BEFORE THE HEARINGS COMMITTEE

IN THE MATTER of hearings on submissions concerning the proposed One Plan notified by the Manawatu-Wanganui Regional Council

---

SECTION 42A REPORT OF JON ROYGARD

ON BEHALF OF HORIZONS REGIONAL COUNCIL

---

1. INTRODUCTION

My qualifications/experience

1. My full name is Jonathon Kelvin Fletcher Roygard. I have a Doctor of Philosophy degree (PhD in Natural Resources) with a specialisation in soil science from Massey University, Palmerston North, New Zealand. I hold a Bachelor of Science Honours Degree (Zoology) from Massey University.

2. I have worked as a Post-Doctoral Scientist and Research Assistant Professor in the Department of Crop and Soil Environmental Science, at Virginia Polytechnic Institute and State University (Virginia Tech), in Blacksburg, Virginia, USA. My research during this time was primarily in the Mid-Atlantic Cropping Systems project.

3. I have been employed by Horizons for more than six years in various roles, including Environmental Information Analyst, Environmental Scientist - Water, and Senior Environmental Scientist – Water. As a part of these roles my duties have ranged from processing hydrological data through to leading water resource assessments, developing the water management zones framework, and contributing to State of Environment programme design and reporting.

4. For more than two years, I have held the role of Manager Science within the Regional Planning and Regulatory Group of Horizons. In this role, I lead and manage the science programme at Horizons Regional Council. The science programme includes research in relation to land, water, air, and biodiversity and the Regional Council's State of Environment monitoring programme. As the manager of the science team, I maintain a science role as well as a management role. My role includes initiating, scoping, project managing, and contributing to many projects relating to water allocation, water quality and land use interactions with water quality. In relation to the subject at hand, I am the primary "land scientist" within the team, although it is noted that much of this work is contracted out to experts external to Horizons and the work is done in close collaboration with other Horizons' staff who also have skills in this area. For more than two years, I have also project managed the fluvial science and monitoring programme for the Regional Council.

5. I have authored and co-authored a range of scientific reports and publications including technical reports to support the One Plan, Water Resource Assessments, and peer reviewed Journal articles in topics relating to Soil Science and Ecology.

6. I have read the Environment Court's practice note 'Expert Witnesses – Code of Conduct' and agree to comply with it.

My role in One Plan

7. I have been involved in the Proposed One Plan since its very early stages. My role has involved scientific advice, contributions to technical reports and coordination of science projects to provide input into the Plan development. I have also been involved in numerous consultation meetings over the duration of the Plan development.

My Role in SLUI

8. In relation to SLUI, I have been involved in providing science support for this project from the early stages. My primary role has been scoping and seeking funding for science projects, then project managing these. I have been involved in the development of the monitoring programmes for SLUI and the State of Environment programmes, including monitoring water quality outcomes. I have also worked as a provider of technical advice to the team who have determined the priority areas for SLUI implementation.

Scope of evidence

9. This evidence provides an overview of the science projects related to SLUI, and summarises some of the key messages and how each of the research projects links into the overall SLUI programme. Horizons recognised early in the SLUI initiative and One Plan process that external expertise would be required to do science in relation to many areas of these programmes. My evidence does not extend to the methodological detail of how each of the specific projects was carried out, rather provides a summary of the work that has been completed and focuses on the key findings and recommendations for Horizons.

10. The evidence also discusses prioritisation of SLUI from a science perspective and presents science projects in relation to the potential outcomes from SLUI with an emphasis on how these will be measured. It is noted that my roles in relation to the science projects mentioned in the evidence have varied and I can provide further clarification to the committee on this if required. My evidence does not address any aspects of the SLUI implementation other than in relation to projects that have established templates or methodologies to use in the implementation eg. the whole farm plan template project and the whole farm plan monitoring project.

2. EXECUTIVE SUMMARY OF EVIDENCE

11. Horizons has commissioned many scientific projects in relation to SLUI; these have been carried out primarily by external experts from Crown Research Institutes (CRIs). This evidence provides an overview of these research projects and summarises some of the

key messages and how each of the research projects links into the overall SLUI programme. The evidence also discusses prioritisation of SLUI from a science perspective, and presents science projects in relation to the potential outcomes from SLUI with an emphasis on the measurement and reporting of these outcomes.

12. Following the 2004 storm event, studies were completed to document the erosion that occurred during the storm event. These included Hicks and Crippen (2004) who studied "Erosion of Manawatu-Wanganui Hill Country during the Storm on 15-16 February 2004 - Calibration of bare ground measured from satellite images with bare ground measured from aerial photographs, for different landforms and vegetation covers."; and Hancox and Wright (2005) "Landslides caused by the February 2004 rainstorms and floods in southern North Island, New Zealand".

13. At the initial community meeting, early in the development of SLUI, the sentiment was that much of the science required for SLUI was known. The science that has been developed since then has focused on varying aspects of SLUI roll out.

14. A scoping study (McKay and Neild, 2005) titled "Horizons Regional Council Sustainable Land Use Initiative Costings and Feasibility" identified the need for some of these science projects; however others have been commissioned as the need for these has been identified.

15. In focusing on the roll out of the SLUI approach, some of the initial projects centred on defining the areas of land that should be targeted. The project by Page et al. (2005) was titled "Defining Highly Erodible Land for Horizons Regional Council". A further project provided a more detailed analysis of where in the Region that land is located, and provided summary tables of areas of highly erodible land in the Region and for the major catchments. The project Dymond and Sheppard (2006) was titled "Highly Erodible Land in the Manawatu–Wanganui Region". Both of these projects were completed by Landcare Research.

16. Ensuring consistency in the process was another goal of the programme. The project completed by AgResearch (Mackay, 2007) titled "Specifications of whole farm plans as a tool for effecting land use change to reduce risk to extreme climatic events" provided a template for completing the main building blocks of the SLUI programme, the whole farm plan. Mackay (2007) also outlined minimum specifications for the people who produced the whole farm plans, and defined an audit and review process for whole farm plans and the template upon which they are based. This project followed the production of the initial six prototype Whole Farm Plans that were produced by AgResearch for Horizons Regional in 2005 and 2006.

