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TRANSFER PATHWAYS PROGRAMME (TPP) – NEW RESEARCH TO DETERMINE PATHWAY-SPECIFIC CONTAMINANT TRANSFERS FROM THE LAND TO WATER BODIES

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Abstract

Land use (source) can only be defensibly linked to an effect on a receiving water body (receptor) if the critical transfer pathways and the hydrological and biogeochemical processes that occur along them are understood. Depending on the natural setting of the catchment and the contaminant concerned, surface runoff, interflow, artificial drainage, shallow and deep groundwater may be critical pathways.

The Transfer Pathways Programme, which was successful in the MBIE 2015 investment round, has therefore been developed to quantify pathway-specific transfers of nitrogen (N) and phosphorus (P) that take lag times and attenuation potentials of the different pathways into account. The multi-disciplinary research team will be working closely with industry (DairyNZ) and council partners (Waikato Regional Council, Environment Canterbury, Marlborough District Council), as well as iwi on achieving the programme's aims.

By 2018 we will have established how N and P transfer is partitioned across the pathways relevant in four case study areas (Wairau Aquifer, Ashley-Waimakariri, Hauraki, Upper Waikato). A catchment typology scheme will facilitate the application of transfer pathway understanding in other, less well studied catchments. Concurrently, we will apply an iterative modelling framework to integrate existing data of different types and quality, identify knowledge gaps, characterise and quantify fluxes, analyse uncertainty, and ultimately derive simplified models for management purposes.

The quantitative understanding of the contaminant transfers through the various pathways together with the tools developed will enable stakeholders in land and water management to develop fit for purpose policies, management practices and mitigation measures. The research will thus help to maximise economic benefits from land use while achieving the water quality targets mandated by the community.

Introduction

Land use (source) can only be defensibly linked to an effect on a receiving water body (receptor) if the critical transfer pathways and the hydrological and biogeochemical processes that occur along them are understood (Archbold et al., 2010). Depending on the natural setting of the catchment and the contaminant concerned (e.g. nitrogen vs. phosphorus) different pathways may be critical e.g. surface runoff, interflow, artificial drainage, shallow and deep groundwater (Fig. 1).

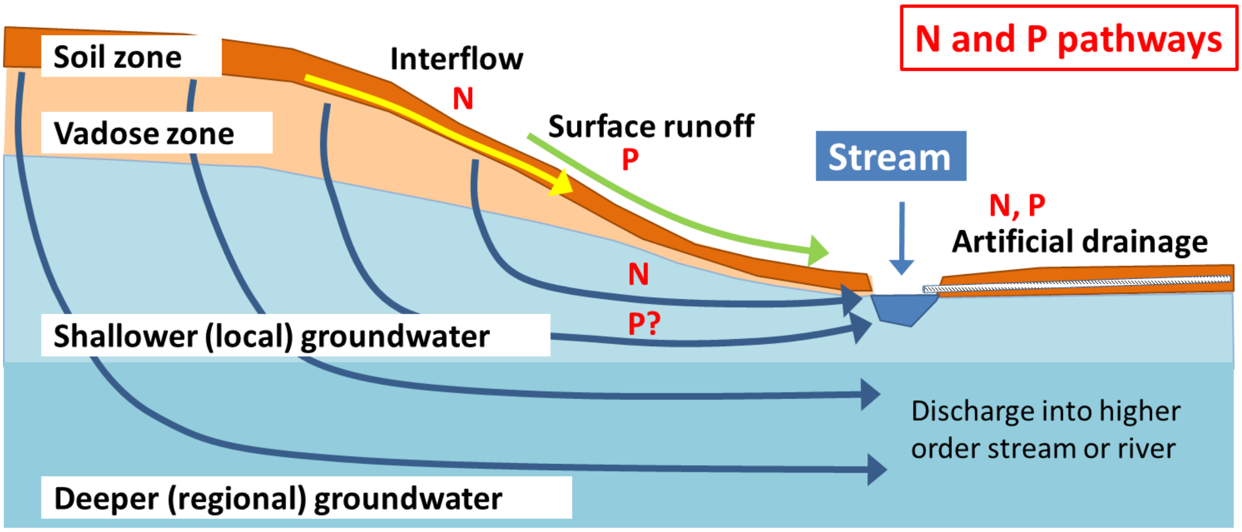

Fig. 1: Schematic of nitrogen (N) and phosphorus (P) transfer pathways that may be relevant on a slope (left) or a flat, artificially drained area (right).

