Barkle, G. F. et al. 2020. Understanding contaminant export pathways is prerequisite for implementing effective nutrient attenuation options. In: *Nutrient Management in Farmed Landscapes*. (Eds. C.L. Christensen, D.J. Horne and R. Singh) http://flrc.massey.ac.nz/publications.html. Occasional Report No. 33. Farmed Landscapes Research Centre, Massey University, Palmerston North, New Zealand. Pages 9.

UNDERSTANDING CONTAMINANT EXPORT PATHWAYS IS PREREQUISITE FOR IMPLEMENTING EFFECTIVE NUTRIENT ATTENUATION OPTIONS

Greg Barkle[1], Roland Stenger[2], Juliet Clague[2], Aldrin Rivas[2], Brian Moorhead[2]

[1] Land and Water Research, P. Box 27 046, Garnett Ave, 3200, Hamilton, New Zealand
[2] Lincoln Agritech, P. Bag 3062, 3240, Hamilton New Zealand
Email: G.Barkle@LaWR.co.nz

Abstract: Drainage pipe discharge from artificially drained land is often targeted as the "best bet" when considering edge-of-field attenuation options. This is because artificial drainage allows contaminants to discharge rapidly and un-attenuated through the drainage pipe into receiving waters and such pipe discharges are more easily treated than diffuse contaminant losses to the groundwater system. However, effective implementation of attenuation measures is fundamentally dependent on understanding the importance of the relevant export pathways for the contaminants being targeted for treatment. To help address this recognised knowledge gap, we quantified the contaminant export pathways and the characteristics of such flows at two artificially drained field sites.

At the Tatuanui site, all the flow and contaminants were exported via the artificial drainage pathway, as compared to the Waharoa site, where averaged over the two drainage seasons approx. 50% of water left via the drainage system and 50% via the underlying groundwater system. The corresponding proportion of total N exported in the shallow groundwater was however lower at only 39% of the total N exported from the site. This reduction occurred, because the shallow groundwater was reduced, and consequently very little nitrate-N was exported via the shallow groundwater. The estimated N exported through the shallow groundwater at Waharoa was dominated by organic-N.

As the drainage season progresses the concentration of N in the aerobic artificial drainage decreases concomitantly with the pool of leachable N in the soil zone. This decreasing trend is perturbated by short term increasing flow events, which result in increasing nitrate-N concentrations in the drainage. This result is due to the saturated zone rising into the active root zone, where soil nitrate concentrations are higher and hence the drainage nitrate concentrations increase relative to when the lower water table levels and flows are lower.

Methods: Drainage flows at two dairy farms (Tatuanui and Waharoa) shown in Figure 1, were monitored, with flow-proportional samples collected automatically and analysed for Nitrogen (N) over the 2016 and 2017 drainage seasons. Sub-soil coring investigations permitted determination of the controls on the drainage hydrology, and shallow wells were used to monitor water table dynamics. Depth profiling allowed N concentrations and redox status through the shallow groundwater to be monitored. This information was obtained using dual packer system to isolate small sampling zones in the shallow groundwater, within specially installed monitoring wells. The wells were tightly fitted into the subsoils materials thereby preventing preferential flow on the outside of the well casing.