17. AgResearch have also led another project aiming to bring further consistency to the SLUI programme. This project, the update of the land use capability (LUC) handbook, is improving the base document on which farm resource mapping is completed. The original classification for LUC is now 30 years old, and AgResearch have scoped improving this document (Douglas et al., 2006) and are currently over 12 months into the 18 month project to update it to include the learnings that have occurred during this time (Envirolink tools contract AGRX604, Douglas et al., 2008a).

18. As part of monitoring the effectiveness of the SLUI project, a focus was placed on identifying the outcomes of implementing the whole farm plan at the farm scale and beyond. This project (Douglas et al. 2008b) was led by Grant Douglas of AgResearch with input of scientists from Landcare Research and Hort Research. The project first reviewed current practices for whole farm plan monitoring by Horizons and its neighbouring Regional Councils. The science team determined a methodology that links on farm implementation of works programmes and regular monitoring of these, to a simple model of sediment export from farms to determine the effectiveness of the implementation works, and to continue to assess these over time. This is a new approach for monitoring whole farm plans, which have historically been monitored using only the initial implementation of works as a predictor of effectiveness.

19. A further study of the potential outcomes from SLUI was carried out by Scherlitz et al. 2006. This study investigated various scenarios of SLUI roll out from no whole farms plans to all 4921 farms in the Manawatu catchment having whole farm plans. The study predicted that a 60% reduction in discharge of sediment to the sea was possible if all farms had whole farm plans when compared to no farms having whole farm plans. Further, it was determined that if whole farm plans were implemented on 500 of the highest priority farms (about 10% of the farms in the catchment), the reduction in sediment discharge would be 47% when compared to the scenario with no whole farm plans implemented in the catchment.

20. Parfitt el al. (2007) investigated the potential to reduce the amount of phosphorus entering waterways by modelling the implementation of best practices for erosion control on all farms in a catchment. This study “Best practice phosphorus losses from agricultural land” was the first of its kind in New Zealand. The report calculated a phosphorus balance for the upper Manawatu catchment (over 126,000 ha) and concluded, for this catchment, that most phosphorus enters the river in particles of eroded sediment from steeper land in major floods. Further it stated that 90% of erosion occurs under pastures and 10% under forests in this catchment. The study concluded that the phosphorus particle losses could be reduced from 511 to 280 tonnes by targeted planting of trees on highly erodible land.

The study also found that the single biggest source of the plant-available form of phosphorus, dissolved reactive phosphorus (DRP), was from sheep and/or beef farms. The contribution from sheep and/or beef farms totalled 14 tonnes out of the catchment total of 35 tonnes and could be reduced from 14 tonnes to 10 tonnes per year with targeted planting of trees and riparian zones.

21. One of the goals of SLUI is to influence the amount of material which contributes to the loss of flood-carrying capacity of the Region’s river engineering (flood control) schemes. It is difficult to calculate exactly the direct benefits to river control management achievable via SLUI implementation. Modelling as a part of the whole farm plan monitoring project can provide an indication on a per farm basis of the scale of reduction in sediment lost from farms (Douglas et al. 2008b). Other modelling by Schierlitz et al. (2006) provides a method to calculate the scale of reduced sediment discharge from the mouth of the Manawatu River. However, quantification of the contribution to reduction in river channel capacity requires a more specific monitoring programme.

22. As a part of its flood plain mapping project to support river engineering design, Horizons has detailed LiDAR data which provides high resolution topography of the natural stream and river channels. Subsequent acquisition of LiDAR data of the same areas following large-scale flood events would provide highly accurate estimates of channel morphology changes above the water surface. To measure changes within the wetted channel, other analysis methods are required. Horizons is currently using cross section information to carry out such analysis and have, through its recent fluvial monitoring and science review (Smart, 2008), had other methodologies suggested as ways to complete such analysis.

23. Horizons will monitor the outcomes of SLUI and some of the methods of the Proposed One Plan through an integrated monitoring approach. This will include pulling together information from a range of sources including the whole farm plans, the recording of operational details from implementing SLUI, whole farm plan monitoring programmes, and catchment monitoring via the State of Environment monitoring programme, the fluvial monitoring and science programme, and using data from the continuous turbidity network. The continuous turbidity monitoring network is currently being upgraded to use turbidity to sediment rating curves to monitor sediment loads in the river on a 15-minute interval. There is also some refinement of the monitoring programmes underway to align with the shift in the priority areas for SLUI.

24. The prioritisation of SLUI has been based on a number of factors. The primary factor has been to target a majority of the whole farm plans to be completed in priority sub catchments or Water Management Zones. Water management zones (McArthur et al. 2007), form the underlying management unit for the integrated catchment management

approach of the Proposed One Plan. Recently, as a part of the contract with the Ministry for Agriculture and Forestry, Horizons has committed to deliver 75% of WFP by area to the five most at risk sub catchments within the Region. This has resulted in a reprioritisation of the areas where SLUI will be targeted. The revised priority areas can be broadly defined as the upper Oroua, upper and middle Pohangina, the Tiraumea, the lower Rangitikei including the Kawhatau, the middle Whangaehu and the upper Turakina.

25. Prioritisation within catchments is now possible through a recent roll out of the models used by Landcare to Regional Councils (Dymond et al. 2008). This roll out funded by the Ministry for Agriculture has also provided the tools for the Highly Erodible Land concept to be used by other Regional Councils.

Summary Report

26. This section provides an overview of research projects, and summarises some of the key messages and how each of the research projects links into the overall SLUI programme. The evidence also discusses prioritisation of SLUI from a science perspective and presents science projects in relation to the potential outcomes from SLUI, with an emphasis on the measurement and reporting of these outcomes.

