SENSOR OBSERVATION SERVICE AND WEB-BASED REAL-TIME PROCESSING OF ENVIRONMENTAL MEASUREMENTS IN THE UPPER RANGITAIKI CATCHMENT

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Introduction

Environmental assessments naturally depend on field observations and technological advancements, such as telemetry, allow the automated collection, transmission and processing of these measurements. However, modelling of natural processes is typically a complex problem and involves applying expertise of scientists as well as a host of data preparation steps (White, 2006, White et al, 2003). In addition, automation of model execution with the most recent observation data is dependent on the integration of the data collection, storage and processing elements (Klug and Kmoch, 2015).

This paper presents a demonstration system that integrates a Sensor Observation Service (SOS) that includes field observations and internet-based environmental data with a rainfall recharge model that allows near-real time calculation of rainfall recharge in the Upper Rangitaiki catchment, Bay of Plenty region. The SOS specification is an Open Geospatial Consortium (OGC) standard for the open and standardised integration of environmental data into an internet-based environmental data infrastructure (Klug and Kmoch, 2014).

Method

A SOS site has been established in the Upper Rangitaiki catchment. It comprises of a field computer (Raspberry Pi) with a direct internet link and a sensor board (Waspmote), that has 12 typical meteorological, hydrological and pedological sensors attached to it (i.e., wind speed, wind direction, rainfall, temperature and soil moisture). The Raspberry Pi and Waspmote can be monitored and reprogrammed from a browser allowing, for example, remote adjustment of the sampling interval. This SOS site setup allows scaling up to a multitude of low cost, low energy, sensor stations throughout a catchment, with only one field computer that serves as data logger.

The Upper Rangitaiki SOS site was co-located with a Bay of Plenty Regional Council climate monitoring station (Rangitaiki at Kokomoka, elevation 760 m) for comparison purposes. The Kokomoka station measures rainfall, soil moisture, soil temperature and groundwater recharge in lysimeters.

The greatest advantage is the direct linkage of the collected data into a hydrological model. In this paper, a simple rainfall recharge model will be described for demonstration purposes; the model is driven off the SOS site observations. This model, which covers 7.5 km2 of the Otangimoana Stream catchment where the SOS site is located, uses 10-minute observations of rainfall, soil moisture and wind direction to calculate maps of key environmental variables associated with groundwater resources (e.g., rainfall, soil moisture, groundwater recharge) at four intervals (i.e., 10-minute, daily, weekly and seasonal). These maps, with summary information (e.g., groundwater recharge over various intervals) are available through a browser.

Results

The Raspberry Pi, running a standard Linux operating system, transferred observation data in 10 minute intervals via a 3G mobile data connection to an online SOS server. The Waspmote, a microprocessor and a custom circuit board with the sensors connected to it, has collected data and forwarded this data to the field computer in 10-minute intervals via robust, low power, ZigBee wireless protocol. From this service the observations were available in a standardised open format. The website accessed the raw data from the

SOS server and plotted data points within 5-10 minutes of field measurement. This website was easily accessible via browsers and smartphones.

The capabilities of the SOS system were demonstrated by the rainfall recharge model of part of the Otangimoana Stream catchment. Potential benefits of the system for water management will be described including the availability of more dynamic water management practices where data and modelling results are available, almost-immediately, to the user.

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NEW ZEALAND LYSIMETER MONITORING SITE INSTALLATIONS

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Introduction

Lysimeter monitoring sites have been installed and are currently operating in the Canterbury (White et al., 2014), Bay of Plenty (Lovett and Harvey, 2013; Lovett et al., 2012), Hawke's Bay (Lovett, 2013; Lovett A., 2014; Lovett and Cameron, 2013) and Southland (Lovett 2015a; Lovett and Payne, 2014) regions. The primary aim of a lysimeter monitoring site is to determine the proportion of water that infiltrates though the soil (from irrigation and/or rainfall) and contributes to groundwater recharge. Information obtained from lysimeter monitoring sites is required for applications including calibration of groundwater models, water resource management, and policy development.

Site selection

There are a number of considerations to make when selecting a site for a lysimeter installation including: location on a recharge zone, soil type and properties, land use, historic rainfall records or nearby climate station, slope and aspect, land ownership, nearby obstacles (e.g. buildings, trees), and whether the site will be dry land or irrigated.

Installation

Due to inherent differences in site specific characteristics, no single installation (to date) has been identical. The lysimeter monitoring sites used in these installations consist of three cylindrical (500 mm diameter by 700 mm deep) galvanised steel drums which are connected to tipping bucket rain gauges inside an underground enclosure. Concrete enclosures prevent shallow groundwater (high water table) flooding the lysimeter enclosure, however are generally more expensive to install compared to wooden enclosures. A ground-level rain gauge is required at each site, and soil moisture sensors can be installed at a single, or various depths. The standard installation process consists of: site layout; isolation of soil column, extraction, sealing, and reinstatement of lysimeters; attachment of pipework from the lysimeters to the instrument enclosure; wiring of instruments; and site remediation.

Design developments

The first lysimeter sites were installed in the Bay of Plenty region using a wooden enclosure. This design was adapted to a conventional precast concrete tank by Hawke's Bay Regional Council staff to prevent flooding of the enclosure in locations with shallow water tables (e.g. < 2 m BGL). All of the operating lysimeter monitoring sites in New Zealand are installed on pasture land due to lack of a suitable design to allow for arable land use (e.g. cultivation). Recent research has been completed to scope out a design for arable land use, which is intended to be trailed in the Hawke's Bay region (Lovett, 2015b).

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Can substrate stability data be used to increase our knowledge on cyanobacteria growth in New Zealand rivers?

CAN SUBSTRATE STABILITY DATA BE USED TO INCREASE OUR KNOWLEDGE ON CYANOBACTERIA GROWTH IN NEW ZEALAND RIVERS?

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Aims

Cyanobacteria, has become a significant water quality issue in New Zealand over the past decade. Cyanobacteria can produce toxins fatal to humans and dogs under certain conditions with obvious public concern. Reduced river flows from drought and increased water abstraction, combined with increasing nutrient levels have been linked with the increased growth of cyanobacteria. However, the relationship between hydrological regimes and cyanobacteria growth is unclear. Does substrate movement, or lack of it, contribute to biomass accrual. Understanding the relationship between substrate stability and cyanobacteria growth may allow river managers to limit growth by managing for greater bed turn-over. However, there is currently no effective method to assess substrate stability. This paper examines a new index for the rapid assessment of substrate stability, and the link with cyanobacterial biomass in a range of Canterbury rivers.

Method

A new index to assess substrate stability was developed using the methodology of Pfankuch (1975) and Schwendel *et al.* (2012). The index was evaluated in 10 streams in the Ruahine Ranges (Neverman *et al.*, 2014), and compared with measured bed movement data from Minchin (2002). The index was then used to assess substrate stability in a range of Canterbury rivers. The results of the index, as well as individual parameters from the index, were compared to cyanobacteria biomass data collected over a 30 week period in those same rivers.

Results and Discussion

The index was also able to group streams as stable or unstable when compared to Death and Winterbourn (1994). There is a strong relationship between the index and biomass. _ENREF_1These results suggest the index may be a useful tool in the assessment of bed stability in ecological studies.

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IMPROVING PREDICTIONS OF THE EFFECTS OF EXTREME EVENTS, LAND USE, AND CLIMATE CHANGE ON THE HYDROLOGY OF WATERSHEDS IN THE PHILIPPINES

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Introduction and Aims

The Philippines is seen as particularly vulnerable to the effects of climate change due to its exposure to tropical cyclones, which can cause severe landslides and floods (Yusuf & Francisco 2009). Tropical cyclones are regular occurrences in the country, with an annual average of twenty tropical cyclones entering the Philippine Area of Responsibility of which about nine make landfall and cause destructive floods (Lasco et al. 2009). Climate change is likely to increase the number of tropical cyclones that occur, and exacerbate these risks further.

To protect populations and infrastructure, robust hydrological modelling is required for near-real time monitoring and flood forecasting, and to assess the vulnerability of river basins to storm events (Mabao & Cabahug 2014; Santillan et al. 2013). Flood modelling technology in the Philippines mainly uses two hydrological models from the Hydrologic Engineering Center (HEC) of the United States Army Corps: the Hydrologic Modeling System (HMS) for construction of a flood hydrograph, and the River Analysis System (RAS) for modelling flood inundation (Santillan et al. 2013).

This study focuses on the Cagayan River, located in Northern Mindanao (Figure 1). It passes through Cagayan de Oro City, which has a population of 600,000 as of May 1st 2010 (Philippine Statistics Office 2010). In 2011, Typhoon Washi caused heavy flooding and destruction in the city, thus underscoring the need for better management of flood risk and understanding of the river basin's hydrology (Mabao & Cabahug 2014).

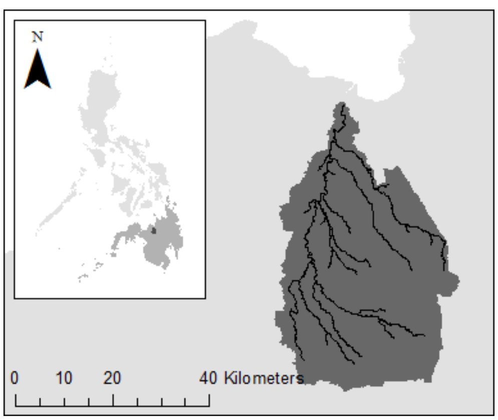

Figure 1. Map showing extent of Cagayan river basin and associated streams relative to the Philippines.

This research intends to apply a model developed to aid in scientifically-sound decision-making regarding the land management of the Cagayan river basin: it will apply the Land Utilisation and Capability Indicator (LUCI) model, a GIS-based (Geographical Information Systems) framework that assesses areas providing a variety of ecosystem services, including floods and water supply, trade-offs between services, and impacts of changing land cover and/or climate (Jackson et al. 2013). This model will be compared to the existing flood models to understand where they can complement each other. The novelty of this LUCI application in the Philippines is that it will be used to identify areas within the Cagayan de Oro basin that are currently providing the ecosystem service of flood mitigation, and areas that can be developed to enhance its service. The LUCI output can be used to create land management scenarios to understand the impacts of the land cover changes on flood mitigation. These scenarios will be used as input for LUCI and HMS, both of which can produce hydrographs. These hydrographs will be put through RAS to compare the resulting floodplain inundation maps.

The main aims of this research are to (1) assess the available imagery and GIS datasets for Cagayan de Oro to produce a more refined set of data for model use; (2) development of GIS dataset support for the Philippine land cover and soil types for the LUCI model; (3) comparison of the LUCI model with existing flood models to identify aspects where they can complement each other; and (4) assessment of different flood regimes under changes in land use, climate change, and storms of different return periods.

Method

Data gathering: This stage involves collecting different datasets from various sources, including: national datasets of land cover and soil types, global datasets that can be clipped to the study area, and remotely-sensed imagery. In order to understand the local government's future plans for river basin management, regional comprehensive land use plans are being compiled.