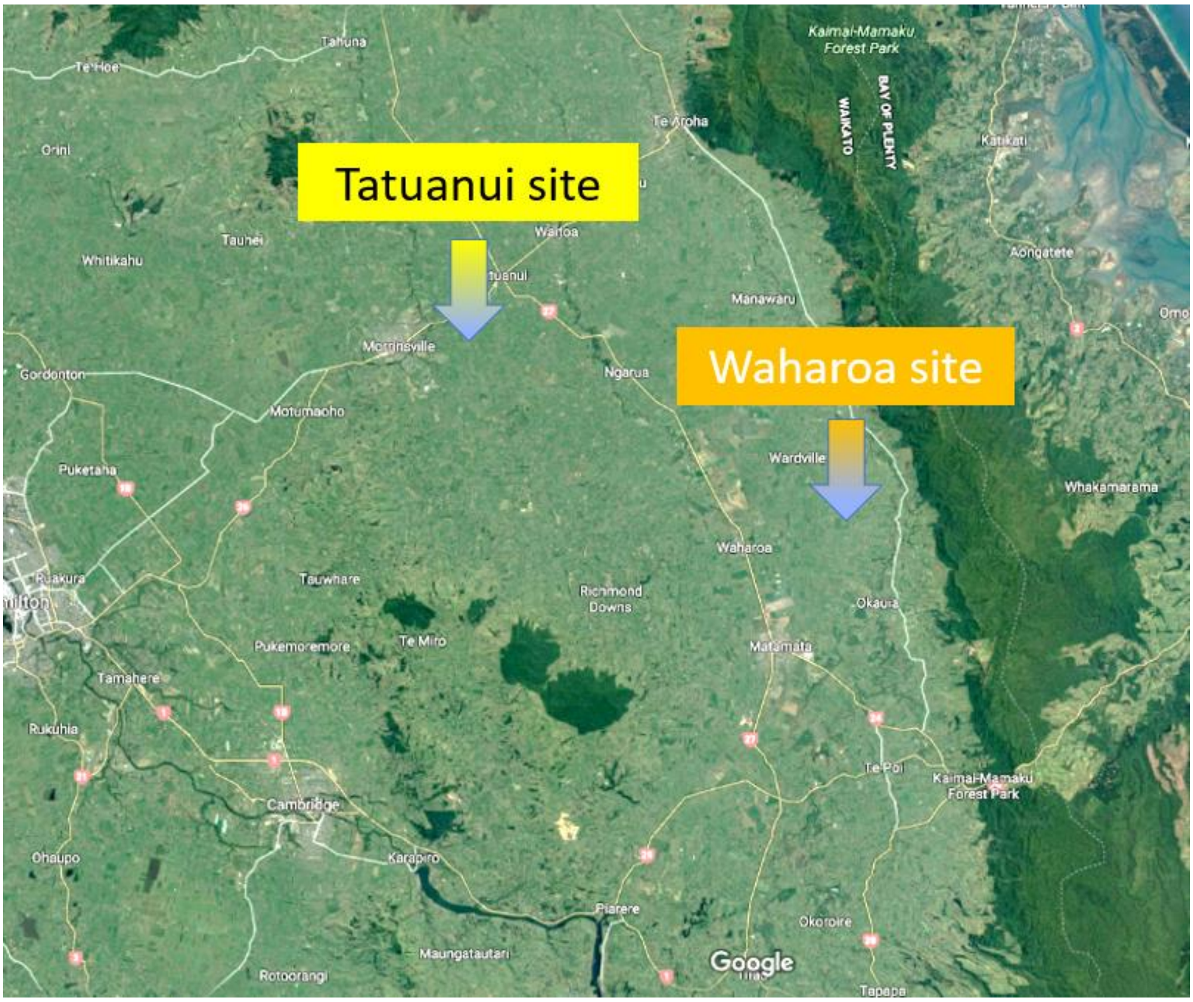


Figure 1 Location of the two field sites used in this investigation, Hauraki Plains, Waikato

To determine the export of N via the shallow groundwater, the concentrations of various forms of N through the saturated profile were linked with hydraulic flow information from the saturated zone.

Results: The water balance for the two drainage seasons at the Tatuanui site (Figure 2) confirmed the soil coring results (Figure 3), that the Tatuanui site was hydraulically sealed in the subsurface and no vertical recharge and contaminant export was occurring through the shallow groundwater pathway.

In contrast, averaged over the two drainage seasons, approximately equal proportions of vertical discharge into the shallow groundwater and lateral discharge through the artificial drainage system were observed at Waharoa (Figure 4).

