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# Application and Evaluation of Sediment Fingerprinting Techniques in the Manawatu River Catchment, New Zealand

**A thesis presented in partial fulfilment of the requirements for the degree of**

## Doctor of Philosophy in Geography

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## Abstract

Suspended sediment is an important component of the fluvial environment, contributing not only to the physical form, but also the chemical and ecological character of river channels and adjacent floodplains. Fluvial sediment flux reflects erosion of the contributing catchment, which when enhanced can lead to a reduction in agricultural productivity, effect morphological changes in the riparian environment and alter aquatic ecosystems by elevating turbidity levels and degrading water quality. It is therefore important to identify catchment-scale erosion processes and understand rates of sediment delivery, transport and deposition into the fluvial system to be able to mitigate such adverse effects. Sediment fingerprinting is a well-used tool for evaluating sediment sources, capable of directly quantifying sediment supply through differentiating sediment sources based on their inherent geochemical signatures and statistical modelling.

Confluence-based sediment fingerprinting has achieved broad scale geochemical discrimination within the 5870 $km^2$ Manawatu catchment, which drains terrain comprising soft-rock Tertiary and Quaternary sandstones, mudstones, limestones and more indurated greywacke. Multiple sediment samples were taken upstream and downstream of major river confluences, sieved to < 63 µm and analysed through step-wise discrimination, principle component analysis and a range of geochemical indicators to investigate and identify the sub-catchment geochemical signatures. Discrimination between the main sub-catchments was attained despite each sub-catchment containing similar rock types, albeit with varying proportions of specific lithologies. This meant that source groups were categorized as a mixture of both lithological and geomorphological sources in order to best capture the unique sediment origins. Comprehensive sampling quantified 8 geomorphological sediment sources using two mixing models; the traditional mixing model after Collins *et al.* (1997) and the Hughes *et al.* (2009) mixing model which were each optimized using a 'Generalized Reduced Gradient (GRG) Nonlinear' and an 'Evolutionary' technique providing four mixing model scenarios. These models showed good agreement attributing mudstone derived sediment (≈ 38 – 46 %) as the dominant source of suspended sediment to the Manawatu River. Sediment contributions were also estimated from the Mountain Range, ≈ 15 – 18 %; Hill Surface, ≈ 12 – 16 %; Hill subsurface, ≈ 9 – 11 %; Loess, ≈ 9 – 15 %; Gravel Terrace, ≈ 0 – 4 %; Channel Bank, ≈ 0 – 5 %; and Limestone, ≈ 0 %. Intra-storm analysis of sediment sources was investigated through hourly suspended sediment samples taken in the lower Manawatu River during a 53 hour storm event to detect changes in sediment sources. The suspended sediment samples

displayed high hourly variability which was attributed to model uncertainty and sediment pulses occurring between sampling. Mudstone proportions fluctuated ≈ 20 – 60 % throughout the storm duration from a range of erosion processes, while Mountain Range sediment fluctuated from ≈ 24 – 46 % and Hill Subsurface and Hill Surface both were near 0 %, but approached upper values of ≈ 23 % and ≈ 24 % respectively. Significant shifts in sediment source proportions were observed between 2:00 – 8:00 am 29th November 2013 in relation to flow dynamics of the Pohangina River and shifting flow dominance from the Pohangina River to the Upper Manawatu. The geochemical suite was reanalysed to determine the variability of source groups and individual geochemical elements, in order to evaluate the suitability and impact of changing the geochemical suite used in estimated relative sediment source proportions. Mountain Range sediment displayed the highest average S.D. % of 39.4, followed by Gravel Terrace (S.D. % = 34.6) and Loess (28.1), while the lowest was found in Limestone (S.D. % = 18.1) and Channel Bank (S.D. % = 18.3). The highest variability of individual elements was found in the transition elements such as Cu, Ni, Cr, and Mn, as well as Ca, and Tm. Revised mixing models were run based on two geochemical tracer suites which removed elements with S.D. percentage of > 40 and > 35 respectively. The revised mixing model estimated Mudstone terrain to contribute 59.3 % and 61.8 %, with significant contributions estimated from Mountain Range (12.0 % and 11.4 %) and Hill Surface (11.5 % and 11.3 %) respectively, indicating that Tm, Ni, Cu, Ca, P, Mn and Cr have an influence on these sediment source estimations.

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## Thesis Structure and Authorship

This thesis consists of four manuscripts written for publication (two accepted and two in submission) with 4 supporting chapters.

Simon Vale carried out all the fieldwork in the Manawatu between April 2012 and December 2014 and was assisted at different times by Dr Ian Fuller and Dr Jonathan Procter. Simon Vale also undertook all the laboratory work included in this thesis with some assistance by Dr Anja Moebis (Massey University), XRF technicians (Auckland University), LA-ICP-MS technicians (Australian National University), as well as Ian Smith (Auckland University) who also assisted in data preparation following XRF and LA-ICP-MS analysis.

Simon Vale wrote all the text in this thesis as the principal author in the preparation of manuscripts included in this thesis (referenced in Appendix B) with all supervisors providing general advice and editing to manuscripts.

Signed by Principal Supervisor

Dr. Ian Fuller

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