Model and data assessment: The current hydrological models (HMS and RAS) are being compared with the LUCI framework to understand their inputs, process, and outputs. This enables identification of their strengths and weaknesses, and possible points for model coupling. The various datasets are being checked for physical (in)consistencies and inaccuracies, and the land cover and soil types in the study site are being integrated into the datasets supported by LUCI, with characteristics consistent with the literature. The resulting processed datasets are undergoing preliminary LUCI runs to assess how the output differs between datasets.

Scenario creation and model runs: Different scenarios are being formulated based on the following: (1) land use changes based on the areas identified by LUCI that provide existing flood mitigation services and the identified areas where additional flood mitigation could be provided, and the land use plan of city hall; (2) climate change based on downscaling of the model results from the IPCC; and (3) extreme events based on records of storms with different return periods.

Results and Applications

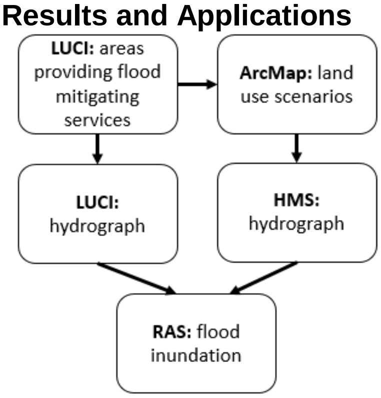

Figure 2. Planned workflow for model coupling.

The different GIS datasets for land cover and soil type are being analysed to translate them into a classification system that is widely-used so they can be analysed in LUCI. The local Philippine soil types have been correlated with the USDA (United States Department of Agriculture) classification, and hydrological parameters are being extracted from the literature and databases.

The different models have been assessed and a workflow has been formulated (Figure 2) to assess the effect on the river basin's flood regime under the different scenarios. The hydrographs from LUCI and HMS under the same scenario will be used as input into RAS to analyse any differences in the actual inundation on the floodplain.

Regarding its application, this research will contribute to more proactive flood risk management through understanding the effects of changing land use in a river basin, and in flood risk planning for extreme events influenced by climate change. This research is intended to aid in refining the existing flood modelling systems in the Philippines, and in more scientifically-sound decision-making through the novel application of the LUCI framework.

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SMART AQUIFER MODELS FOR AQUIFER MANAGEMENT

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The interactions between groundwater and surface water systems such as rivers, lakes, wetlands and estuaries are complex. Current models simulating these interactions are too complex and slow to be practical, or lack necessary integration, or are too simple to be accurate yet the new National Policy Statement for Freshwater Management 2014 (NPS-FM) requires holistic freshwater management that satisfies community aspirations. This necessitates integrated groundwater-surface water modelling over larger areas and at finer spatial and temporal scales than ever before. The critical deficiencies of current modelling approaches therefore present a real risk to adaptive management of New Zealand's aquifers under the NPS-FM.

This paper introduces a large newly funded project which will develop technologies to develop appropriate, fit for purpose, ‘smart’ models built on the aquifer management decisions being considered using available data. Smart models are defined as having appropriate complexity and model run times required for robust model based decisions. Importantly, the project will develop and validate approaches to make existing groundwater flow and transport models fast without introducing unacceptable biases or inaccuracies thus addressing the critical gap in current modelling tools. We refer to these fast simplified models as ‘smart’ meta-models; a subset of meta-models (model simplifications derived for fast model run times) in general. Smart models incorporate available data and accommodate model complexity, model predictive reliability and decisions to be made in parallel whereas current modelling practise is sequential, ignoring the interplay between these elements leading to weaknesses such as unnecessary complexity, slow run times, or oversimplification and inflated predictive uncertainty. By understanding the interplay of these strands and their impacts on predictive reliability, we can identify the most appropriate, ‘smart’ model for each different management decision.

Three integrated groundwater-surface water catchment studies will provide the focus for this research program. They will be located in Mataura (Southland), Hauraki Plains (Waikato) and Ruamahanga (Wellington). The key management decisions in each catchment, defined by end-users, will identify questions that the meta-models must address. Testing of meta-models across these case studies and additional international catchments will ensure that programme outputs are relevant, workable, and transferable to a range of New Zealand groundwater-surface water contexts.

THREE-DIMENSIONAL GEOLOGICAL MODEL OF ENVIRONMENT SOUTHLAND'S AREA OF INTEREST FOR FRESHWATER MANAGEMENT

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Introduction

The collaborative Fluxes and Flows Project, involving GNS Science (GNS), Environment Southland (ES) and the National Institute of Water and Atmospheric Research (NIWA), aims to develop a regional-scale groundwater flow and contaminant transport model loosely-calibrated to surface water flow, as part of ES's response to the 2014 National Policy Statement on freshwater management. Ultimately, the large-scale model will be split into catchment-scale models to inform policy development for the Southland region.

The construction of robust groundwater models requires a clear understanding of the geology at a relevant scale. The best way to acquire this understanding is through a 3D geological model that uses all available geological data to provide a comprehensive view into the sub-surface.
This paper focuses on the construction of a large-scale 3D geological model, which encompasses most of the Southland region, and how it's relevant to the construction of a similar-scaled groundwater flow model.

Method

A combination of GIS (Geographical Information System, ESRI ArcGIS 10.1) and 3D geological modelling software (Leapfrog Geothermal 2.8) has been used to construct the ES geological model. Data sets available to create the model include: topographic data (high-resolution DEM), bathymetric data, geological maps, geological cross-sections, well logs and interpreted geophysical data. Due to the large scale of the model, all relevant geological units were grouped into model units, based on the available input datasets and expected hydraulic behavior of the geological units. Major faults have also been included in the model.

Results

The 3D geological model (Figure 1) covers a surface area of approximately 21,000 km^2 and is the largest geological model developed in New Zealand to date. The model extends to a depth of 8.5 km below MSL, to provide a continuous basement surface, and the resolution of the model is set to not be coarser than 250 m, based on the large size of the model area. The complex geology of the region has been simplified into eight key model units. These key model units have been constructed based on the age of the sediments and this decision was founded mainly on the data available to model the units:

1) Quaternary unconsolidated sediments - predominantly sand and gravel with good aquifer potential

2) Pliocene conglomerates - moderate aquifer potential but not well investigated

3) East Southland Group (separated from Miocene due to hydrogeological significance and data availability) – Mudstone and Sandstone layers including lignite measures, high aquifer potential in interbedded sand and gravel deposits

4) Early Miocene

deposits include sandstone and limestone - moderate aquifer potential but not well investigated

5) Miocene

6) Oligocene

7) Eocene predominantly deep sandstone and mudstone deposit, hydraulic basement

8) Basement

Additionally, the ES geological model includes a water-body layer, for lakes and estuaries.

The geological model is now being transferred into a regional-scale groundwater flow model. Recommendations have been made for possible future refinements of the geological model. These recommendations focus mainly on improvements to the model that decrease the uncertainty in areas with limited data availability; and enhance the spatial definition and structure of model units in areas of specific interest for groundwater investigations or other intended applications.

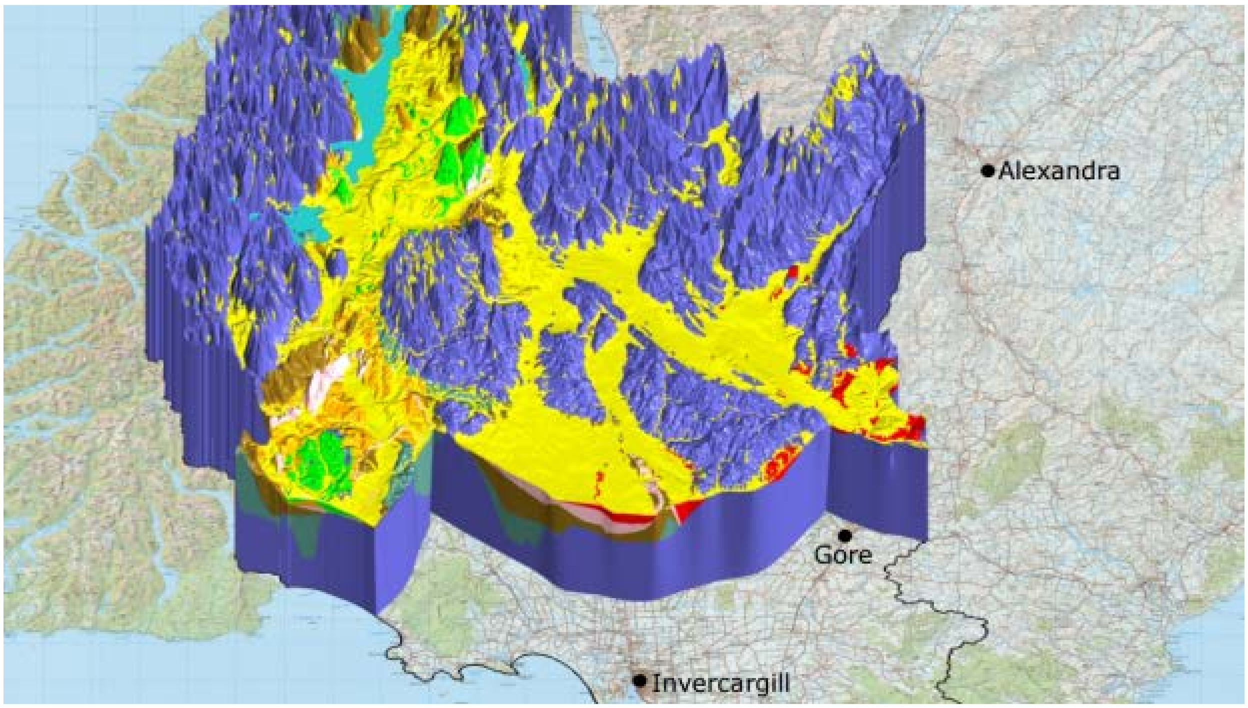

Figure 1 A look into the 3D geological model for Environment Southland's areas of interest for freshwater management. Areas in teal blue are lakes; other colours represent different model units, with the basement in dark blue and the Quaternary in yellow. The entire model extends to the black boundary in the south.

AN EXAMINATOIN OF FOAM GLASS AS A MEDIUM FOR USE IN CONSTRUCTION OF DENITRIFICATION WALLS

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Background

New Zealand's alluvial gravel aquifers are particularly vulnerable to nitrate impacts from intensified land-use because they are ineffective at naturally attenuating nitrate (e.g. Burbery et al., 2013). Denitrification walls are engineered permeable reactive barrier (PRB) systems that function as passive groundwater treatment systems and offer a potential nitrate mitigation measure for managing nitrate impacts in New Zealand hydrological catchments, in particular those comprising alluvial gravel aquifers.

The concept of a denitrification wall is to emplace a PRB across the path of nitrate contaminated groundwater flow. Conventional practice is to construct the 'wall' with sand or gravel aggregate to which some solid organic material has been added (typically wood-chip). The aggregate component is required to: enhance and maintain the permeability of the barrier; act as a weighting material for wall emplacement, and; reduce the amount of compaction after installation (USAF, 2008), whereas the organic fraction promotes anoxic conditions and acts as both a substrate and support matrix for denitrifying organisms which metabolise any dissolved nitrate in the groundwater, converting it to gaseous nitrogen products.