Definition of Highly Erodible Land

27. The report of Page et al. (2005) titled "Defining Highly Erodible Land for Horizons Regional Council" was commissioned by Horizons Regional Council as a part of examining options to reduce hill country erosion risk. The report was commissioned by Alistair Beveridge on behalf of Horizons. The project was funded by an Envirolink medium advice grant project 8-HZLC6. This project provides the scientific definition of highly erodible land (HEL) for the Horizons Region. The following quote from a section of the summary provides an overview of the content of the report.

"*This report, commissioned by the Council, provides improved definitions and guidelines for the assessment of erosion, to help council staff in the identification of highly erodible land (HEL). HEL as defined by the Council is hill country with a potential for 'severe erosion' or hill country with a potential for 'moderate erosion' but where erosion debris will enter directly into water ways.*

This report will help identify HEL at the Farm-scale by recognising the types of erosion of concern, and then setting out criteria for deciding the severity of erosion. At the Regional-scale (and as a guide to recognising HEL at the Farm-scale) we provide a list of LUC units that fit the HEL criteria and we have prepared a map of HEL. The map is derived *from NZLRI data and a 15 m pixel DEM, and accompanies this report (the digital data have been supplied to Horizons). A bibliography is included to provide additional information on erosion processes, erosion severity and LUC units.*"

The objectives of the study were "*To help recognise HEL within the Horizons Regional Council area by providing*

1. *definitions of types of erosion*
2. *criteria and guidelines for assessing erosion severity*
3. *a table of LUC units with a potential for severe erosion or moderate erosion where sediment enters a watercourse (ie. Highly Erodible Land)*
4. *a Regional–scale map of HEL, using NZLRI data and 15 m pixel DEM*
    - § *With forest excluded*
    - § *Land identified as capable or not capable of delivering sediment to streams*
    - § *On a per hillslope basis*
    - § *Including riparian areas severely eroded in February 2004 storm,*
    - § *Areas of earthflow and slump identified by erosion severity*"

Section 5.1.3 of this report concludes the report as follows "*The guidelines in the previous section of the report are designed to help the assessment of* ***present*** *erosion severity. The Land Use Capability system of land classification (Soils Conservation and Rivers control Council, 1971) is designed to identify, by considering physical land characteristics, climate and response to land use and management, where the* ***potential*** *for erosion is a limitation to sustainable land use (ie. land that is highly erodible).*

This section identifies the "Key features that influence the potential for erosion and therefore the identification of Highly Erodible Land (HEL) are:

1. *Parent Material of soils (rock and/or cover deposits)*
2. *Geological controls (structure, faults, crush zones)*
3. *Slope (angle length)*

Table 10 [Table 1 below] *lists LUC units recorded in the Horizons Regional Council area in Hill country that meet HEL criteria. There are three NZLRI [New Zealand Land Resource Inventory] Land Use Capability Classifications in the Horizons Regional Council area (Taranaki – Manawatu, Southern Hawke's Bay – Wairarapa, and Wellington), and this made it necessary to provide a correlation of LUC units in Table 10* [Table 1 below]*. Table 11* [Table 2 below] *lists LUC units that comprise other areas of HEL within the Region (Sand Country, Volcanic Plateau, and Axial Ranges), But these environments are not the main interest of this study, although they are listed to give a full Regional view of*

HEL. Decision trees will be provided to aid in recognition of individual LUC units in the field in a future project.

Table 1. LUC units comprising HEL in hill country*. Sourced from Page et al. 2005 (Table 10).

NZLRI Region	**Taranaki-Manawatu**	**Southern Hawke's Bay-Wairarapa**	**Wellington**	
Terrain (and main erosion type)	LUC units			Slope threshold (degrees)
Mudstone hill country (landslide)	6e3, 6e4, 6e5, 6e7, 6e8, 6e21, 7e1, 7e2, 7e7, 7e9 7e20, 8e3,	6e2, 6e3, 6e7, 6e8 7e1, 7e2, 7e12		24
Mudstone hill country (earthflow)	6e19, 6e20 7e12, 7e14	6e10, 6e12 7e6, 7e7, 7e8, 7e9, 8e3		24
Consolidated sandstone hill country (landslide)	6e2, 6e3, 6e4, 6e10, 6e12, 6e13, 6e14, 6e15, 6e17, 6e23 7e3, 7e4, 7e5, 7e11, 7e13, 7e17, 7e23, 8e3	6e9 7e4, 8e1, 8e2		28
Moderate to unconsolidated sandstone hill country (landslide, gully)	6e11, 6e13, 6e14 7e6, 7e16, 8e2			22
Greywacke hill country (landslide, scree)	6e16 7e8, 7e10	6e11 7e10	6e6, 6e8, 6e10 7e1, 7e2	32

Table 2.LUC units comprising HEL – non-hill country*. Sourced from Page et al. 2005 (Table 11).

NZLRI Region	**Taranaki-Manawatu**	**Southern Hawke's Bay-Wairarapa**	**Wellington**
Terrain (and main erosion type)	LUC units		
Sand country (wind)	6e24, 7e15, 8e1	6e14, 7e14, 8e4	6e5, 7e3, 8e1
Taupo flow tephra terraces and basins (gully, streambank)	6e26, 7e19, 8e2		
Upland plains and plateaux (wind, sheet)	7e24, 7e25, 7e26, 8e10		
Greywacke ranges (landslide, scree)	8e4, 8e7, 8e8, 8e9	8e5, 8e6	7e5, 8e3, 8e4, 8e5
Greywacke ranges (sheet, wind, scree)	6e27, 7e21, 7e22, 8e5, 8e6, 8e8, 8e9		
Volcanic ranges (landslide)	7e18, 8e4, 8e7		
Volcanoes (scree, wind, sheet)	8e8, 8e9		

* Classes 7 and 8 LUC units have a potential for severe or greater erosion, and Class 6 units have a potential for moderate erosion. Class 6 LUC units comply with HEL only when they have the potential to deliver sediment into water courses

28. The report Dymond and Sheppard (2006) titled “Highly erodible land in the Manawatu-Wanganui Region” was commissioned to provide further reporting on the definition of HEL including a by catchment analysis (Table 3) of what areas are HEL, and also quantifying the areas that could be HEL but have protective cover and therefore fall outside the definition of Page et al. (2005). To clarify my role in this project, I commissioned and project managed the project on behalf of Horizons.