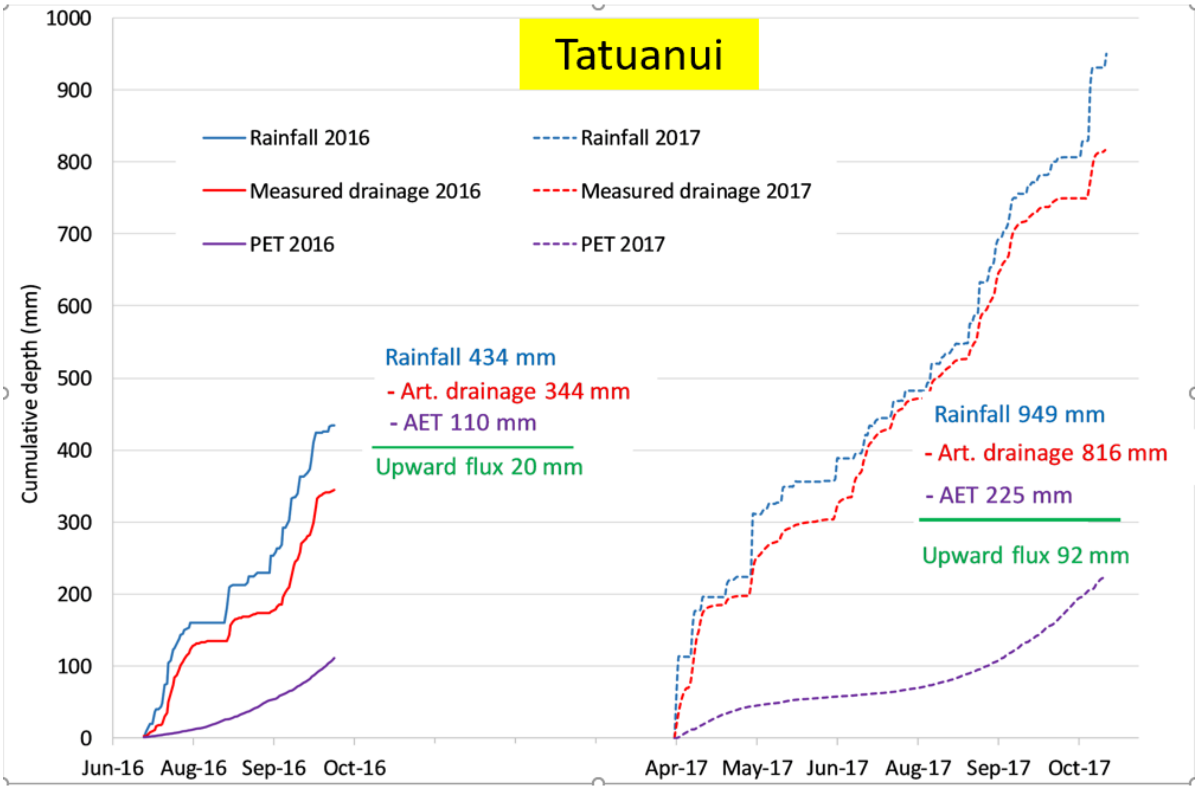


Figure 2: Water balances for the 2016 and 2017 drainage seasons at Tatuanui.

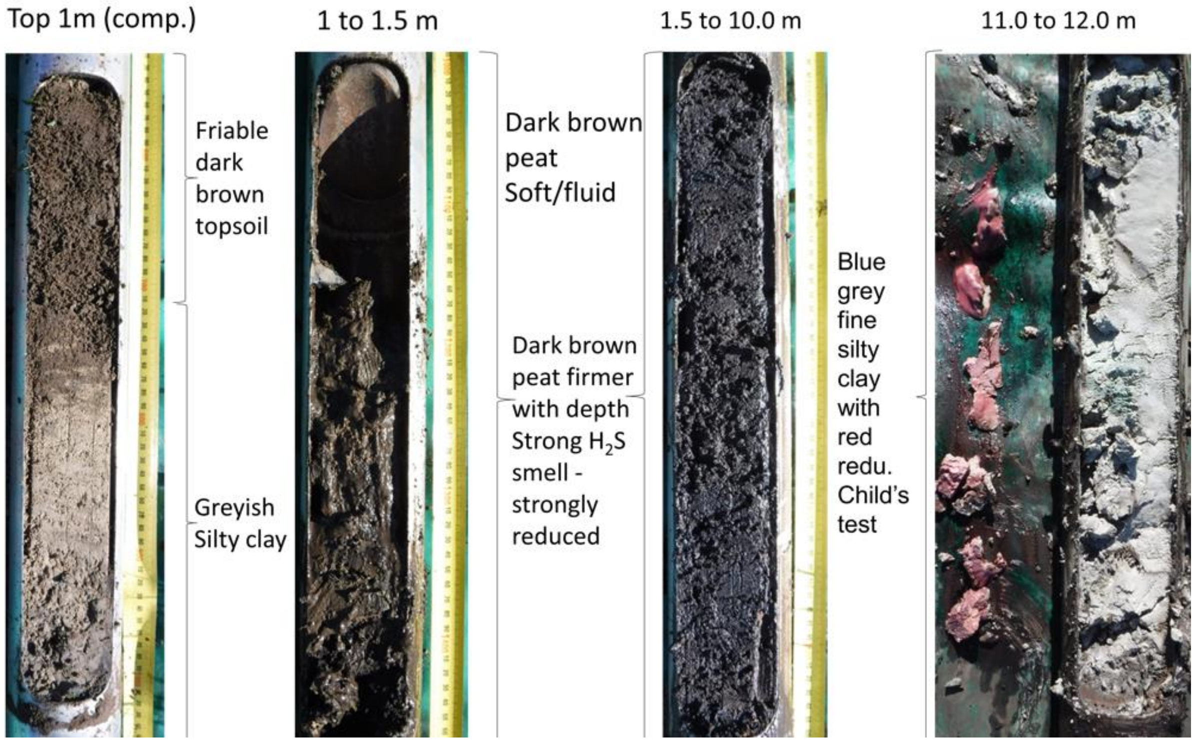


Figure 3: Soil and subsurface cores collected from the soil surface down to 12 m depth, showing reduced decomposing peat in subsurface from 1.0 m depth down to 10 m at Tatuanui.