So far there are no examples of denitrifying walls having been installed or designed for an alluvial gravel aquifer setting, although we are working on changing this. Previous research we have conducted on this topic has focused on identifying a binary mixture of wood-chip and gravel with hydraulic properties that would be commensurate with an alluvial gravel aquifer (Burbery et al., 2014). The technical challenge of how such a mixture could be emplaced in an aquifer effectively remains to be addressed. Conceivably, if a pre-prepared mixture of wood-chip and gravel was deposited in an open saturated excavation, similar to the PRB emplacement methods Barkle et al. (2008) describe, the two different elements would separate out due to differences in their specific weights. This presumably would result in a non-uniform wood-chip/gravel mixture that would have implications for the performance of the denitrification wall. If a trench dug below the water table were dewatered this presumably might offer a better outcome, although how practical/cost-effective it is to do this in a gravel aquifer setting is questionable.

Foam glass (also known as cellular glass) is a lightweight recycled glass product with physical properties similar to pumice. Being composed of glass, the medium is relatively inert and in countries such as Japan is used as a light sub-grade material in civil engineering applications, including use as a porous fill medium in construction of buried reservoirs to store rainwater (e.g. http://trims.co.jp/english/product/index.html). We perceive the high effective porosity and low specific weight of foam glass (which is comparable to that of wood-chip) are attributes that benefit its use in the construction of denitrification walls, as an alternative to conventional mineral aggregate. The aim of this work was to examine the settlement properties of binary mixtures of wood-chip/foam glass as model denitrification wall fill. Also, to compare the results against binary mixtures of wood-chip/greywacke gravel, which we assume as the benchmark case.

Aims

We hypothesise that a more uniform packing arrangement is obtainable for mixtures of wood-chip/foam glass aggregate than wood-chip/greywacke aggregate, and that a useful application of foam glass is therefore in the construction of denitrification walls to treat groundwater nitrate.

Method

Bench-scale tests were performed to study the settlement characteristics of the binary mixtures, using a clear plastic column apparatus of 40 mm diameter, containing a 600 mm column of water. 50% v/v binary mixtures (100 mL total) were examined and the experiment was scaled adopting particle size as the reference dimension – the nominal particle size for all media being approximately 4-6 mm.

Foam glass aggregate was provided by Hadlee and Brunton Recycling Ltd., Timaru. It represented 'Supersol' product, manufactured by the Trim Co. Ltd., Japan. Three different grades of product were examined, these being: Supersol L1, L2 and L4, the physical properties of which are given in Table 1. Some manual processing was required to break the glass down to the particle size required for our bench-scale tests. Greywacke aggregate used in the experiments was sourced from a local quarry in Christchurch. Macrocarpa shavings were used as a model wood-chip component. Wood shavings were first oven-dried then amended with water to provide a moisture content of 30% w/w, comparable to that of freshly chipped wood (e.g. EECA, 2010).

Care was taken to ensure the binary mixtures examined were uniformly mixed (see Figure 1), before they were tested, in triplicate. The settlement experiments involved pouring a pre-prepared binary mixture instantaneously into the column apparatus. The separation of particles as they settled in the column of water was filmed and the resulting mixture at the bottom of the water column was photographed. A visual assessment was made of how uniformly-packed the settled particles were at the end of each test.

Medium	Specific gravity
Supersol foam glass L1	0.3 – 0.6
Supersol foam glass L2	0.4 – 0.5
Supersol foam glass L4	1.0 – 1.6
Greywacke	2.2 - 2.8
Wood (pine; 30% moisture content)	0.78-0.81

Table 1: Reported specific gravities of the components used in binary mixture settlement tests (data sources: http://www.trims.co.jp/english/product/index.html; http://www.edumine.com/xtoolkit/tables/sgtables.htm; http://www.engineeringtoolbox.com/wood-density-d_40.html)

Figure 1: 50% v/v mixture of wood-chip and Supersol L1 foam glass before settlement test. Pottle height is 75 mm.

Results

As predicted, due to the large specific weight differential between wood-chip and greywacke gravel, the two elements completely separated out during settlement in the water column. Surprisingly, Supersol L4 similarly settled at rates faster than the wood-chip, producing a reasonably non-uniform wood-chip/foam glass mixture. Supersol L1 and L2 were discovered to produce the most uniform wood-chip/foam glass mixtures, and we believe either of these products would make an ideal aggregate for use in wood-chip denitrification walls. Besides the favourable density properties we examined here, the high effective porosity of the foam glass media is another conceivable benefit for its application in PRBs.

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TRANSFER PATHWAYS – NEW RESEARCH TO IMPROVE CONTAMINANT TRANSFER UNDERSTANDING

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Aims

Land use (source) can only be defensibly linked to an effect on a receiving water body (recipient) 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, surface runoff, interflow, artificial drainage, shallow and deep groundwater may be critical transfer pathways. The time it takes a contaminant to move from source to recipient ('lag time') is one of the key hydrological characteristics of each transfer pathway. Amongst the biogeochemical processes, those that result in contaminant attenuation (e.g. denitrification of nitrate) are generally of greatest importance. Failing to explicitly consider both types of 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.

The Transfer Pathways programme has therefore been developed to quantify pathway-specific contaminant transfers that take lag times and attenuation potentials of the different transfer pathways into account. The contaminants considered in this research are the plant nutrients nitrogen (N) and phosphorus (P). The quantitative understanding of the contaminant transfers through the various pathways together with the tools developed in this programme 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 outcomes on the land while achieving the surface water quality targets mandated by the community.

This programme was successful in the Aquifer Management investment priority of the MBIE 2015 Targeted Research investment round. 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.

Methods

Our research will focus on case studies in three regions, the Upper Waikato and Hauraki sub-regions in Waikato, the Wairau Plain in Marlborough, and the Waimakariri water management zone in Canterbury. These case studies differ in the hypothesised critical transfer pathways, attenuation potential as well as their resource management issues (Fig. 1).

By 2018 we will have established how N and P transfer is partitioned across the pathways relevant in the case study areas. This will be achieved by applying a range of analysis methods, including end member mixing analysis (Barkle et al., 2014) and lumped component modelling (Woodward et al., 2013), which build heavily on data existing from previous research programmes and state of the environment monitoring programmes ('data mining'). Targeted new investigations will be carried out to close key knowledge gaps identified during the initial data screening phase of the programme. In particular, we will initiate high-resolution water flow and water quality monitoring at locations and/or during periods where dynamic N or P concentrations are to be expected. This will be facilitated by the development of a novel in-situ nitrate sensor by Lincoln Agritech. This sensor, developed outside of this programme, is designed to break the affordability barrier to nitrate measurements in high temporal and spatial resolution.

Concurrently to the transfer pathway partitioning, 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.

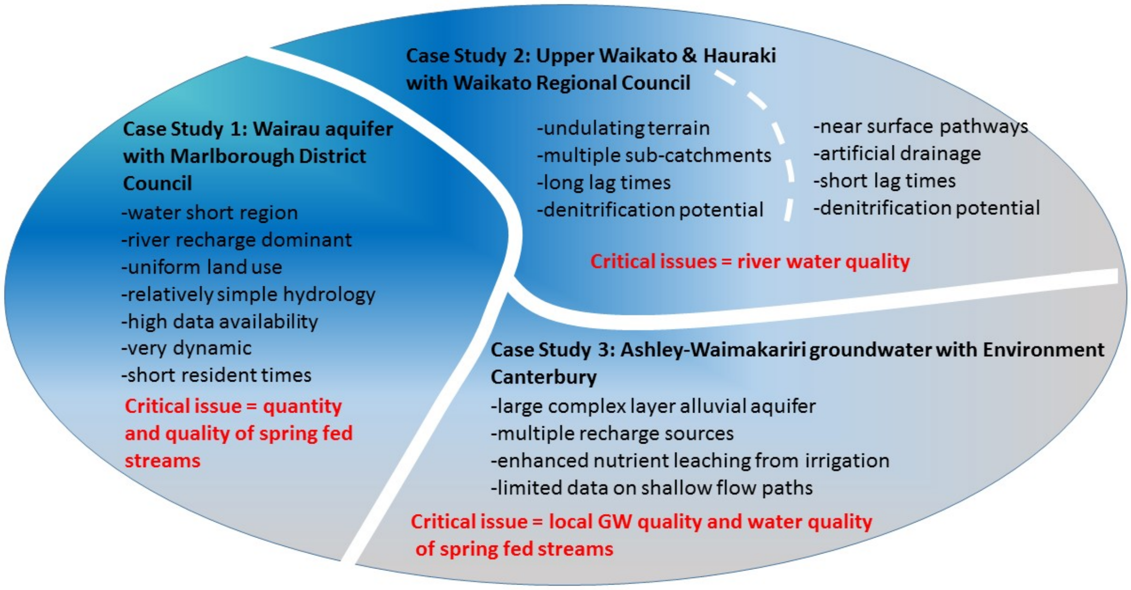

Fig. 1: Case studies overview

Programme Outputs

In close collaboration with our industry and council partners we will produce the following outputs:

1. Conceptual catchment models to convey the relevant hydrological understanding of how each catchment works.
2. Transfer pathway partitioning methods suited to a range of natural settings and data availabilities.
3. Catchment typologies that allow pathway partitioning results to be transferred from well-investigated catchments to catchments with little information.
4. Spatially distributed models that simulate water flows and contaminant loads for all relevant pathways from source to discharge 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 land and water management.

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HALON-1301 – FURTHER EVIDENCE OF ITS PERFOMNCE AS AN AGE TRACER IN NEW ZEALAND GROUNDWATER

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Introduction and Aims

Groundwater age or residence time is the time water has resided in the subsurface since recharge. The determination of groundwater age can aid understanding and characterization of groundwater resources, because it can provide information on groundwater mixing and flow, and volumes of groundwater and recharge, etc. Groundwater age can be inferred from environmental tracers, such as SF_6 and tritium. The currently used age tracers face limitations regarding their application range and reliability. To reduce these limitations, it is now recognized that multiple tracers should be applied complementarily. There is also a need for new groundwater age tracers and/or new groundwater dating techniques to supplement the existing ones.

We only recently discovered a new groundwater age tracer, namely Halon-1301, which can be used to date groundwater recharged after the 1970s (depending on the limit of detection and mixing model assumptions). In the majority of 18 assessed groundwater samples Halon-1301 inferred ages agreed with ages inferred from SF_6 and tritium, two relatively reliable groundwater age tracers. In the remaining (anoxic) water samples reduced concentrations of Halon-1301 were found. It was unclear if these were caused by degradation of Halon-1301 under anoxic conditions or sorption of Halon-1301 to aquifer material. No sample indicated contamination of Halon-1301 from local sources. Both contamination and degradation can result in misleading age estimates.

This study aimed to further assess the performance of Halon-1301 as a groundwater age tracers under other groundwater conditions than previously assessed. Of particular interest was to confirm the absence of local sources of Halon-1301 that contaminate groundwater samples and to confirm the cause(s) of reduced Halon-1301 concentrations.