Table 3. Summary statistics of highly erodible land in the Manawatu-Wanganui Region according to the Region and major catchments. Source Dymond and Sheppard, 2006.

Row	Land Areas (hectares)	Wanganui catchment	Whangaehu catchment	Turakina catchment	Rangitikei catchment	Manawatu catchment	Region
1	Total	712185	196561	96606	397931	596861	2220890
2	Lowland	111089	61703	24842	127547	248878	652785
3	Hill Country	550465	106131	71642	131290	291196	1295235
4	Mountain Land	45758	27818	98	138336	51532	272871
5	**Land Proportions (%)**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
6	Lowland	15.6%	31.4%	25.7%	32.1%	41.7%	29.4%
7	Hill Country	77.3%	54.0%	74.2%	33.0%	48.8%	58.3%
8	Mountain Land	6.4%	14.2%	0.1%	34.8%	8.6%	12.3%
9	**Highly erodible land areas (hectares)**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
10	Landslide Connected	230370	44493	21853	56092	57919	440353
11	Landslide Connected – Not Protected	48248	29628	15795	22410	18779	146532
12	Landslide Disconnected	93156	17992	12544	14757	15871	162945
13	Landslide Disconnected – Not Protected	33428	11867	9581	10691	11693	81672
14	Moderate Earthflow	19273	555	1659	1082	5515	40283
15	Moderate Earthflow – Not Protected	12964	445	1426	917	4834	31591
16	Severe Earthflow	706	147	6	899	4902	17778
17	Severe Earthflow – Not Protected	560	133	6	615	4050	13733
18	**Highly erodible land proportions (%)**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
19	Landslide Connected	32.35%	22.64%	22.62%	14.10%	9.70%	19.83%
20	Landslide Connected – not Protected	6.77%	15.07%	16.35%	5.63%	3.15%	6.60%
21	Landslide Disconnected	13.08%	9.15%	12.99%	3.71%	2.66%	7.34%
22	Landslide Disconnected – not Protected	4.69%	6.04%	9.92%	2.69%	1.96%	3.68%
23	Moderate Earthflow	2.71%	0.28%	1.72%	0.27%	0.92%	1.81%
24	Moderate Earthflow – not Protected	1.82%	0.23%	1.48%	0.23%	0.81%	1.42%
25	Severe Earthflow	0.10%	0.07%	0.01%	0.23%	0.82%	0.80%
26	Severe Earthflow – not Protected	0.08%	0.07%	0.01%	0.15%	0.68%	0.62%
27	**Total highly erodible land**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
28	Area (hectares)	343505	63188	36062	72830	84207	661359
29	Proportion (%)	48.2%	32.1%	37.3%	18.3%	14.1%	29.8%
30	**Total highly erodible land – not protected**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
31	Area (hectares)	95201	42073	26808	34633	39356	273527
32	Proportion (%)	13.4%	21.4%	27.7%	8.7%	6.6%	12.3%
33	**Total highly erodible land connected**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
34	Area (hectares)	250349	45195	23517	58073	68336	498414

35	Proportion (%)	35.2%	23.0%	24.3%	14.6%	11.4%	22.4%
36	**Total highly erodible land connected – not protected**	**Wanganui**	**Whangaehu**	**Turakina**	**Rangitikei**	**Manawatu**	**Region**
37	Area (hectares)	61772	30206	17228	23942	27663	191855
38	Proportion (%)	8.7%	15.4%	17.8%	6.0%	4.6%	8.6%

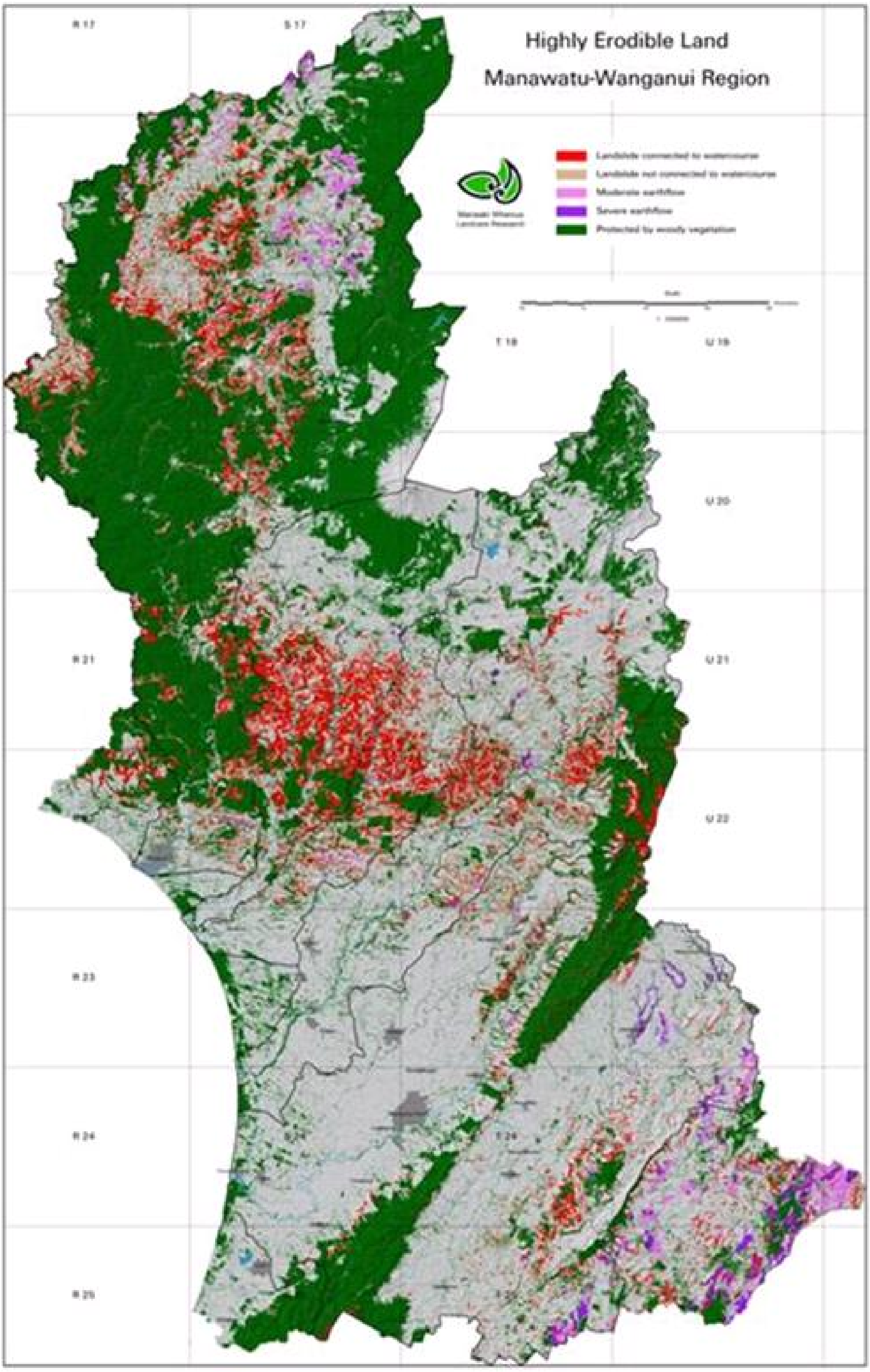
29. Table 3 contains a lot of information about the extent of the Highly Erodible Land within the Region and its major catchments. In the Region there are 661,359 ha of Highly Erodible Land identified (Region column of row 28, Table 3), where the definition of highly erodible land includes areas of land that are covered by protective vegetation. However the definition used by Horizons and Page et al. (2005), and Dymond and Sheppard (2006) to assess options to reduce hill country erosion risk, is for highly erodible land that is not protected by protective cover. This is a total area of 273,527 ha for the Region (region column of row 31, Table 3).