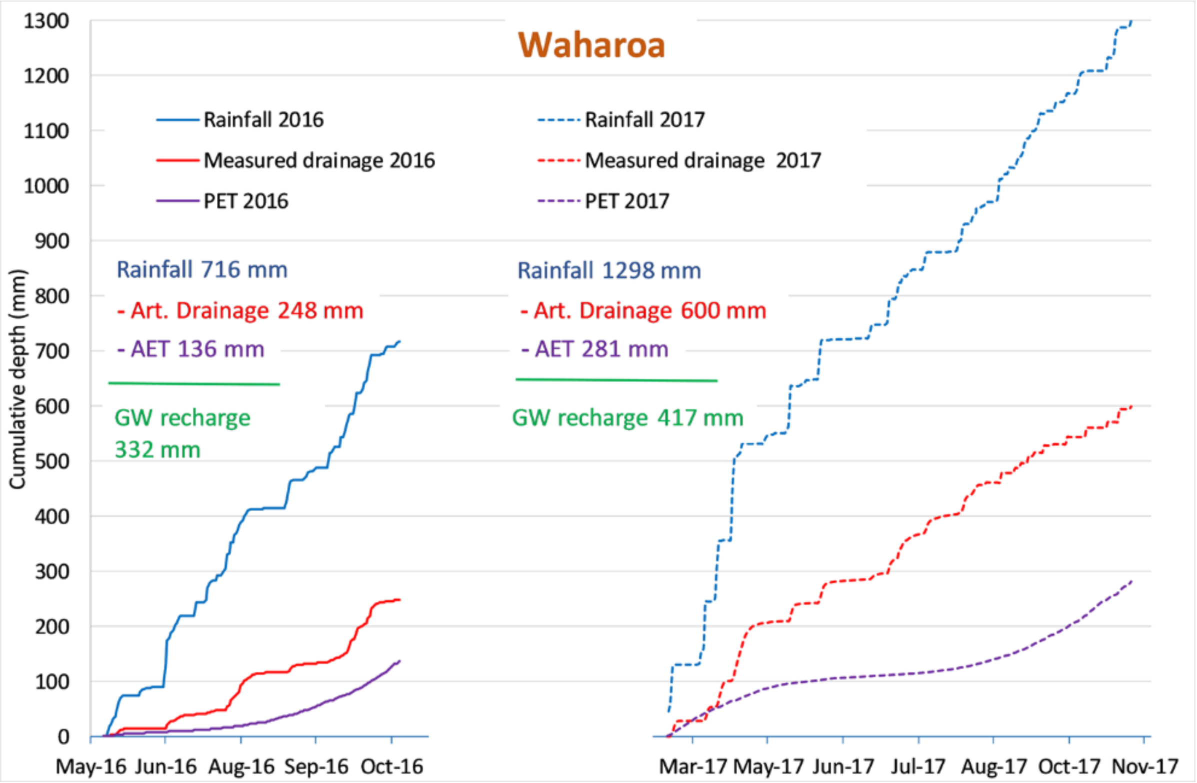


Figure 4: Water balances results for the 2016 and 2017 drainage seasons at Waharoa.

The soil coring at Waharoa (Figure 5) showed evidence of fluctuating redox conditions above a thin clay lens at a depth of approximately 0.7 m. A number of different, but all hydraulically permeable sandy materials laid down during alluvial formation processes were found beneath. The red colour response to the Childs test reagent indicates the presence of dissolved iron from about 1.7 m depth, and therefore a reduced redox status (Childs, 1981).

From flow proportional sampling of the artificial drainage at both sites it was found that nitrate-N was the predominant form of N in the aerobic artificial drainage pathway at both sites (72-86% of total N, Figure 6). Both sites had similar average masses of N exported over the drainage season in the artificial drainage waters.