Methods

In this study, we analysed 91 groundwater samples for Halon-1301. The samples were taken from over 20 different aquifers in New Zealand and included anoxic to oxic samples. The samples were also dated with tritium and/or SF_6 with mean residence time (MRTs) ranging from < 2 years to over 150 years old (tritium free) water. All samples were also dated with the CFCs -11, -12 and -113. The majority of these samples showed reduced/elevated concentrations of CFCs which made it impossible to infer a reliable age with the CFCs for these samples.

The water samples were analysed on a GC-ECD (gas chromatography with attached electron capture detector) setup described in Beyer et al., 2014, which also allowed for simultaneous analysis of SF_6. Lumped parameter modelling was used to infer age distributions and MRTs from concentrations of Halon-1301 (and SF_6). Simultaneous analysis of Halon-1301 with SF_6 in the same water sample allowed for identification of contact with air during sampling (which can lead to contamination of the water sample with the higher modern atmospheric concentration of both SF_6 and Halon-1301), contamination from other sources or degradation (elevated/reduced concentration of either Halon-1301 or SF_6). Comparison of Halon-1301 and SF_6 inferred ages to tritium inferred ages allowed for assessment of unsaturated zone processes and confirmation of degradation/contamination of one or both Halon-1301 and SF_6. Assessment of Halon-1301 in CFC degraded or contaminated samples allowed further assessment of the degradation and contamination potential of Halon-1301.

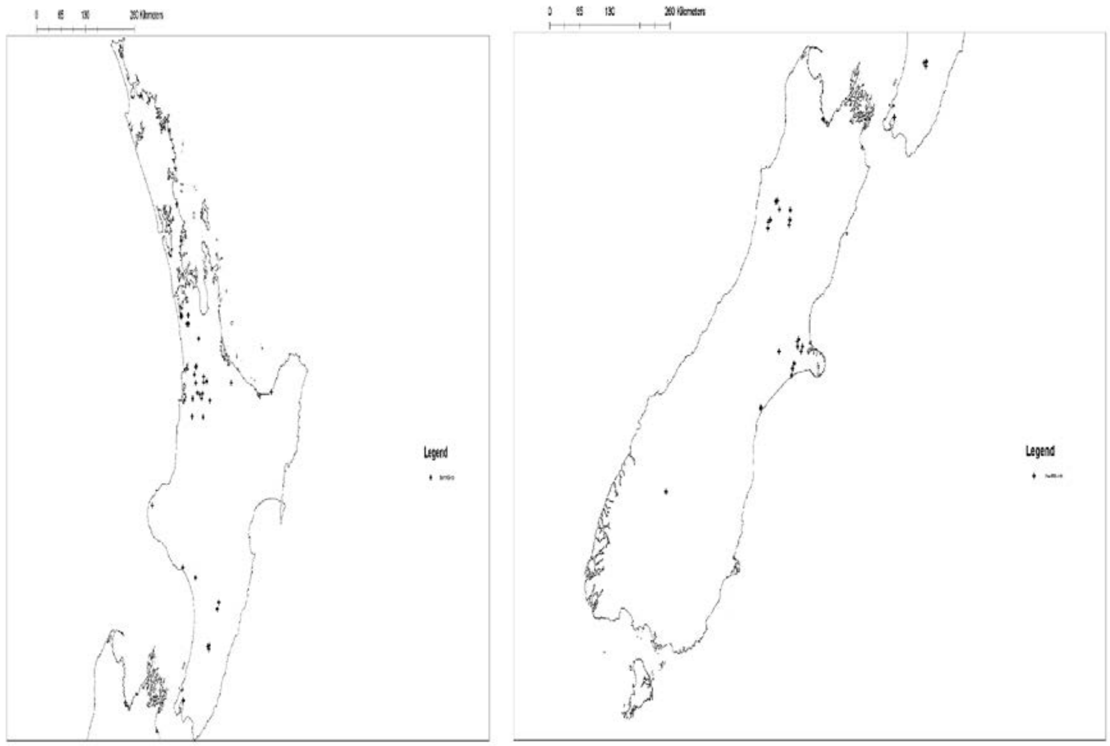

Figure 1: location of groundwater samples analysed for Halon-1301 (symbolized as crosses) in New Zealand's North Island (left) and South island (right)

Results

The majority of assessed groundwater samples in this study showed matching Halon-1301 and SF_6 and/or tritium inferred ages, which confirmed that Halon-1301 can be used to reliably infer groundwater age. None of the samples showed elevated Halon-1301 concentrations, which confirms the absence of local sources of Halon-1301 at the studied sites. The remaining samples showed reduced concentration of Halon-1301. All samples that were reduced in Halon-1301 were anoxic, which confirmed our previous suspicion that reduced concentration may be caused by degradation of Halon-1301. We could not previously exclude that reduced concentrations were caused by sorption of Halon-1301 to aquifer material. Since reduced concentration of Halon-1301 in this study were also found in very young groundwater samples that are not likely affected by sorption (due to the short exposure of the water to aquifer material), we suggest that reduced concentrations of Halon-1301 are more likely caused by degradation rather than sorption in the aquifer.

Overall, Halon-130 performed well as an age tracer in the majority of groundwater samples. Although reduced Halon-1301 concentrations were found in a few samples resulting in misleading Halon-1301 inferred age estimates, overall Halon-1301 performed significantly better than the CFCs which are prone to degradation and contamination (in this and our previous study).

Acknowledgement The New Zealand Ministry of Business and Innovation is thanked for funding in line with the SAC (smart aquifer characterization) project.

SUSTAINABLE YIELD MODEL- A WATER SUPPLY PLANNING TOOL

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Greater Wellington Regional Council (GWRC) operates a water supply system that is heavily reliant on run of the river supplies. The system is very dynamic in its response to changes in the weather. Hence to get the best out of the system requires up-to-date information on system components, and modelling tools able to estimate what will happen under various scenarios, so that choice of the most robust options can be taken. To assess the reliability of their wholesale water supply to meet the 2% Annual Shortfall Probability (ASP) level of service target published in the GWRC long term plan, GWRC uses an objective-orientated network linear programming model. The model, called the Sustainable Yield Model (SYM), is also used as a planning tool to determine the benefits of future supply options and distribution upgrades. Objective-orientated network linear programming model satisfied all the objective set in all the nodes and arc by taking account of incoming and outgoing flow.

The SYM is made up of nodes connected together by arcs. Nodes represent network components such as reservoirs, pipe junctions and demand centres. The arcs represent flows in pipes and stream channels. One of the innovative aspects of the SYM is the use of a series of reservoir nodes and streamflow channels to simulate the behaviour of the Lower Hutt aquifer system that is subject to pumped abstraction. The SYM has been set up to simulate the operational and environmental controls that affect running of the actual supply network, e.g., minimum flows in rivers. Owing to the nature of New Zealand's environmental legislation many of the environmental rules are complex and the system is able to handle these satisfactorily.

The SYM uses daily demand, rainfall and river flow data to model water supply under specific operating procedures. The network can be altered easily to add new components, such as reservoirs, or to change the properties of existing components, such as pipe size. This allows assessment of the response of the water supply system to changes in infrastructure and/or changes in operating practices, such as changes in environmental constraints. The rainfall and river flow data can be altered to assess the sensitivity of the system to changes in climate, and the demand data can be altered to assess changes in water use under different climate scenarios, new stresses imposed by population growth, or the potential effects of demand restriction scenarios. SYM can also be used to assess the effect of sea level rise or aquifer subsidence due to movement of the Wellington Fault.

In this study capability of SYM will be discussed.

VERIFICATION STRATEGIES FOR OPERATIONAL FLOOD FORECASTING

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Forecast are generally imperfect due to various kinds of error and uncertainty involved in forecasting system. Any forecast without a proper verification is not complete. In order to provide the highest level of service possible, every forecast created should have a corresponding verification component that provides information concerning its performance. Both the forecaster and users of the forecast products benefit from such information, especially when the forecasts are verified thoroughly and systematically. Thus, forecast verification is necessary to evaluate the quality of the forecasts and to guide the development and improvement of a forecasting system.

Aims

In this study, we verify operational flood forecast of NIWA. Operational flood forecast of NIWA uses Recursive Ensemble Kalman Filter (REnKF) to assimilate streamflow data. From year 2012, operational flow forecasting system of ten catchments in New Zealand is running to give 48hr flood forecasting with every 3hr updates.

Method

NIWA operates the flood forecasting system for many rivers in New Zealand. Systems are used to provide 48h lead time deterministic forecasts for 10 water gauging sites on an hourly basis. In this study, archived forecasts covering the period from 2012 to 2015 were analysed.

We performed a series of tests on operational flood forecasting of NIWA, using the 10 catchments located in both North and South Island of New Zealand. The forecasts were tested for lead times between 0 - 3 h and 45 - 48 h, in 3 h increments, and the forecast performance was quantified in terms of Nash Sutcliffe score, RMSE etc. The Nash Sutcliffe score is calculated using equation below:

Where NS is Nash Sutcliffe coefficient, O is observed and M is model flow. is mean observed flow.

We evaluated the median ensemble member with observed discharge with following evaluation criteria:

9) Relative difference of peak flow
    - o Hit and miss Rate

Results

We tested the performance of each simulation for a range of lead times. The lead times used were from 0 - 3 h, to 45 - 48 h, in 3 h intervals. The presented results are based on an evaluation of exceedances of the "flood watch" threshold.

Figure 1 depict cases where observed peak were identified and corresponding peak identified for different forecasting time period. The first 3 and 2nd 3hr forecast have better match as compared to other higher forecast period. Mostly model is under predicting for higher flood and error increased with forecast time. Similarly in timing of peak is mostly after the real events and there is more timing error for lower events with respect to very high flood. It simply indicate modelling is doing better prediction in timing than magnitude. This can be due to calibration of model parameters, model structure or input from NWP.