30. This by deference calculates 661,359 – 273,527 = 387,832 ha of land that if the vegetation is removed would be classified as Highly Erodible Land. For the Council to meet its goal of reducing hill country erosion risk, it is important that this land is also considered as a part of its approach as any gains made in the 273,527 ha of land could easily in be in vain if there are losses in terms of erosion risk from the 387,832 ha that currently has protective cover.

31. It is noted for those interpreting the Table 3, that the 661,359 ha of the Region in row 28 is made up as the sum of rows 10, 12, 14, and 16. The 273,527 ha of the Region in row 31 is the sum of Rows 11, 13, 15, and 17.

32. The map from Dymond and Sheppard (2006) is presented in Map 1.

33. The analysis of the extent of the HEL in the Region by Dymond and Sheppard (2006) used available information including databases such as EcoSat (http:\www.landcareresearch.co.nz/services/ecosat). These databases provide very useful data for Regional scale analysis. However, due to the scales of data collection, when relating this information to the specific farm scale, ground-truthing is required. For this reason, Horizons had the information from the Dymond and Sheppard (2006) definition scaled up by overlaying property boundaries and shading the area within the property boundaries on all properties where Highly Erodible Land was mapped by Dymond and Sheppard (2006). This is how Figure A:1 “Highly Erodible Land” in Schedule A: “Properties Containing Highly Erodible Land” of the proposed One Plan was derived.



Map 1. Distribution of highly erodible land in the Manawatu-Wanganui Region (Sourced from Dymond and Sheppard, 2006)

Land Use Capability Handbook upgrade

34. The Land Use Capability Handbook was last updated in 1974. The handbook was provided by the Soil Conservation and Rivers Control Council to enable national standards to be attained by land resource managers dealing with sustainable land use issues and soil conservation.

35. Douglas et al. (2006) completed a scoping study for the upgrade of the Land Use Capability Handbook to produce a handbook that will include the learning's from science and applied management in the intervening 30 years, and will provide the standards for at least the next decade of sustainable land management planning. The scoping study was commissioned by Horizons Regional Council via an Envirolink medium advice grant (36HZLC8). The study stated "*Published last in 1974, the handbook requires significant updating to address some inconsistencies in allocation of units to land class, incorporate advances in land management research and practices, and ensure consistency of interpretation across the Region. With this update in place, HRC can then revise its Regional land inventory in a consistent and transparent manner."* The report scoped a project to carry out the upgrade.

36. Following the scoping report, Horizons Regional Council and Hawke's Bay Regional Council sought funding of the LUC handbook upgrade via the Envirolink tools funding mechanism. This project is one of the first Envirolink tools to be funded. Envirolink tools projects provide funding to adapt or develop new and/or existing resource management tools that may be of use for more than Council (http://www.Envirolink.govt.nz/grants/index.htm). The structure of Envirolink tools is based on one or more Regional Council champions working with a science team led by a scientist from a CRI. In the case of the LUC handbook upgrade project, the work is being carried out by a science team led by Grant Douglas of AgResearch with input from Landcare Research and GNS science. The project is being carried out with close consultation with a range of Regional Councils (Douglas et al., 2008a). Project Champions for the LUC handbook are Garth Eyles from Hawke's Bay Regional Council and Horizons Regional Council (Greg Carlyon). Although Greg is the official project champion, he has delegated this role to myself. However, Horizons involvement in the project includes input from other Horizons staff, of which Grant Cooper has had a primary role. The LUC handbook upgrade commenced in March 2007 and is progressing toward the planned completion in December 2008.

37. There are three NZLRI [New Zealand Land Resource Inventory] Land Use Capability Classifications in the Horizons Regional Council area (Taranaki – Manawatu, Southern Hawke's Bay – Wairarapa, and Wellington). The Regional correlations are a satellite

component of the Handbook upgrade. However the project is providing a description of how Regions can complete the correlation process (Douglas et al., 2008).