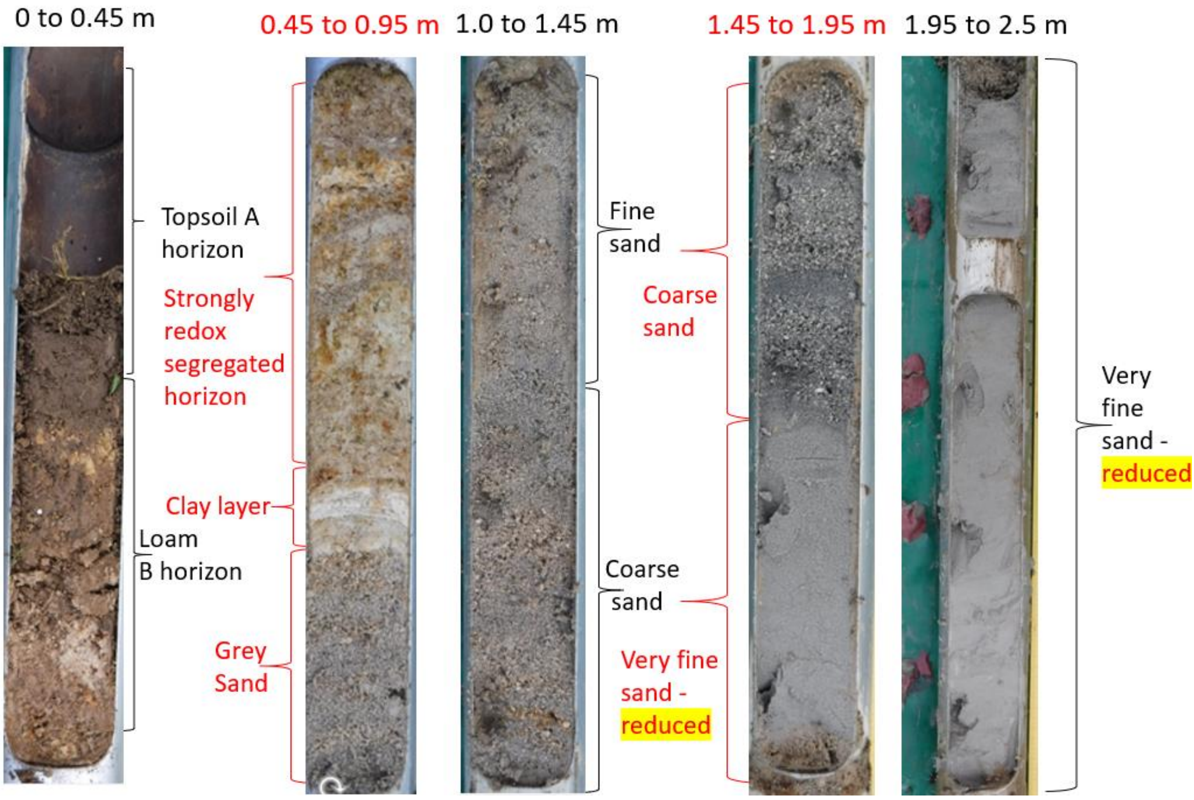


Figure 5: Cores of soil and subsurface materials down to 2.5 m depth at the Waharoa site.

This N concentration information in the shallow groundwater was linked with hydraulic flow information to estimate the mass flux of various forms of N exported via the groundwater pathway at Waharoa (Figure 6).