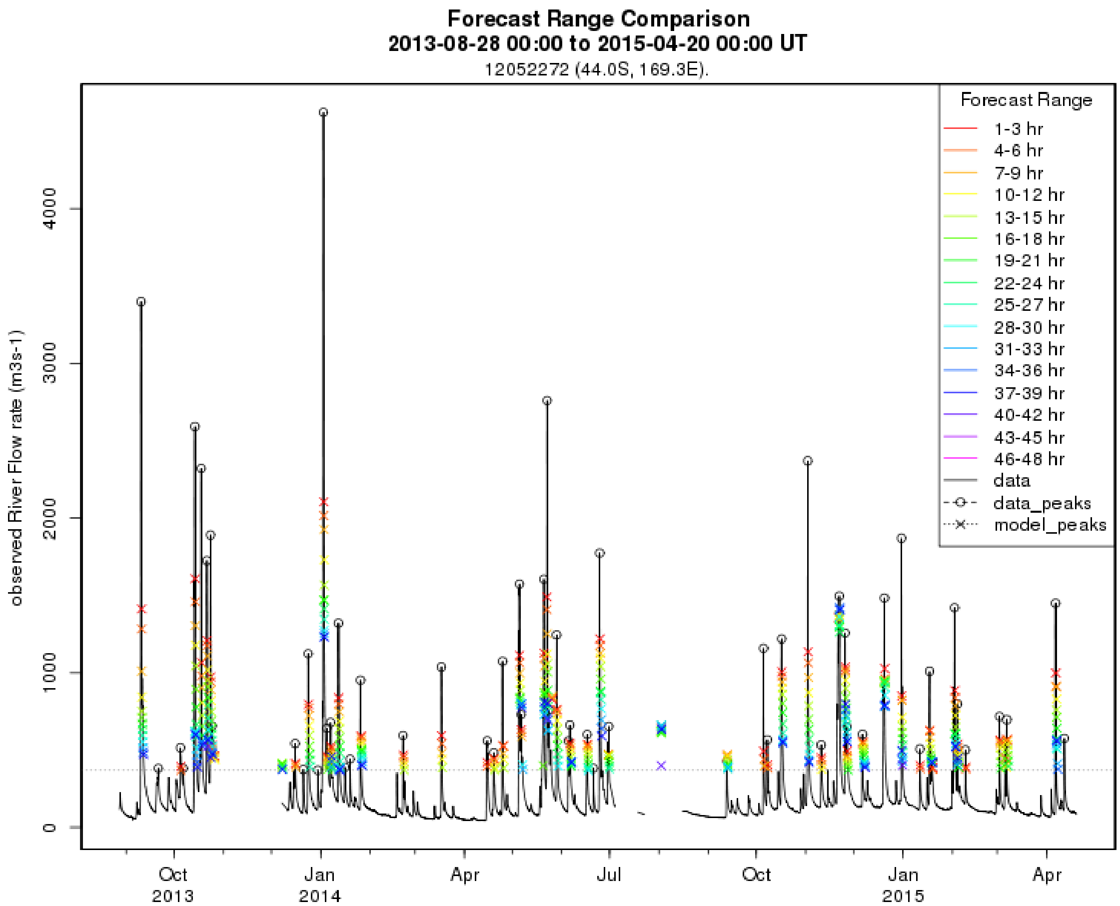

Figure 1 observed peak were identified and corresponding peak identified for different forecasting time period

STREAMFLOW COMPONENT SEPARATION USING THE BRM FILTER IN THREE NEW ZEALAND CATCHMENTS

Dr Michael Stewart[1]
[1]*Aquifer Dynamics & GNS Science, Lower Hutt, New Zealand*

Aims

To demonstrate the use of the BRM filter for streamflow component separation in three New Zealand catchments.

Method

Tracers such as stable isotopes or chemicals have been used for over forty years to separate hydrographs into different flow components. They have shown that baseflow (groundwater) plays an active and often dominating role in streamflow generation, and in fact is surprisingly responsive to rainfall. This has led to a novel baseflow separation filter (the 'bump and rise' method or BRM filter) that can be applied to streamflow data to extract baseflow or other components from the streamflow record (Stewart 2015). The BRM algorithm is calibrated by fitting to tracer separation data or by an optimisation technique.

Results

Glendhu Catchment, Otago, NZ. The BRM filter was calibrated by fitting to ^2H tracer data which separates streamflow into event and pre-event components (Bonell et al., 1990). A good fit is obtained between the BRM and the pre-event water (better than those obtained by other baseflow separation methods, Stewart 2015).

Toenepi Catchment, Waikato, NZ. Tritium and silica concentrations were used to identify three components in the streamflow (quickflow, fast groundwater and slow groundwater). The BRM filter was applied to separate these components in the hydrograph using the optimising method. The components were then used to simulate the nitrate-N concentration in the stream.
Tutaeuaua Catchment, Taupo, NZ. The BRM filter was applied using the optimising method. Tritium measurements were available for a period of eight years and the BRM baseflow separation is useful in determining the makeup of the streamwater when the samples were collected, since baseflow and quickflow have very different tritium concentrations.

The table gives information on the catchments and the BRM parameters derived. The catchments have similar baseflow indexes (BFIs), but very different bump fractions (f) ranging from 0.78 for Toenepi to 0.01 for Tutaeuaua. This means that at Toenepi most of the storm peak is composed of baseflow (actually the fast groundwater), while at Tutaeuaua almost none of it is. This extreme difference in catchment response is considered to be due to the different subsurface permeability structures of these two catchments, but needs to be checked by tracer measurements.

Table. Catchment information and BRM filter parameters for the studied catchments. f is the bump fraction, k the slope of the rise, and BFI the ratio of baseflow to streamflow.

Catchment	Rock type	Area km^2	f	k $mmd^{-1}h^{-1}$	BFI
Glendhu	Schist	2.18	0.4	0.009	0.78
Toenepi	Volcanic ash	15.1	0.78	0.00006	0.83
Tutaeuaua	Volcanic ash	4.73	0.01	0.0029	0.83

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BUILDING A STABLE ISOTOPE MAP OF NZ GROUNDWATER FROM EXISTING DATA: PART 2

Mrs Vanessa Trompetter[1], Ms Heather Martindale[1], Mr Rob van der Raaij[1], Mr Uwe Morgenstern[1]
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Aims

To map stable isotope data that was previously unuseable.

Stable isotopes are valuable tracers for groundwater, allowing recharge source determination. During the analysis of tritium, stable isotopes are measured before and after enrichment as part of the calibration procedure. This stable isotope data, however, cannot be used directly for understanding groundwater flow processes because the isotope ratios have been altered due to pre-treatment by vacuum distillation.

We have quantified the isotope shifts during the distillation process to allow for correction of the altered isotope data and therefore can make a vast amount of stable isotope data available for the understanding of groundwater processes that was previously not possible to use.

Method

Our experiments showed a good correlation between the isotopic shift and the amount of water recovered. The total shift for clean NZ samples distilled to dryness was found to be 3.8 ‰ which can be quantified with accuracy 1.0 ‰. Applying this correction to the distilled stable isotope data results in an increase in measurement error of 1 - 2 ‰, which is insignificant. The vacuum distillation is performed in a consistent way and we have shown that the isotopic shift can be quantified and therefore the distilled stable isotope data can be corrected turning this previously unusable data into knowledge.

Conclusions

Our distilled stable isotope data has been corrected for hundreds of NZ tritium samples, which has increased our bank of stable isotope data available. This corrected stable isotope data can now be mapped and the data used to increase our knowledge of groundwater flow processes.

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FROM DATA TO KNOWLEDGE: IDENTIFYING LITHOLOGIC CONTROLS ON GW/SW INTERACTION USING A HYBRID CLUSTERING APPROACH, SOUTHLAND, NZ

Mike Friedel[1], Clint Rissmann[2], Chris Daughney[1], Lawrence Kees[2]
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Aims

Numerical models provide a way to evaluate GW/SW systems, but determining the hydrostratigraphic units (HSUs) used in devising these models remains subjective and uncertain. A hybrid-clustering approach is proposed to identify HSUs controlling groundwater/surface-water interaction, as part of a cooperative study between GNS Science and Environment Southland.

Method

First, an unsupervised machine-learning algorithm (self-organizing map) is applied to fuse hydrochemistry (major ions, trace metals, carbon, dissolved gases, environmental tracers, isotopes, and nutrients), aqueous field parameters, aquatic biology, stream flow, hydraulic head, and lithologies. Information associated to neurons is connected through weight vectors sometimes called a codebook. Second, the application of a partition-based algorithm (k-means clustering with a Davies-Bouldin criteria) to the machine-learning network resulted in statistical descriptions of meaningful patterns.

Results

Six HSUs are identified that differ in their SW and GW contributions, and the lithologies controlling hydrochemistry. Each of these HSUs is associated with a primary and minor lithology. For example, the groundwater dominated (99%) HSU 1 is characterized by mudstone (36%), gravels (20%), sand and gravels (10%), sandstone (10%), and lessor amounts of limestone (2%) and sandy clay (3%). In total, these lithologies explain 81% of the lithologies controlling the GW chemistry. The second GW dominated (97%) HSU is characterized primarily by sandstone (69%), and minor clay bound gravels and small boulders (29%). These two lithologies explain 97% of the lithologies controlling the water chemistry. HSU 3 is characterized by mostly GW (64%) but also some SW (36%) interaction. This HSU is characterized as a heterogeneous formation of minor lithologies, such as clay (12%), lignite (16%), mudstone (17%), and sand (9%). These lithologies explain 82% of the control on water chemistry. HSU 4 has equal proportions of GW (51%) and SW (49%) interaction in the peat (86%). By contrast, HSU5 is SW (72%) dominated with minor GW (28%) contributions. The predominant lithology is clay bound gravels (48%) with minor amounts of lignite (17%) and sandstone (15%). Collectively these lithologies account for 91% of the controls on hydrochemistry. HSU 6 is SW (97%) dominated with 97% of the lithology characterized as lignite. In this application, the increased certainty from two-step hybrid-clustering approach provides a mechanism to constrain HSUs, quantify uncertainty when constructing SW/GW models and using their predictions. Improvements in the model can increase the defensibility, application, and value of predictions to the end users.

FROM DATA TO KNOWLEDGE: HYDROGEOPHYSICAL DATA FUSION AND ESTIMATION OF PROBABLE AQUIFER PROPERTIES IN THE OTAGO REGION, NZ

Mike Friedel[1], Zara Rawlinson[1], Kolja Schaller[1]
[1]*GNS Science, Avalon, New Zealand*

Aims

A novel approach is proposed for mapping aquifer characteristics in the Strath-Taieri Basin as part of the Smart Aquifer Characterisation Programme.

Method

An unsupervised vector-quantization algorithm, called Self-Organizing Map, is used for the simultaneous fusion of sparse and scale-dependent airborne (electromagnetic measurements and their numerically inverted resistivities) and borehole (lithologies, water levels, hydraulic properties, and hydrochemistry) data. Component planes technique is used to evaluate relations among data variables. Cross-validation (leave-one-out strategy) is conducted to evaluate model uncertainty for selected variables. Least-squares minimization of the topological and quality error vectors is used to estimate lithologies at airborne sounding locations across the region. Lastly, clustering of lithologies is used to differentiate spatial distribution of likely aquifer characteristics.

Results

Component planes (fig 1) plots provide a visual comparison among the fused (disparate and sparse) data variables: inverted 1D layer resistivity profiles (res), airborne electromagnetic (EM) measurements (CP400I, CP400Q, CP1800I, CP1800Q, CX3300I, CX3300Q, CP8200I, CP8200Q, CP40KI, CP40KQ, CP140KI, CP140KQ; CP=coplanar configuration, CX = coaxial configuration, I = in-phase component, Q=quadrature component,), lithologic fractions (grv=gravel, snd=sand, slt=silt, cly=clay, bdrk=bedrock), hydraulic conductivity (Ks), and major ions (TDS=total dissolve solids, Ca=calcium, Cl=chloride, Cond=electrical conductivity, HCO3=bicarbonate, Na=sodium, NH4=methane, NO3=nitrate, PO4=phosphate, SO4=sulfate). Hot colors indicate high values and cold colors low values, and similar patterns and colors indicate high positive correlation, similar patterns with opposite colors indicate high negative correlation; different patterns but same color at same component location indicate positive correlation in a subset of the data variables and vice versa. Principal component analysis of the component planes (fig 1) reveals groupings of related variables, for example group 1: Ks, grv and snd; group2: TDS, HCO3, Cond, res; group 3: slt and cly; and group 4: EM measurements. Group 4 is inversely (opposite sides) related to group1 with selected EM measurements, indicating CP140KQ is more sensitive to group 2 and CP400I more sensitive to group 3. Exploitation of these relations provided quasi-3D estimates of lithologic fractions. Grouping of fractions are used to indicate likely aquifer, likely flow-restricted aquifer, unlikely aquifer, and no aquifer as depth slices. The future application of Davies-Bouldin clustering criteria is suggested to determine an optimal number of hydrostratigraphic units for development of catchment-scale numerical flow models.