Whole Farm Plan Template

38. The whole farm plan template development was a recommendation of the Mackay and Neild, (2005) report “Horizons Regional Council Sustainable Land use Initiative costings and feasibility”.

39. Horizons commissioned AgResearch to produce six prototype whole farm plans by mid 2006. These plans provided some guidance as to what was required to be in a whole farm plan. The development of a standardised template for completing whole farm plans was seen as an essential part of the SLUI programme to ensure consistency in approach and to ensure the whole farm plans are completed to a level that will lead to the goals of the programme being reached. The consistency was seen as a key step to gaining sound underlying data that is useful at the farm scale and beyond.

40. A project to complete the development of the whole farm plan template was commissioned as an Envirolink medium advice grant 243-HZLC25. To clarify my role in this project, I commissioned and project managed the project on behalf of Horizons. I also sought the Envirolink funding.

41. The report (Mackay, 2007), titled “Specifications of whole farm plans as a tool for effecting land use change to reduce risk to extreme climatic events” documents the details for the development of a whole farm plan (WFP) template and includes the critical components in a WFP, the minimum data sets and documentation of the protocol to be used in the development and implementation phases of the WFP with land owners.

42. The report also provides comment on land evaluation and planning skill sets, required by a land manager to complete the environmental component of the plan.

43. A draft audit and review process is also included in the report for evaluating quality, consistency and effectiveness of delivery of the 40 plans at the end of 2006/07 and in future years.

SLUI outcomes - Whole Farm Plan Monitoring and reporting

44. The report of Douglas et al. (2008b) titled “Monitoring and reporting of whole farm plans as a tools for effecting land use change” was completed in February 2008. This project was funded via an Envirolink medium advice grant HZLC26. To clarify my role in this

project, I commissioned and project managed the project on behalf of Horizons. I also sought the Envirolink funding.

45. Horizons sought to have a monitoring programme for whole farm plans that provided information to measure and analyse the outcomes from the implementation of whole farm plans at the farm scale to the subcatchment and catchment level. This project had several components including a review of how neighbouring Regional Councils and Horizons monitor and report on whole farm plans. The project then developed a monitoring programme that was focussed on the measurement of outcomes. This was a significant change from the existing monitoring which tended to focus on measuring implementation of conservation planting works. A key part of the project was to include a method for ground-truthing on-farm, the effectiveness of implemented works over time. The methodology includes some physical measurements within the implemented works once every three to five years to assess progress. These measurements are then linked to a simple model that links vegetation type and land use at the farm scale with sediment export off-farm. This provides a framework for quantitative assessment of the effectiveness of conservation works.

46. The report provides the detail of the whole farm plan monitoring and reporting programme that has been developed. An overview is provided via the following notes from the report.

"*Current monitoring activities and future plans of four Regional Councils (Horizons, Greater Wellington, Hawke's Bay and Taranaki) were surveyed and reported."*

"Án effective on-farm monitoring programme is essential and must be useful at measuring and analysing progress at both the farm and broader scale. It will need to provide information to the landowner for decision making and also be suitable for scaling up to the catchment scale. Monitoring to date of the effectiveness of WFPs has been largely limited to monitoring implementation of the conservation works programme, an activity-based approach. Shifting the emphasis from actions/tasks to environmental outcomes will provide council with direct measures of the achievements towards the target goals of land stabilisation, retention of soil on farm, reduced sediment loading, less damage to infrastructure from slips, and reduced flooding. It will also indicate the rate at which progress is being made towards these goals, both at the farm and catchment scales, through appropriate amalgamation of data from several or many farms.

This report documents a set of guidelines to assist in the development and implementation of a customised monitoring programme for an individual WFP. This will ensure that the information collected is appropriate for that farm, and useful for scaling up beyond the farm boundary. This will enable the generation of a robust dataset in terms of *environmental monitoring at a range of scales. This represents a significant change in approach to the current monitoring programmes completed as a part of a farm plan.*

In this report, current monitoring techniques and aims are reviewed before developing monitoring guidelines and approach, to determine overall effectiveness of all conservation works in a WFP, in terms of sediment discharge off-farm"

47. Douglas et al. (2008b) outlines the methodology in detail and provides the following example of the sediment loss model being applied to a works programme developed for the whole farm plan produced for the Grays' property. The whole farm plan for the Grays' property was completed as one of the six initial whole farm plans produced by AgResearch. The example from Douglas et al. (2008b) is as shown below:

    "According to the NZEEM the Grays' property currently exports 2640 tonnes of sediment per year on average. If the following soil conservation methods (from the WFP) were implemented:

    Year 1 – 200 space-planted poplars
    Year 2 – Afforestation of 3.4 ha; 200 space-planted poplars
    Year 3 – Afforestation of 8.6 ha; 130 space-planted poplars; 70 poplars for gully control
    Year 4 – Afforestation of 12 ha; 130 space-planted poplars; 70 poplars for gully control
    Year 5 – Afforestation of 6.6 ha; 200 space-planted poplars

    then the sediment export from the farm would reduce gradually from 2640 tonnes/year to 820 tonnes/yr over 20 years [Figure 1]*"*

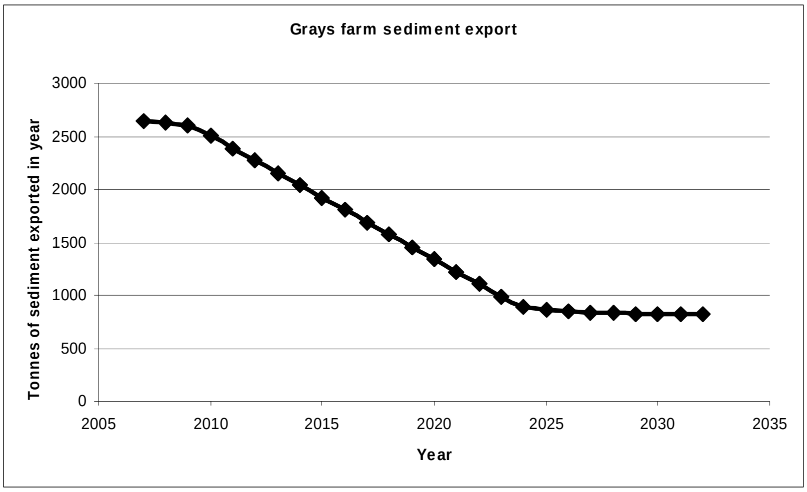


Figure 1. Sediment loss predicted from the Grays' property over time, if the recommended works programme is implemented (Source Douglas et al. 2008b).