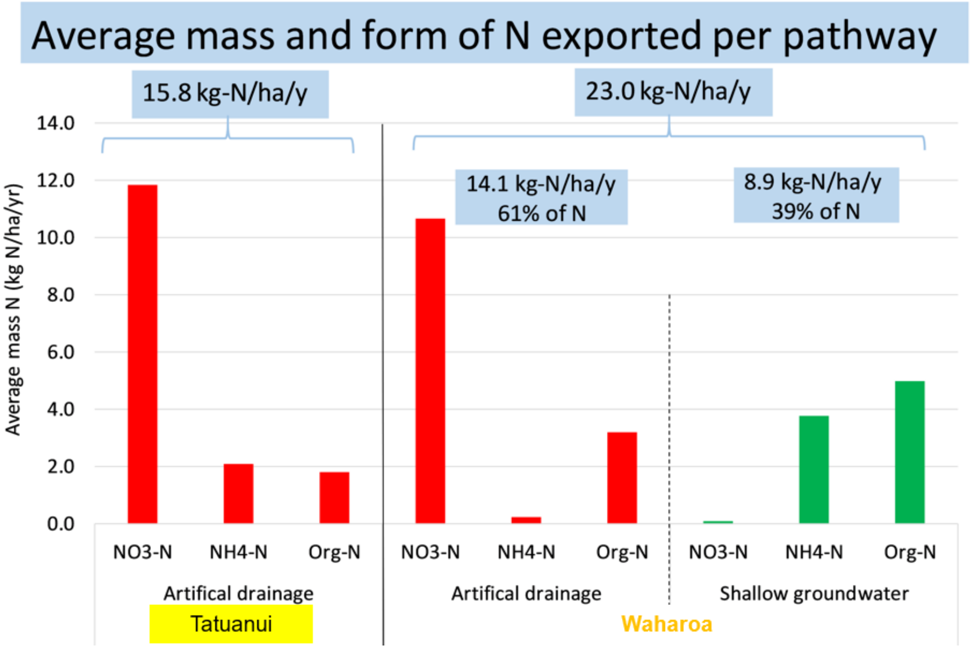


Figure 6: Annual averages of masses of N (kg-N/ha/y) exported off site, in various forms of N, via the artificial drainage at Tatuanui and Waharoa, and additionally in the shallow groundwater at the Waharoa site.

The average nitrate-N concentration in the groundwater at both sites was less than 0.2 mg NO_3-N/L, and redox indicators (not all presented) demonstrated the reduced status of the shallow groundwater (Figure 7). Consequently, any nitrate-N recharged into the shallow groundwater is likely to be denitrified.

At the Waharoa site, the ratio of total-N exported in artificial drainage and groundwater was approximately 60:40, however, the N forms in each pathway were substantially different with very little nitrate-N exported via the shallow groundwater.

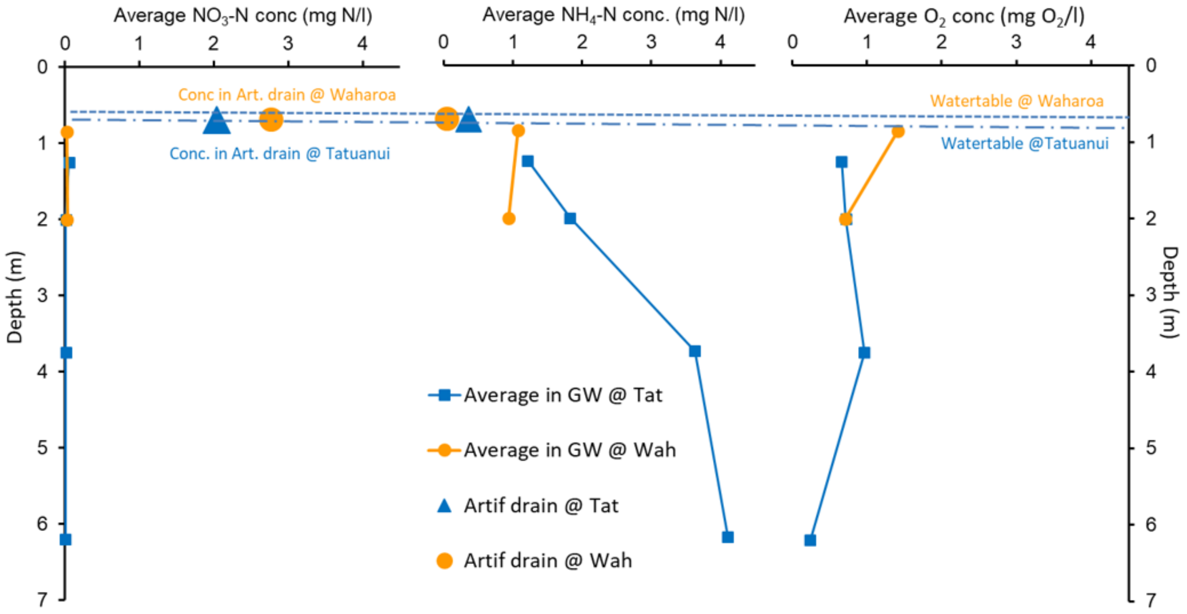


Figure 7: Concentrations of nitrate-N, ammonium-N down through the shallow groundwater, and flow weighted average concentrations in the artificial drainage. Average O_2 concentrations through the shallow groundwater also included.

Monitoring of the artificial drainage flows at both sites and both years revealed that the concentrations of nitrate-N generally increased with flow (Figure 8). This results in a compounding effect on the mass of N requiring treatment in increasing flow situations. Increasing concentrations with increasing flow are thought to reflect that the water table rises into the nitrate-rich soil zone during periods of excess rain and flushes out the nitrate stored higher in the soil profile.