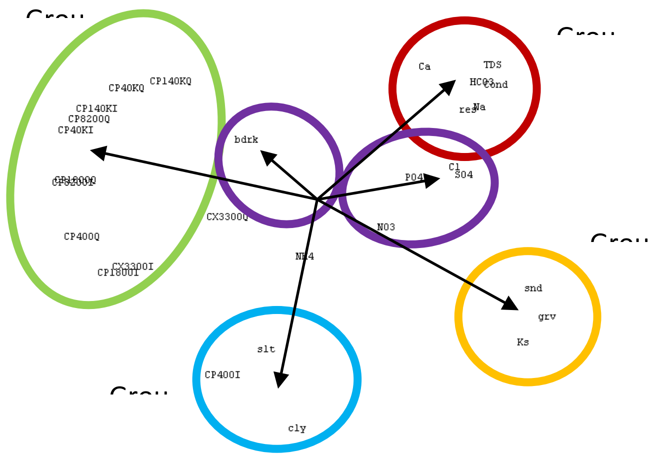

Fig. 1. Principal component projection of component plot revealing fusion of disparate and sparse data variables and relations to each other.

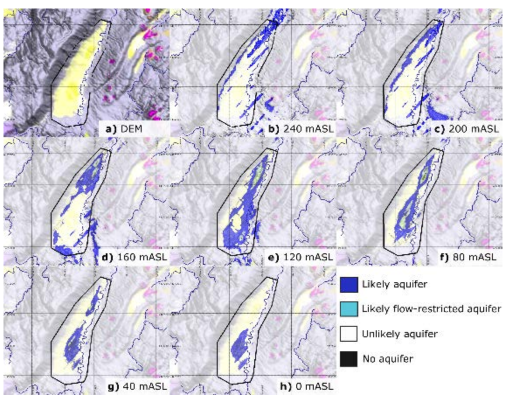

Fig. 2. (a) Distribution of aquifer characteristics with depth. Characteristics are based on groupings of machine-learning estimates. (b) Gravity modeled thickness of aquifer materials.

FROM DATA TO KNOWLEDGE: ARTIFICIAL ADAPTIVE SYSTEMS APPLIED IN HYDROLOGY

Mike Friedel[1], Massimo Buscema[2]
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Aims

This work focuses on revealing emergent properties and features of complex hydrologic systems that are often hidden from traditional view but important to water-resource managers.

Method

Models are developed using algorithms associated with Artificial Adaptive Systems (AAS). The ASS use natural computation whose generative algebra creates artificial models of natural processes from a set of observations. The stronger correlation that exists between original and model-generated process, the more likely the AAS explained the functioning rules of the original process. The success and applicability of AAS to extract knowledge is demonstrated using performance testing and uncertainty quantification techniques.

Results

The application of AAS is successfully used to for: estimating spatial continuity to assist groundwater model calibration, near real-time 3D mapping of heterogeneous alluvial aquifers, northwest Kansas, USA; identifying optimal model input for reduced prediction uncertainty, Central Colorado, USA; forecasting climate-change effects on ground water recharge, southeast Wisconsin, USA; and forecasting long-term conditional trends in temperature and precipitation. Southwestern USA. The applicability of AAS to solve otherwise intractable hydrology problems provide impetus for their application in New Zealand. Currently, GNS Science is applying AAS techniques for applications in groundwater with Southland regional council and Ministry of Business, Innovation and Employment, and in climate with National Institute of Water and Atmospheric Research.

USING THE NATIONAL TOPNET MODEL TO ESTIMATE FLOOD MAGNITUDE

Mr Roddy Henderson[1], Mr Nathan Martinet[2], Dr Christian Zammit[1]
[1]*NIWA, Christchurch, New Zealand,* [2]*Polytech Montpellier, Montpellier, France*

The uncalibrated national hydrological model was able to produce mean annual flood statistics across a large range of catchments (internally and at the outlet) within the North and South Island with a bias of -25% and a root mean squared relative error (RMSRE) of ±52%.

Aims

This short student project aimed to investigate the potential use of the uncalibrated national TopNet model to estimate flood magnitude. A longer term aim is to develop interpolation procedures whereby the national TopNet results can be used to guide interpolation of various flow statistics at all reaches of the REC digital network.

Method

The national Hydrological model of New Zealand is a long-term hydrological modelling project whose goal is to make reliable estimates of all water fluxes and storages of New Zealand, and reliable estimates of potential changes in those water resources. This is an extremely ambitious scientific project, with many practical implications for water use and water planning.

The national hydrological model is uncalibrated, but uses information on elevation, land use, soils, geology and recession analysis to provide *a priori* parameter estimation based on the national dataset and physical catchment characteristics. Climate information is provided by the Virtual Climate Station network (VCSN), which provides daily climate information on a 0.05 degree grid across New Zealand since 1972, derived from both NIWA and regional council climate datasets.

Catchments were selected on the basis of the number of flow recorders within each, so that model results could be assessed against flood statistics (see Table 1). Catchments with large lakes and significant flow controls were avoided.

Table 1: Selected catchments.

Catchment	No of flow recorders
Jollie	1 (test catchment)
Hutt	9
Ruamahanga	13
Waimea	7
Motueka	10
Waiau	7
Opihi	10
Waihou	11
Wairoa	15
Waitara	8
Tukituki	9
Rangitaiki	5

TopNet model simulations were run from 1972 for each catchment. Time series were then extracted from the model output at the catchment outlet (most downstream recorder) and at reaches within the catchment where measured flood statistics were available. These time series were used to extract annual maxima, which were then processed to calculate mean annual flood and 100 year flood values at each site.

Results

Initial results are promising as shown in Figure 1. Bias of -25% is partly explained by the use of Virtual Climate Station Network rain as input, because of the 5 km grid spacing and daily timestep of the fundamental data. RMSRE of 52% is comparable to the recent check on the McKerchar and Pearson flood intensity contours with the updated flood dataset (see Henderson and Collins presentation at this meeting).

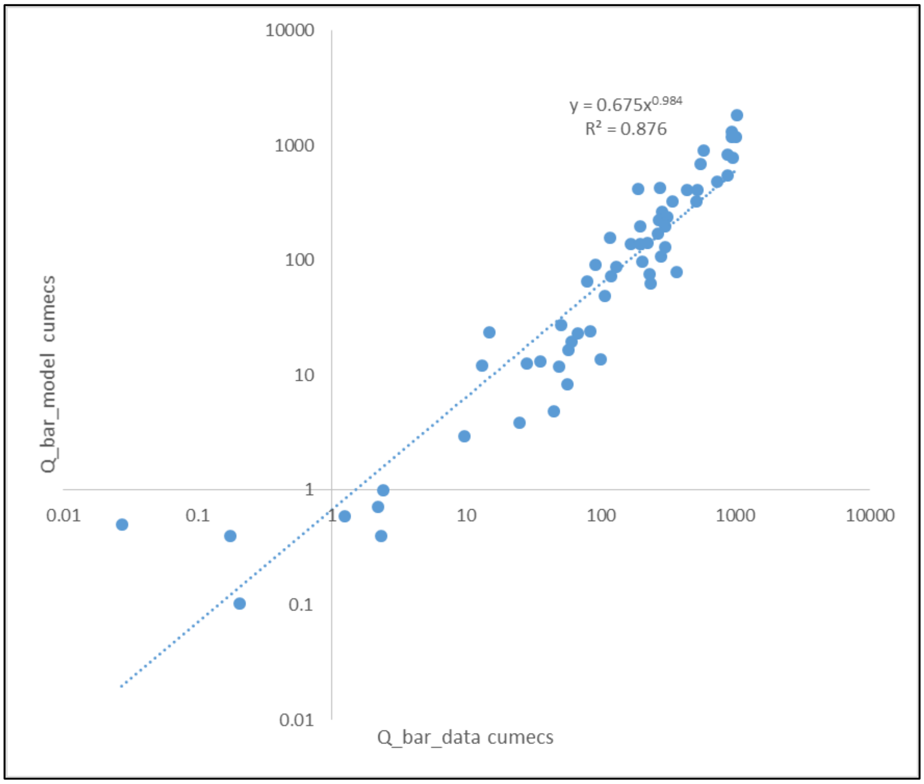

Figure 1: Mean annual flood values, modelled vs. at site data.

In future the national hydrological model could be used to analyse flood generation mechanisms and associated statistics across a range of landscape, soil land use and climate conditions.

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ASSESSMENT OF RADIOACTIVITY IN NUCLEAR-FREE NEW ZEALAND'S WATER ENVIRONMENT

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Aims

New Zealand is a proudly nuclear-free country, and the author has found since arriving a widespread perception amongst environmental professionals, regulatory authorities and the population at large that radioactivity is not a phenomenon of concern in New Zealand's water environment, other environmental sinks, or more generally. But is this a justified point of view?

Background

Radioactivity in the environment originates from three main sources, which interplay to a significant degree. These are Naturally Occurring Radioactive Materials (NORM), Technologically-Enhanced NORM (TENORM) and artificial / anthropogenic sources.

NORM comes about from the fact that low concentrations of radionuclides are present naturally in earth materials, and originate from primordial process, as part of radioactive decay chains, or are produced continuously in small quantities from sources such as cosmic rays. These radionuclides become incorporated into environmental media including ground- and surface water, the oceans, and living organisms through natural processes. Much of the natural burden of NORM in the global water environment comes about from the dissolution of minerals, but in the case of the deep oceans sources such as hydrothermal vents contribute NORM (IRPA, 2009).

Artificial processes can lead to NORM becoming concentrated, creating Technologically-Enhanced NORM (TENORM). Notable sources of TENORM include mining tailings and ore processing wastes, waste materials and processing effluents from hydrocarbon extraction including hydraulic fracturing, geothermal fluids, and agricultural fertiliser runoff (USEPA, 2015). Waste effluents enriched in radioactivity may be discharged directly to the water environment, or interaction of natural waters with waste materials may also produce contaminated runoff.

Artificial sources are largely from nuclear power generation and fuel reprocessing, military activities and radioisotope manufacture (for medical, industrial and other uses). The radionuclides generated often cannot be readily or economically recovered, so therefore are or have been discharged (legally or otherwise) directly to rivers, lakes, estuaries and the ocean.