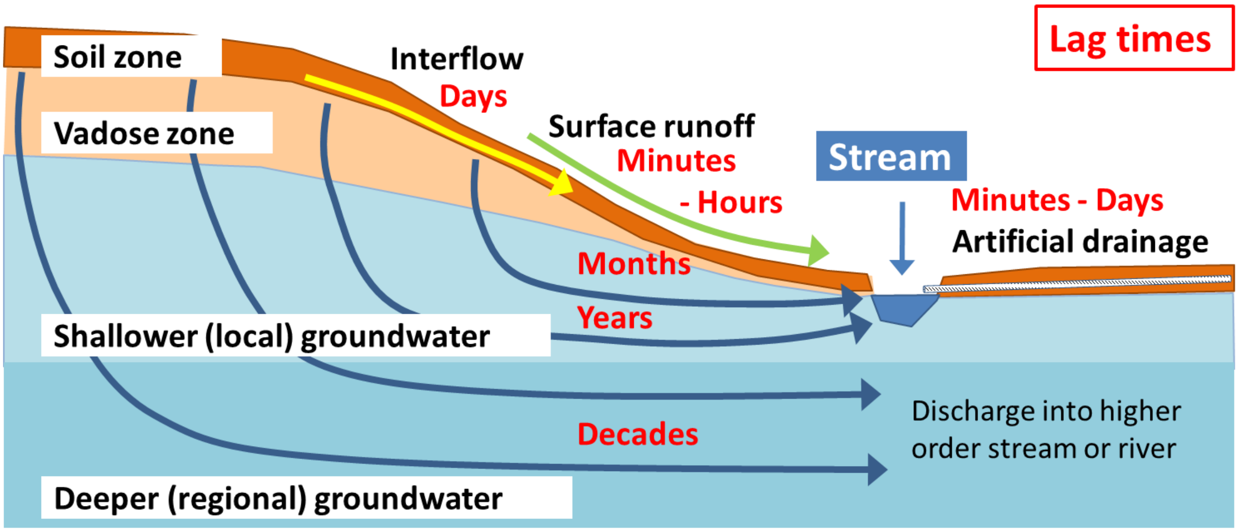

Fig. 2: Schematic of typical lag times associated with different transfer pathways.

The time it takes a contaminant to move from source to receptor (‘lag time’) is one of the key hydrological characteristics of each transfer pathway. While contaminant transfers by surface runoff and artificial drainage may only take minutes to hours, transfers on the groundwater pathway may take years to decades (Fig. 2).

Amongst the biogeochemical processes, those that result in contaminant attenuation (e.g. denitrification of nitrate) are of greatest relevance. A substantial reduction in nitrate load can occur where recharged nitrate enters a zone of reduced groundwater (Fig. 3, left), while short-circuiting of water flows by artificial drainage means that the groundwater system's attenuation potential is not utilised in artificially drained land (Fig. 3, right).

