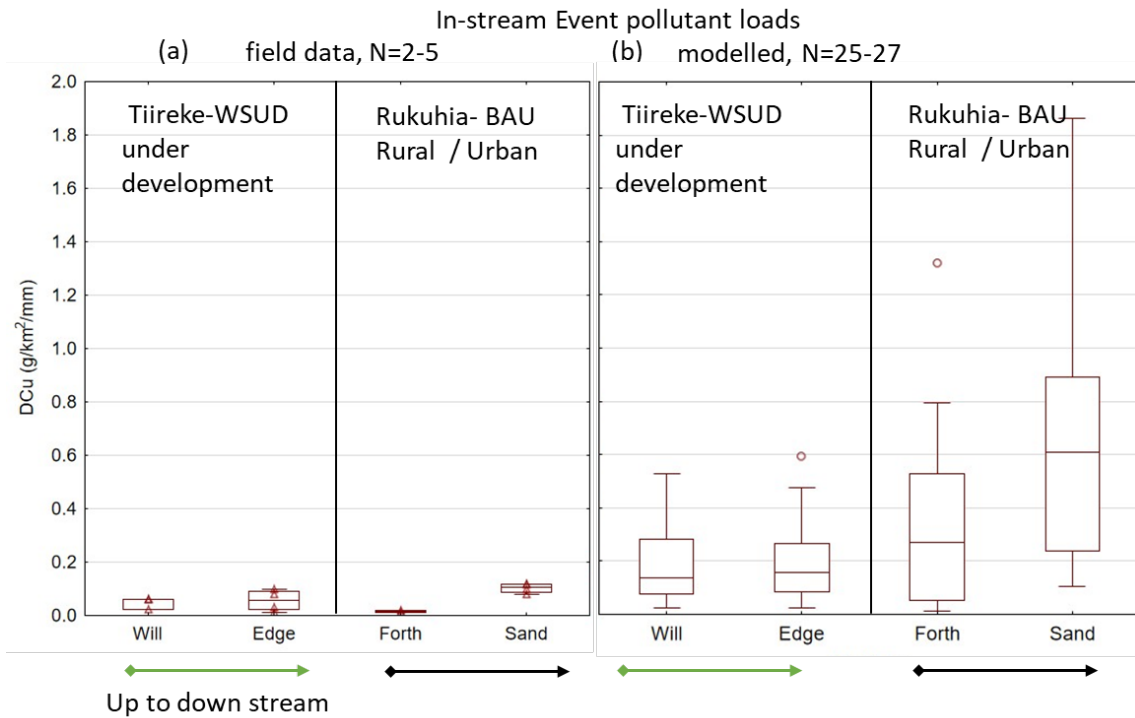


Figure 4 Dissolved copper event loads at each site per km² of catchment per mm of rainfall, (a) field data, (b) modelled data. Will=Williams, Edge=Edgeview, Sand=Sandford. Triangles represent individual field event loads.

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