Despite its diverse environmental settings, NZ has no notable occurrences of NORM affecting the water (or other) environments. Phosphate minerals found on the NZ oceanic continental shelf are known to contain uranium, but at very low concentrations (Bull, 2014). Radon is a notable form of gaseous NORM, but despite the occurrence of source geological features (most commonly granitic plutons) in NZ this is not a significant issue (MoH, 2015a). TENORM is likely to be the most significant sources for radionuclide input to water environments in NZ, with widespread intensive agriculture, mining and hydrocarbon extraction (including past instances of disposal of hydraulic fracturing fluid onto farmland), some ore processing, and extensive geothermal power generation. With artificial sources, NZ benefits from having no significant, widespread sources of artificial radioactivity of its own. Furthermore, due to its geographical isolation, discharges of radioactivity from other countries (including singular events such as nuclear weapon testing) undergo huge dilution and dispersion environmental before reaching NZ.

Method

These radiation sources combined produce background radiation. The quantification of public dose in NZ doesn't receive significant regulatory attention; no average annual background radiation figure is published for NZ, and the Environmental Radioactivity Report published by the Ministry of Health annually in NZ involves 6 sampling points (MoH, 2015). By comparison the UK equivalent, the Radioactivity in Food and the Environment (RIFE) report, gathers data from many thousands of sampling points and quantifies background radiation (UK Government, 2015).

The author proposes that compiling of a nationwide inventory of natural (NORM) and anthropogenic (TENORM and artificial sources) additions of radioactivity to water (and other) environments across NZ, including the nearby ocean, would be a useful exercise, as this would allow a quantitative assessment of actual impacts and risks to humans and other organisms.

Modelling of radionuclide dispersion in the water environment, in conjunction with other environmental media, using specialist software could provide robust quantitative underpinning to the assertion that NZ sources of radioactivity are insignificant, and result in insignificant doses to the general population. Furthermore, the UN World Average Dose figure (3.01 mSv yr^{-1} (UN, 2008)) could be replaced with a calculated, NZ-specific figure which may be significantly lower, thereby providing assurance of the low risks.

PC-CREAM (Consequences of Releases to the Environment Assessment Methodology) is radiological impact assessment software designed for the European nuclear industry, which models radionuclide dispersion in environmental media, and the resultant doses to exposed persons. The software consists of a number of modules for different environmental pathways, including modules for the modelling of river and ocean (local and regional scale) dispersion of radionuclides. These would allow for standalone assessment of impacts to the hydrological (aquatic and marine) environments from NZ sources of radioactivity, as well as wider impacts.

Conclusions

Generally, NZ has a very strong claim to be an environment where radioactivity and radiation are not a cause for concern, and there are no obvious, credible threats to that status. There is however little quantification of the sources, whether natural or artificial, which contribute to the radioactivity burden in NZ's water (and other) environments.

Quantification of radioactivity inputs to various environmental sinks, with a focus on water, combined with calculation of average background radiation dose for the average NZ resident using the PC-CREAM software package, could provide underpinning to that claim. This could also allow further consideration of due diligence and environmental best practice for industries and activities that handle radioactive substances in NZ.

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IMPLEMENTING ENVIRONMENT SOUTHLAND'S AUTO SAMPLER NETWORK IN RESPONSE TO THE NATIONAL POLICY STATEMENT FOR FRESHWATER MANAGEMENT

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Aims

The overall aim of this work stream is to quantify nutrient and sediment loading in Southland's major catchments to assist in future limit setting requirements. In order to achieve this, Environment Southland's Environmental Data team was tasked with the installation and programming of 11 Teledyne 6712 ISCO automatic water samplers which can be triggered remotely during high flow events.

Utilising this technology means that samples can be taken at regular intervals throughout an event without a staff member being present. This has advantages for more efficient data collection and improved health and safety of staff members.

Method

The ISCO auto samplers are self-contained units consisting of 24 sample bottles, a distributor arm, peristaltic pump, control panel, power supply, communication device and suction line.

Environment Southland has installed the auto samplers at existing continuous monitoring sites which have been set up with 12V power. They are housed either inside our larger enclosures or under large drums.

There are two methods currently being used to activate the auto samplers, one is via SMS and the other is via a DAA Waterlog data logger. After activation, a staff member needs to go out and collect all the samples within 24 hours of the first sample being taken to retain the integrity of the samples.

Method 1: SMS

The ISCO's standard programming option is easy and efficient. A time paced programme was created to sample two one litre bottles every 3 hours until all 24 bottles were filled.

The auto samplers have an inbuilt cellular modem which allows the unit to send and receive SMS text messages. This was used to activate sampling at a predetermined flow, where a txt message was sent to the ISCO by a staff member's phone when they received an alarm generated by Hilltop alarmist software.

Method 2: DAA Waterlog

Roughly half of the proposed auto sampler sites in Southland have poor cell phone coverage; therefore flow proportional sampling using a DAA Waterlog was developed to address this.

This is significantly more complex than Method 1 and requires the use of extended programming on the ISCO and generation of two specialised basic scripts for the DAA.

The two basic scripts are generated using a visual basic programme. Basic script 1 generates a flow rating curve and basic script 2 sets sampling thresholds (m^3/s) and flow intervals (m^3) that are used to start and stop sampling and generate increasing sample numbers that are recognised by the auto sampler.

The ISCO is connected to the DAA via SDI12 input into the rain gauge port on the ISCO and recognises the DAA as an SDI12 sonde. Extended programming is used to tell the ISCO to recognise the sample number sent by the DAA and initiate pumping.

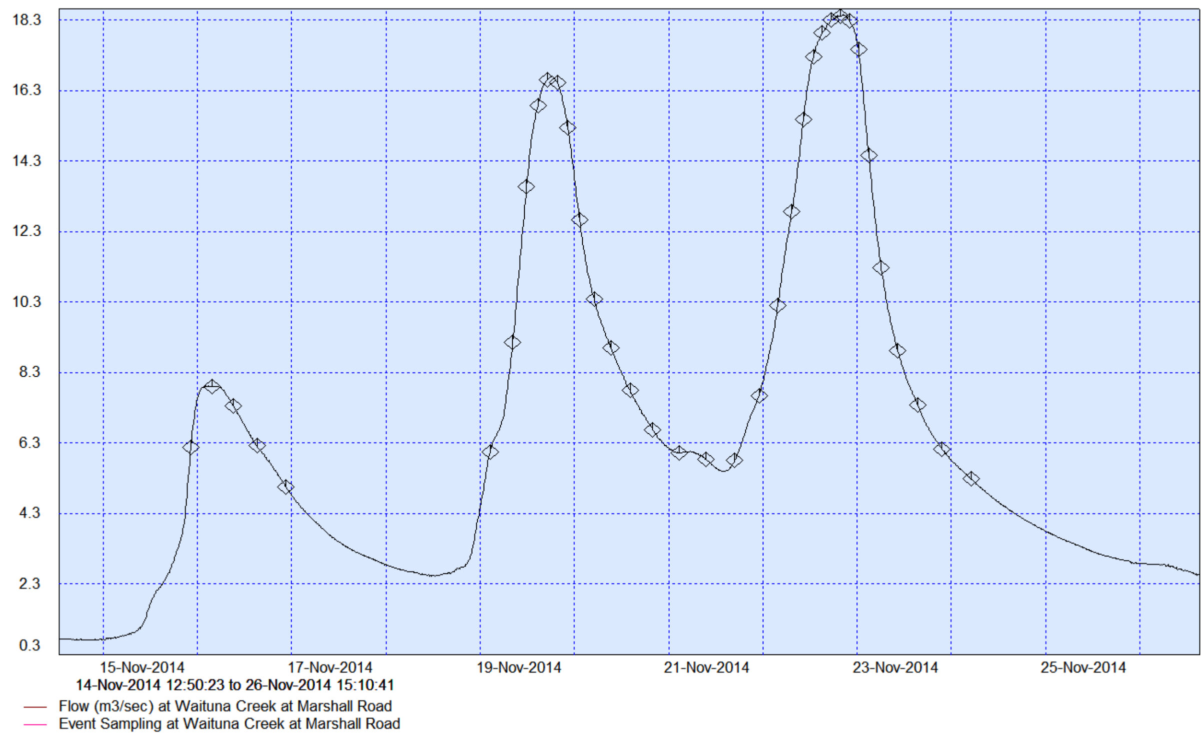

Figure 1
An example of a sampling event where the trigger flow is set to 6m^3/s, will sample every 150,000m^3 and will stop sampling at 5m^3/s

Results

Environment Southland has been using both of these methods for a significant period of time and as a result the advantages and disadvantages have been discovered.

Use of the SMS method has been somewhat unreliable with instances where they haven't started sampling and have to be manually reset on site. Additionally, the standard programming option is only able to purge and not rinse the suction line so there is often extra sediment in the first sample. Finally, using time paced sampling generates a full set of 24 samples every time which is time and cost intensive. However, this method of programming is much easier to apply.

Flow proportional sampling is a more efficient way of sampling as it allows for a good distribution of samples during a high flow event and often involves fewer samples which reduces the time and cost of processing the samples. The programming was initially very complex and time consuming but will prove to be more efficient in the long run as sampling will be initiated automatically and we can view sampling progression at the office via Hilltop.

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COLLECTION OF MULTIPLE DATA TYPES IN A LARGE RAINGARDEN: OVERCOMING NUMEROUS DIFFICULTIES

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Rain gardens are one of several versatile low impact design approaches; they have a significant effect on controlling runoff, groundwater recharge, and water quality. Rain gardens can provide a wide variety of worthy benefits, one of which is reducing runoff by increasing evapotranspiration (ET).

Estimating the amount of ET is necessary for predicting and quantifying such benefits. Study of the hydrology of rain gardens, including seasonal and diurnal effects, will provide a theoretical basis for their design.

Although field hydrology is more expensive than computing power and is accompanied by many risks and difficulties, field research can bring new fundamental understanding and mechanistic explanations of processes. It thereby contributes to hypothesis development (*Burt & McDonnell, 2015)*.

Aims

Our study has the following aims:

- to estimate ET for the design of rain gardens
- to determine the crop coefficient for rain gardens, for use with FAO crop coefficient method of estimating ET from reference ET

Method

The Hooton Reserve Raingarden which is located in North Shore (Auckland, New Zealand) was selected as the research site. The Hooton Reserve Raingarden has dimensions of 60m length by 22 m width and an area of about 1300 m^2.

The study involves the setup of an experimental site to measure a variety hydrological, meteorological, soil and plant variables (Figure 1).