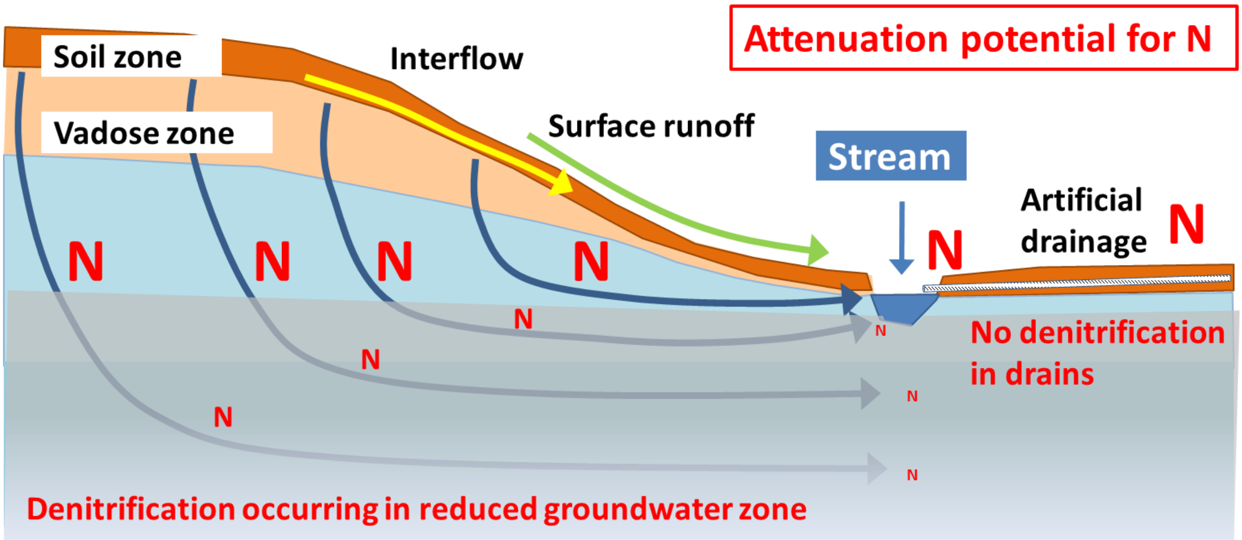

Fig. 3: Schematic of nitrogen attenuation potential in reduced groundwater zone (left) vs. by-passing of that potential in artificially drained land (right).

Failing to explicitly consider hydrological and biogeochemical processes concurrently will inevitably result in poor contaminant transfer understanding. For example, the effects of long lag times can easily be misinterpreted as indication of high attenuation rates and vice versa.

Aims of the Transfer Pathways Programme

The Transfer Pathways Programme (TPP) has specifically been developed by Lincoln Hub members and partners to quantify pathway-specific transfers of nitrogen and phosphorus that take lag times and attenuation potentials of the different pathways into account. This new knowledge will successively be incorporated into a) conceptual catchment models, b) complex, spatially distributed models, and c) simplified management models. A catchment typology scheme will be developed that allows pathway partitioning knowledge to be transferred from well-investigated catchments (e.g. case study sites) to catchments with little information.

The understanding gained and the tools developed in this programme (funded by MBIE for 2015 – 2018) will enable stakeholders in the land and water management space to develop fit for purpose policies, appropriate land management practices and implement viable mitigation measures. The outcomes of this research will help to maximise economic benefits from the land while achieving the surface water quality targets mandated by the community. The multi-disciplinary research team will be working closely with industry (DairyNZ) and council partners (Waikato Regional Council (WRC), Environment Canterbury (ECan), Marlborough District Council (MDC)), as well as iwi on achieving the programme's aims.

Methods

The ambitious timelines of the Government's Fresh Water Reforms agenda, as well as the required investment, mean that it is not feasible for New Zealand to follow European examples of initiating new, nationwide catchment monitoring programmes to fill major data and information gaps. Accordingly, we are emphasising novel methods that have the potential to close gaps by analysing existing data from resource inventories (soil and geology data bases), State of Environment (SoE) monitoring (by partner councils), and previous research projects. Transfer pathway partitioning will be achieved by applying a range of analysis methods (incl. hydrograph separation, end member mixing analysis, and lumped component modelling) that build heavily on existing data ('data mining') (Barkle et al., 2014; Woodward, 2014; Woodward et al., 2013 + 2016). Targeted new field investigations will be carried out to close key knowledge gaps. The extent and nature of these investigations (e.g. soil physics, soil and groundwater biogeochemistry) will therefore differ between the case study areas.

With regard to their value for pathway partitioning, existing SoE time series typically suffer from two key shortcomings: the low frequency of water quality samplings (usually monthly), and the limited range of parameters analysed. To overcome the shortcoming of low frequency, we will initiate high-resolution water quality monitoring at selected locations and/or during periods where dynamic N or P concentrations are to be expected. This will not only enable better understandings of the dynamics of contributing transfer pathways, but also result in more accurate load calculations. Moreover, such data is necessary to inform the complex, spatially explicit transient models required to adequately describe dynamic groundwater systems under stress, and therefore will enhance the reliability of these tools. In terms of the limited range of parameters analysed in SoE monitoring programmes, we will test whether inclusion of relatively inexpensive measurements of environmental tracers (e.g. silica) could substantially improve the utility of such data sets.