SLUI Outcomes - Sediment discharge

48. The report by Schierlitz et al. 2006 investigated a range of scenarios of completing whole farm plans in the Manawatu catchment to predict the impact of these on a catchment level outcomes as measured by changes to the long-term mean sediment discharge of the Manawatu River to the sea. To clarify my role in this project, I commissioned and project managed the project on behalf of Horizons.

49. The modelled scenarios were completed using a simplified version of the SedNet Model which is described in the report. The model calculated a sediment budget for the Manawatu Catchment to predict the long-term mean sediment discharge at the ocean outlet of the Manawatu River (in units of tonnes/year). The scenarios tested, ranged from no whole farm plans being implemented in the Manawatu catchment, to all the farms in the Manawatu catchment having a fully implemented whole farm plan. Schierlitz et al. (2006) stated "*… the results are based on the assumption that fully implemented Whole Farm Plans reduce erosion by 70% (Hawley & Dymond 1988; Hicks 1995)*". The results of the modelled scenarios are shown in Table 4 and Figure 2.

50. The modelled scenarios predicted that a sixty percent reduction in sediment discharge was achievable if all farms had fully implemented whole farm plans, when compared to the "no farms with whole farm plans" scenario.

51. Scenarios 3, 4 and 5 each tested completing 500 whole farm plans in the Manawatu catchment. This represents just over 10% of the farms in the catchment. Scenario 3 selected the 500 farms at random and predicted an 8% reduction in sediment discharge when compared to the "no farms" scenario. Scenario 4 selected the 250 of the highest priority farms (ie. with the greatest area of "eroding land" connected to stream) and 250 selected at random and predicted a 37% reduction in sediment discharge when compared to the "no farms" scenario. Scenario 5 selected the 500 of the highest priority farms (ie. with the greatest area of "eroding land" connected to stream) and predicted a 47% reduction in sediment discharge when compared to the "no farms" scenario. Scenario 6 which modelled having whole farm plans on all of the farms predicted a reduction in sediment discharge of 60%.

52. This modelling predicts that considerable reduction can be achieved by fully implementing whole farm plans on all 4921 farms. It also predicts that 78% (47/60) of that gain can be made by fully implementing whole farm plans on just over 10% (500/4921) of those farms if absolute targeting is done ie. only implementing whole farm plans on the highest priority farms.

Table 4. Predicted mean sediment discharge of the Manawatu River associated with six whole farm plan coverage scenarios. Modified (percentage column added) from Schierlitz et. al. 2006.

Land-use scenario	Predicted mean sediment discharge (10^6 tonnes/yr)	Percentage reduction in mean sediment discharge when compared to the no farms scenario
(1) No farms	3.8	0
(2) Random selection of 50 farms (ie. the present situation approximately)	3.8	0
(3) Random selection of 500 farms	3.5	8
(4) 250 of the highest priority farms (.e. with the most area of "eroding land" connected to streams) and 250 randomly selected	2.4	37
(5) 500 of the highest priority farms (ie. with the most area of "eroding land" connected to streams)	2.0	47
(6) All the farms	1.5	60

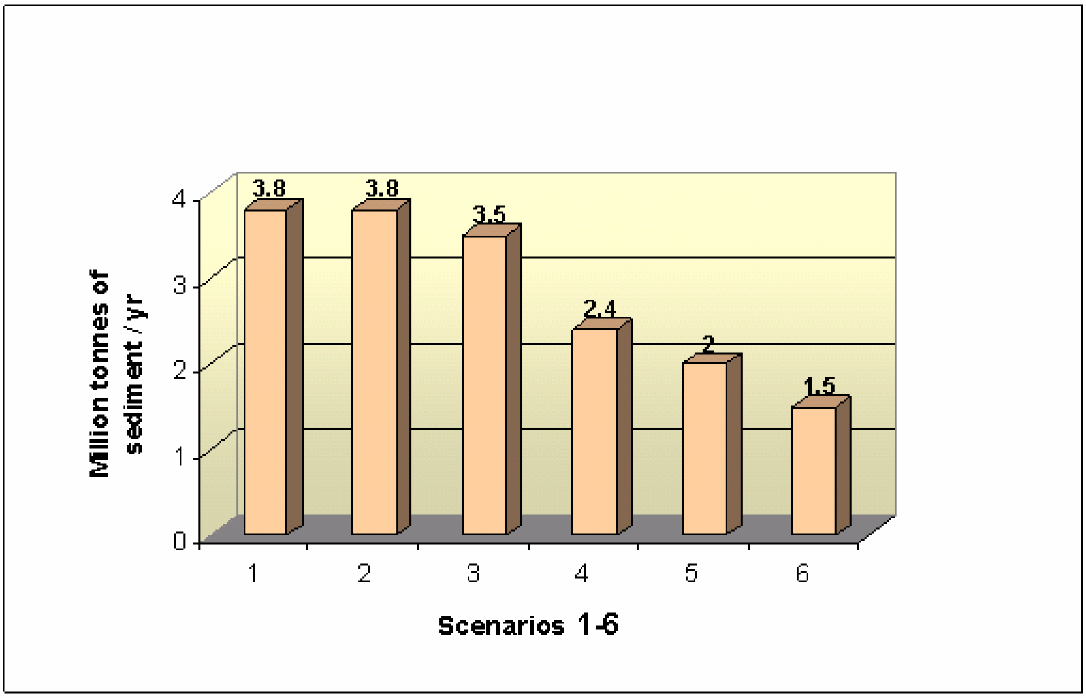


Figure 2. Mean sediment discharge of the Manawatu River associated with each of the Whole Farm Plan scenarios: (1) no farms; (2) present situation; (3) random selection of 500 farms; (4) 250 of the highest priority farms and 250 randomly selected farms; (5) 500 of the highest priority farms; and (6) all farms (4921). Sourced from Schierlitz et al. 2006

53. Given the voluntary nature of the role of this non-regulatory initiative it is more likely that the outcomes in terms of targeting farms will be closer to those of Scenario 4 if Horizons were to target 500 farms in the Manawatu Catchment. Scenario 4 modelled 250 of the highest priority farms being targeted and 250 randomly selected farms. In this modelled

scenario, the model predicts that 61% (37/60) of the potential gain by implementing on all farms will be achieved.