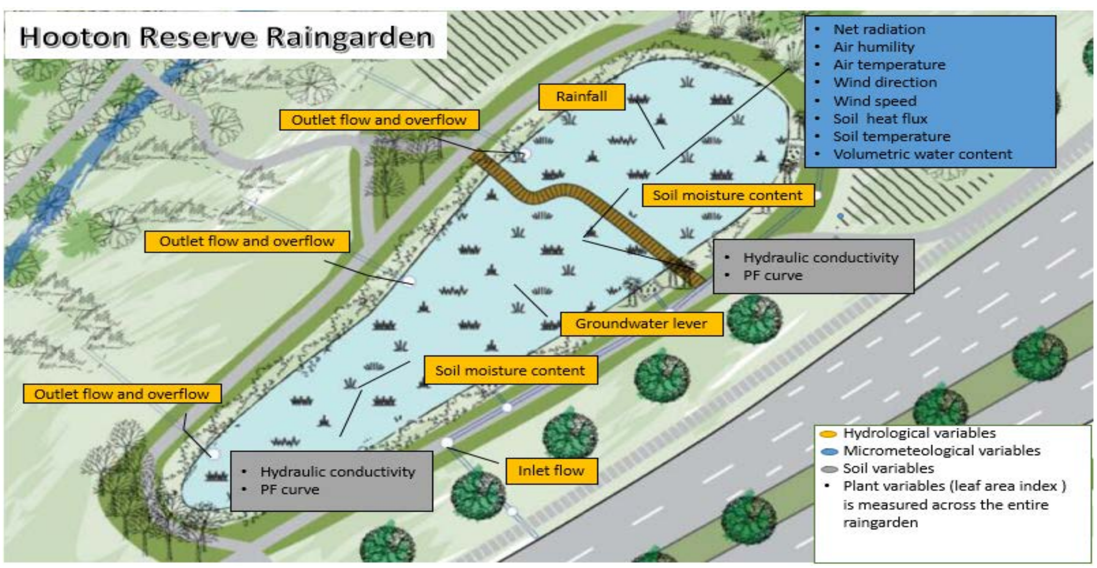


Figure1 Design of experiments in the Hooton Reserve Raingarden

The research focus is on conducting a comparative study between two approaches for estimating evapotranspiration in the raingarden ecological system: (a) experimental, utilizing both the water balance method and the energy balance method; and (b) theoretical, including theory based equations, empirical equations and hydrologic modelling (Figure 2).

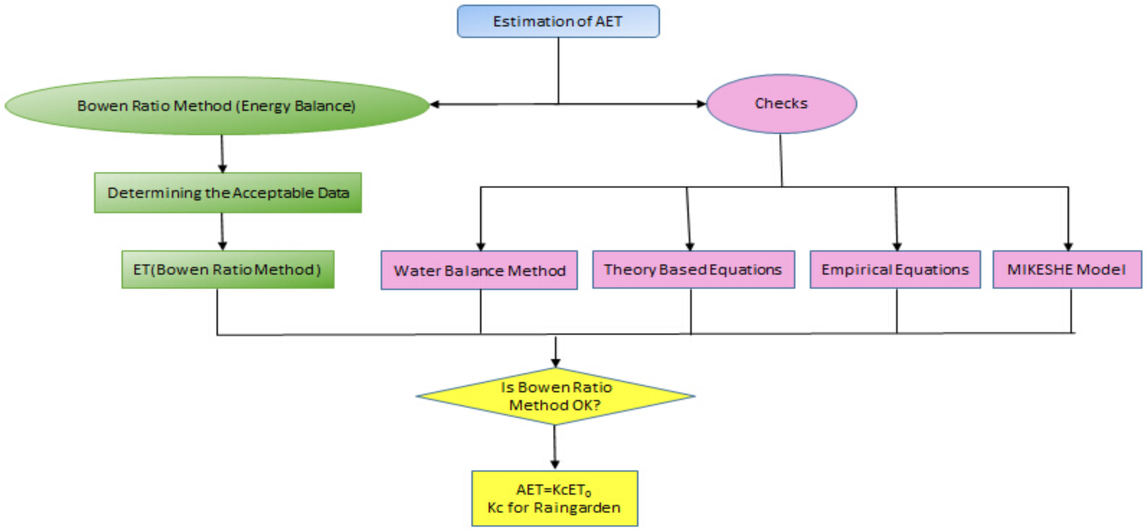


Figure 2 Research methodology

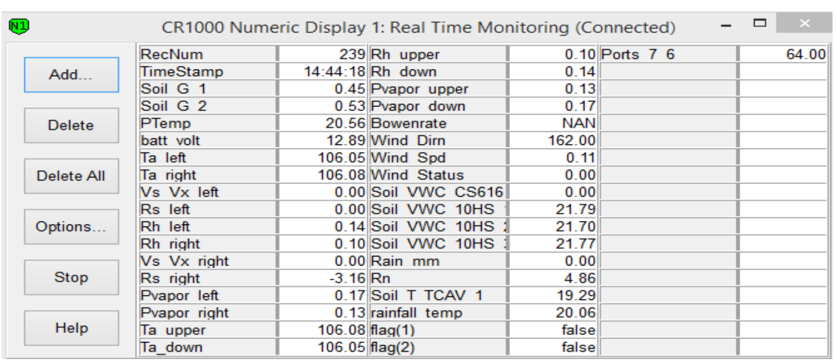
During establishment of the research site, numerous difficulties have been encountered: finding a suitable site, obtaining permissions from Auckland Council, locating suppliers and obtaining instruments, instrument comparison and compatibility, borrowing instruments from other institutions, providing data storage and retrieval, establishing telemetry, obtaining power supply, organising site security, and ensuring personal security.

With the generous assistance of university lab technicians, Auckland Council, other academic intuitions, and instrument supply companies, we overcome all the problems faced by us.

Results

Our results so far are from laboratory testing of all instruments associated with the Bowen Ratio system, as shown in Figure 3. Field monitoring will be commence soon.

We have concluded that field research is not easy, but the wealth of data obtained will permit a comprehensive comparative study of raingarden ET and will also be available for associated research work.



RecNum	239	Rh upper	0.10	Ports 7 6	64.00
TimeStamp	14:44:18	Rh down	0.14		
Soil G 1	0.45	Pvapor upper	0.13		
Soil G 2	0.53	Pvapor down	0.17		
PTemp	20.56	Bowenrate	NAN		
batt volt	12.89	Wind Dirn	162.00		
Ta left	106.05	Wind Spd	0.11		
Ta right	106.08	Wind Status	0.00		
Vs Vx left	0.00	Soil VWC CS616	0.00		
Rs left	0.00	Soil VWC 10HS	21.79		
Rh left	0.14	Soil VWC 10HS	21.70		
Rh right	0.10	Soil VWC 10HS	21.77		
Vs Vx right	0.00	Rain mm	0.00		
Rs right	-3.16	Rn	4.86		
Pvapor left	0.17	Soil T TCAV 1	19.29		
Pvapor right	0.13	rainfall temp	20.06		
Ta upper	106.08	flag(1)	false		
Ta_down	106.05	flag(2)	false		

Figure3 Laboratory testing (Bowen Ratio system)

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HIGH SENSITIVITY RADON MEASUREMENT TO DISTINGUISH BETWEEN GROUNDWATER RECHARGE, DISCHARGE AND HYPORHEIC FLOWNEW ZEALAND LYSIMETER MONITORING SITE INSTALLATIONS

Miss Heather Martindale[1], Dr Uwe Morgenstern[1], Dr Ranvir Singh[2], Dr Bob Stewart[2]

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Aims

Radon-222 is a useful tool for measuring groundwater and surface water interaction and can be used to identify locations of groundwater discharge. There are several methods for measuring radon samples. However, to measure large numbers of radon samples, liquid scintillation counting (LSC) is the most efficient and sensitive measurement technique (Belloni et al., 1995). The standard LSC method involves mixing approximately equal proportions of sample water and a scintillation cocktail in a 20 mL scintillation vial (Hahn & Pia, 1991). Radon samples prepared in this way have a lower limit of detection of approximately 0.2 BqL^{-1} (Leaney & Herczeg, 2006). This relatively high lower limit of detection of the direct count LSC method limits its application for measuring water samples that are low in radon concentration close to, or below, the detection limit of the direct count LSC measurement. Furthermore, it is difficult to assess whether small increases in radon concentrations are produced by groundwater discharge, influence from the hyporheic zone, or whether a small increase in radon concentration is not captured due to the range of the detection limit. Therefore, the aim of this work was to establish a cost and time effective, reproducible method for high sensitivity radon measurement which can be applied to large scale radon surveys.

Method

To increase the sensitivity of the LSC method, the radon in the scintillation cocktail needs to be concentrated from a larger volume of sample water than what is used in the direct count method. This involves mixing a large volume of sample water with scintillation cocktail, then extracting the enriched cocktail for measurement in a scintillation vial. The transfer efficiency of radon from the larger amount of sample water into the cocktail, as well as the transfer of the enriched cocktail into the measuring vial, needs to be optimised. The parameters of sample bottle size and shape, extraction method, sample volume, cocktail volume and mixing time were investigated. Once optimised the enrichment factor was found by comparing the count rates for 10 direct count samples and 10 enriched samples from the same water source.

The developed higher sensitivity methodology was then applied to the Hutt River, analysing eighteen high sensitivity samples collected 50 - 500 m apart in two different surveys on 20 March 2015 and 28 March 2015. Both of the surveys began in a section of the river where bedrock outcrop occurs, as the geology dictates that no groundwater can be discharged.

Results and Discussion

The high sensitivity radon measurement method described here was developed using custom made 273 mL volumetric flasks with an elongated neck. The elongated neck allowed for easy extraction by syringe of the enriched cocktail for measurement. The high sensitivity method gives an enrichment factor of 14.9 and provides a lower limit of detection of 0.002 BqL^{-1}, an improvement of the direct count lower limit of detection by a factor of 100.

From the two surveys in the Hutt River using the enriched LSC method, the degassing rate of radon was estimated to be 0.0002 $BqL^{-1} m^{-1}$. Using this estimated degassing rate, small gains in radon concentrations, identified by high sensitivity sampling, along particular stretches of the river where direct count sampling had indicated no groundwater discharge, could be identified as areas of parafluvial exchange from the hyporheic zone.

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MODELLING BANK DYNAMICS IN GRAVEL-BED BRAIDED RIVERS

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A distinctive feature of the morphologically active braided and transitional rivers flowing in the alpine areas and planes of New Zealand is that the banks of individual braids evolve over relatively short time scales. This implies a strong feedback between in-channel processes, driven by fluvial transport, and bank processes. Bank retreat can provide significant local sources of sediment to the river over a single flood event; it can reshape the channel geometry (width and curvature) and thus interact with bar formation and progradation; and it can affect bifurcations, driving changes in the flow and sediment transport partition between the downstream channels. Modelling bank erosion is therefore essential in the prediction of river morphodynamics by two-dimensional modelling, even over relatively short time scales.

Aims

Over the last two or three decades, many approaches to modelling bank erosion have been developed. Here we first aim to analyse some existing models of bank erosion, presently embedded in two-dimensional morphodynamic models or proposed in the literature, to show their strengths and weaknesses for the purpose at hand. Then, based on this review, we aim to propose an original bank erosion algorithm.

Methods and Results

We propose a classification of the existing bank erosion models based on the algorithm used for identifying eroding banks, the approach used in the computation of bank retreat, the management of the related domain deformation, and the required grid resolution. We implement these models in a simplified, one-dimensional cross-sectional morphodynamic model to compare their different response the flow conditions.

Unfortunately, most existing models of bank erosion are only suitable for single-thread rivers, and are unfit for application to complex morphologies such as those of braided and transitional rivers. We therefore propose a new algorithm, able to automatically detect eroding banks and suitable for general (Cartesian and unstructured) meshes at various mesh resolutions. The algorithm is tested in a suite of cases, including the widening of a straight narrow channel, the erosion of the outer bank in a meandering channel over a flood, and the development of a self-sustaining braiding network.