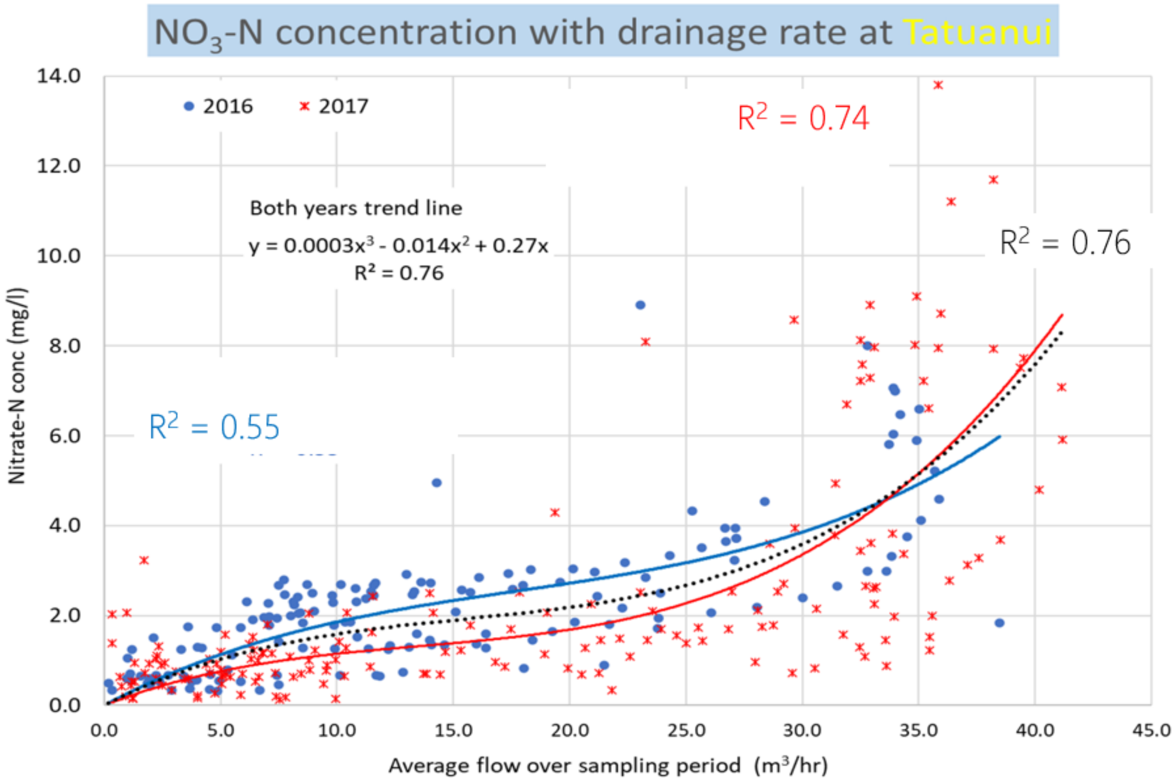


Figure 8: Concentrations of nitrate-N (mg/l) with average flowrate (m^3/hr) over sampling period for the 2016 and 2017 drainage seasons at Tatuanui.

The nitrate-N concentrations in the artifical drainage were observed to decrease in each drainage season at both sites, after the initial drainage event when it was minor (2016); the data from the Tatuanui site is shown in Figure 9. It is considered that as, typically the largest pool of nitrate stored in the soil zone is at the onset of the drainage season (i.e. after long period with little or no drainage). This relatively large pool gets diminished with each drainage event. Replenishment is relatively small and slow as there is lower overall dung and urine N deposition as the herd is not lactating and therefore is being feed less, and the subsequent conversion of dung and urine N during the drainage season into nitrate is slow due to lower temperatures.

This soil zone leachable N reduction is thus reflected in the decreasing trend in the artifical drainage nitrate-N concentrations through the drainage season.