Conceptual models for our case study areas (discussed below) will be developed by compiling all available data and using our knowledge of hydrological and biogeochemical processes to understand how and when relevant contaminant transfer pathways operate. The fundamental understanding contained in these conceptual models provides a valuable tool for stakeholder engagement. Subsequently, in close collaboration with our regional council and industry partners we will apply an iterative modelling and field investigation framework to identify and fill critical knowledge gaps, incorporate the new pathways knowledge into spatial models, and derive simplified, but reliable models for management purposes. While the overall approach is the same across the four case study areas, the relative proportions of each component will differ in response to differing natural settings, identified key knowledge gaps, and regional council and industry partner priorities.

Case Studies

Jointly with our council and industry partners, we have selected four case study areas that differ in the critical transfer pathways, time lags, attenuation potentials, and in their resource management challenges:

1. Wairau Aquifer (Marlborough)
2. Ashley-Waimakariri Water Management Zone (Canterbury)
3. Hauraki Plains (Waikato)
4. Upper Waikato (Waikato)

The temporal and spatial variation of pathways feeding spring-fed streams, particularly Spring Creek, will initially be our focus on the Wairau Aquifer case study. Groundwater modelling for this area is already at an advanced stage due to earlier work carried out by Wöhling et al. (2015).

Building on a conceptual groundwater model developed by ECan, we will investigate in the Ashley-Waimakariri case study how the different pathways, combined with the geochemical environments, control the contaminant transfers to terminal groundwater discharge locations (springs, estuaries, or off-shore). We will determine the vertical variation of nitrate in groundwater near the water table and use a continuous nitrate sensor giving high resolution data to distinguish different sources and pathways. The relationships between land uses, soil types, anoxic groundwater and sediments, and the concentrations of P in shallow groundwater and receiving waters in the coastal zone (shallow lakes, estuary and streams) will also be investigated.

Quantifying water, N and P fluxes leaving artificially drained land is the focus of the Hauraki case study. This work includes quantifying the episodic transfer of contaminants via near-surface lateral pathways (subsurface and surface drains) to local streams, as well as vertical recharge into the underlying groundwater system.

Research in the Upper Waikato case study area will initially focus on five sub-catchments (Waiotapu, Otamakokore, Tahunaatara, Mangakino, Pokaiwhenua) for which long-term surface water flow and chemistry time series exist (from WRC, NIWA, Mighty River Power). Upon analysis of this data using a range of data stratification and hydrograph analysis techniques we will select two contrasting sub-catchment for more in-depth field studies and modelling (incl. spatially distributed groundwater models).

We are committed to working within and embracing a Vision Matauranga-driven approach. Establishment of relationships with the local hapu/iwi of our case study areas is a key task for early 2016. It is our goal to maintain a mutually beneficial dialogue with relevant iwi partners throughout the duration of the programme.

Outputs

The successful completion of this programme will provide a range of stakeholders (catchment committees, land users, iwi, regulators) with underpinning science and tools to maximise economic benefits from land use while achieving the surface water quality targets mandated by the community. The outputs include:

1. Transfer pathway partitioning methods suited to a range of natural settings and data availabilities.
2. A catchment typology scheme that allows pathway partitioning results to be transferred from well-investigated catchments to other catchments with little information.
3. Conceptual catchment models that convey the hydrological and biogeochemical understanding of how the contaminant transfers along all pathways relevant in a catchment function.
4. Spatially distributed models that simulate water flows and contaminant loads for all relevant pathways from source to receptor within each catchment.

5. Simplified management models that encapsulate the key ingredients of the spatially distributed models in a way that can be understood and trusted by non-technical people and stakeholders in water management.

The Transfer Pathways Programme's outputs no. 1–3 are very closely aligned to the planned 'Sources and Flow' programme within the National Science Challenge – Our Land and Water (NSC-OLW). Successful completion of the research in TPP's case study areas is therefore expected to contribute substantially to NSC-OLW's overarching nation-wide goals. Ongoing intensive information exchange between NSC-OLW and TPP is facilitated by overlap between the programmes in contributing research providers and key individuals within each programme.

Additionally, we will be collaborating with the Smart Aquifer Models (SAM) programme (Moore et al., 2015) that is also funded by MBIE for the 2015-2018 period. This will in particular involve collaboration on advanced model reduction techniques, which are required to produce 'simplified models' suitable for decision-making by resource managers.

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