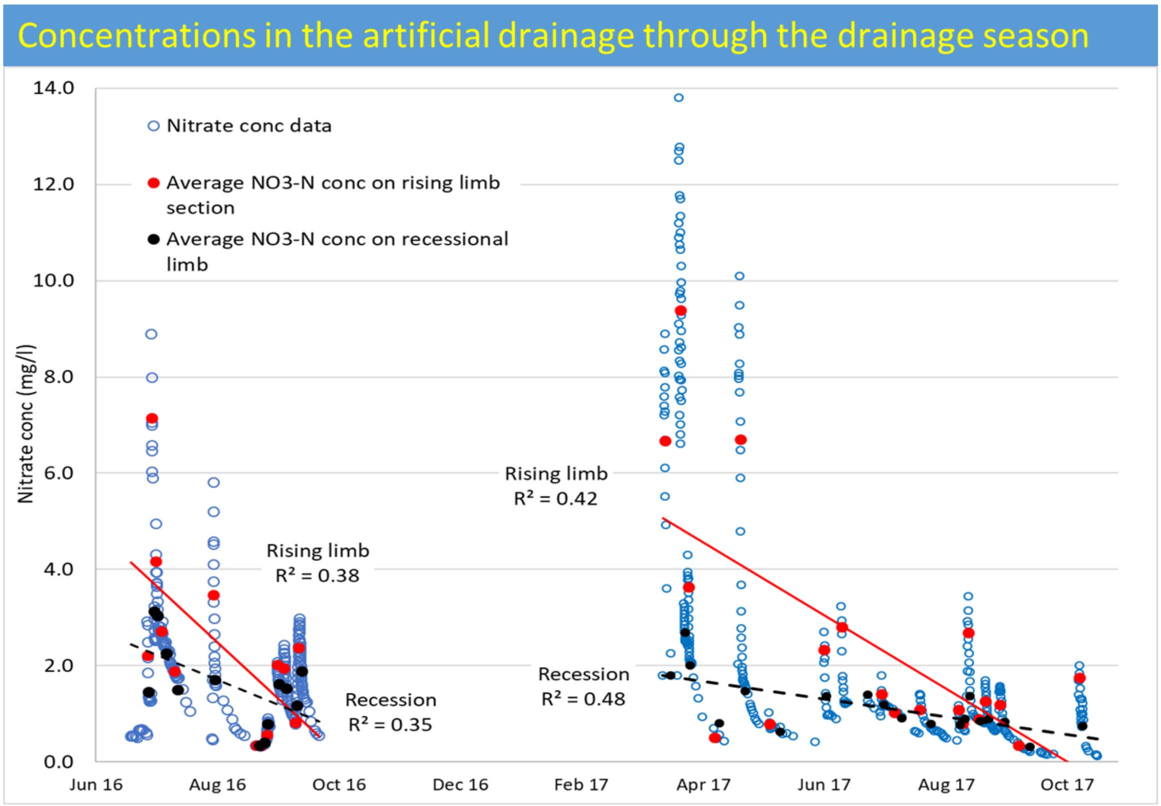


Figure 9: Concentrations of nitrate-N (mg/l) in the drainage water over the 2016 and 2017 drainage seasons at Tatuanui with linear lines of best fit through the average concentrations of the respective components, first drainage event in 2016 excluded.

Conclusions:

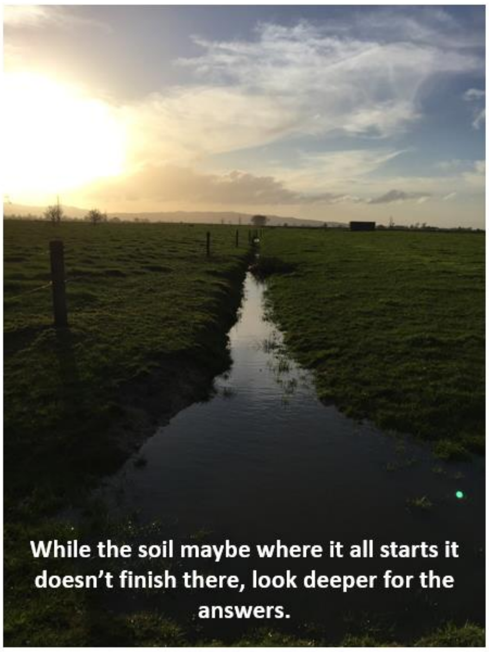
The subsurface materials and the hydrogeochemical characteristics of the shallow groundwater are important factors for controlling contaminant exports, and therefore the success of edge-of-field attenuation options under poorly or imperfectly drained soils.

1 – Where artificial drainage is installed, not all contaminants leave via the drainage lines.

2 – When the shallow groundwater is reduced nitrate-N will not leave by this pathway, however ammonium-N and organic N still can.

3 – When the water table rises, and drainage flow increases so do the concentrations of the nitrate in the drainage water.

4 – As the drainage season progresses, the concentrations of nitrate in the drainage will decrease as the pool of leachable N in the soil decreases.


While the soil maybe where it all starts it doesn’t finish there, look deeper for the answers.

Reference:

Childs, C.W. 1981. Field test for ferrous iron and ferric-organic complexes in soils. Aust. J. Soil Res., 19: 175- 180.

***Acknowledgement*:**

We gratefully acknowledge that this research would not have been possible without the invaluable assistance of the Allen and Hedley families, on whose farms this work was carried out as part of Lincoln Agritech's MBIE-funded Critical Pathways and Transfer Pathways Programmes. We also thank Waikato Regional Council and DairyNZ for additional support.