54. To implement Scenario 4, would require Horizons to engage in the non-regulatory approach with all of the 250 top priority farms. It is noted that, given the initiative is voluntary, not all of these landowners are likely to engage in the initiative. Furthermore, there is no requirement to fully implement the whole farm plan. This part of the implementation of Scenario 4, would suggest the results would be less than that predicted by Scenario 4. However, the other part of Scenario 4 is the random selection of farms. To ensure the goals of the programme are being met, Horizons is unlikely to prioritise farms where there is little gain in terms of implementing a whole farm plan. In this way the programme will likely achieve better results than predicted in scenario 4 for the 250 random farms as the farms where whole farm plans are likely to be completed would not be selected randomly but by using prioritisation.

SLUI outcomes – Phosphorus in water ways

55. The report Parfitt et al. (2007) titled "Best practice phosphorus losses from Agricultural Land" investigated the potential outcomes from implementing best practice on farm (including erosion control) on phosphorous in water ways.

56. The report was commissioned to the Sustainable Land Use Research Initiative (SLURI) with Landcare as the lead provider. SLURI is partnership between the Crown Research Institutes, AgResearch, Hort Research, Landcare Research and Crop and Food Research. SLURI provides the capacity to appoint teams of scientists from several CRIs to work on research projects. This project was funded via an Envirolink medium advice grant HZLC41. To clarify my role in this project, I commissioned and project managed the project on behalf of Horizons. I also sought the Envirolink funding.

57. This report used a test catchment, the upper Manawatu (defined as the area upstream of the Manawatu at Hopelands flow recorder site), to determine a phosphorus (P) balance for the catchment. The project also modelled how this would change if best management practices were implemented on all farms. One of the best management practices modelled was implementation of best practice to reduce sediment loss from farms via erosion.

58. The project reports on the loads of P from non-point sources and point sources for current management practices, and provides a better understanding of the P sources in the upper Manawatu Water Management Zones (UMWMZ) above Hopelands. This project sets out to quantify the impact of implementing best practice on the water quality of those

catchments, and thus better targeted approaches to P management. It also provides some further indication as to whether erosion control or nutrient management should be the priority management target in that catchment.

Objectives addressed were:

- § Estimate current P loadings in the Manawatu River at Hopelands
- § Estimate relative contributions of P from sediment, nutrients on farms, point sources and other sources
- § Identify best practice P losses in relation to erosion control
- § Determine what the implementation of best practice for erosion control would achieve in terms of a water quality outcome
- § Identify best practice P losses in relation to nutrient management on sheep and beef, and dairy farms
- § Determine what the implementation of best practice for nutrient management control would achieve in terms of a water quality outcome
- § Determine the combined effect of implementing best management for both erosion control and nutrient management.

59. The study, which was the first of its kind in New Zealand, concluded there were considerable gains to be made in terms of reducing P in the upper Manawatu River by reducing inputs from erosion. The report supported the proposed approaches recommending "*Based on the findings of this* [study]*, we recommend the two pronged approach offered by SLUI to reduce total P loadings to the river and FARM strategy to reduce DRP during low flow, to improve the water quality by reducing P contamination in the UMWMZ* [upper Manawatu Water Management Zones]". It is noted that the area of this study upstream of Hopelands contains five water management zones.

60. In relation to SLUI, the report recommended "*SLUI Farm Plans should be targeted on high priority farms*"

61. To provide further information on this study, the following notes from the executive summary are repeated below.

"*For the first time in New Zealand, SLURI estimated both the total and dissolved phosphorus losses for a large catchment (Upper Manawatu Water Management Zones above Hopelands) by using the Overseer® and NZEEM models together. Using these models for this catchment (126669 ha), that has 77% sheep and beef, 16% dairy and 6% forest, and data for the catchment above Weber Rd, we were able to assess the likely sources of these losses.*

Most phosphorus comes down the rivers in particles of eroded sediment from steeper land during major floods – about 511 tonnes of phosphorus per year goes under the bridge at Hopelands attached to particles of sediment.

90% of the erosion occurs under pastures on steep land and 10% under forest.

These phosphorus particle losses could be reduced from 511 to 280 tonnes by targeted planting of trees on Highly Erodible Land (Figure A).

During low flows sediment particles on the bed of the river release about 4 tonnes of dissolved phosphorus per year. This could be halved by reducing erosion.

Dissolved phosphorus causes blooms of periphyton in summer. Most dissolved phosphorus, however, comes from pastures. For sheep and beef farms this could be reduced from 14 tonnes per year down to 10 tonnes per year with targeted planting of trees and riparian zones. For dairy farms it could be reduced from 9 tonnes down to 5 tonnes per year with changes to management of effluent, excluding cows from streams and limiting soil P fertility to the optimum agronomic range (Figure B).

Dissolved phosphorus from point sources at Dannevirke and Oringi could be reduced from 7 down to 2 tonnes per year with changes to management of effluent.

Based on the finding of this, we recommend the two pronged approach offered by SLUI to reduce total P loadings to the river and the FARM strategy to reduce DRP during low flow, to improve the water quality by reducing P contamination in the UMWMZ.

Monitoring of phosphorus concentrations in the Manawatu River should be carried out on a regular basis to define a more precise base line, and to monitor improvements to water quality as SLUI and the FARM strategy programmes progress.

[Figure A] **[Figure B]**

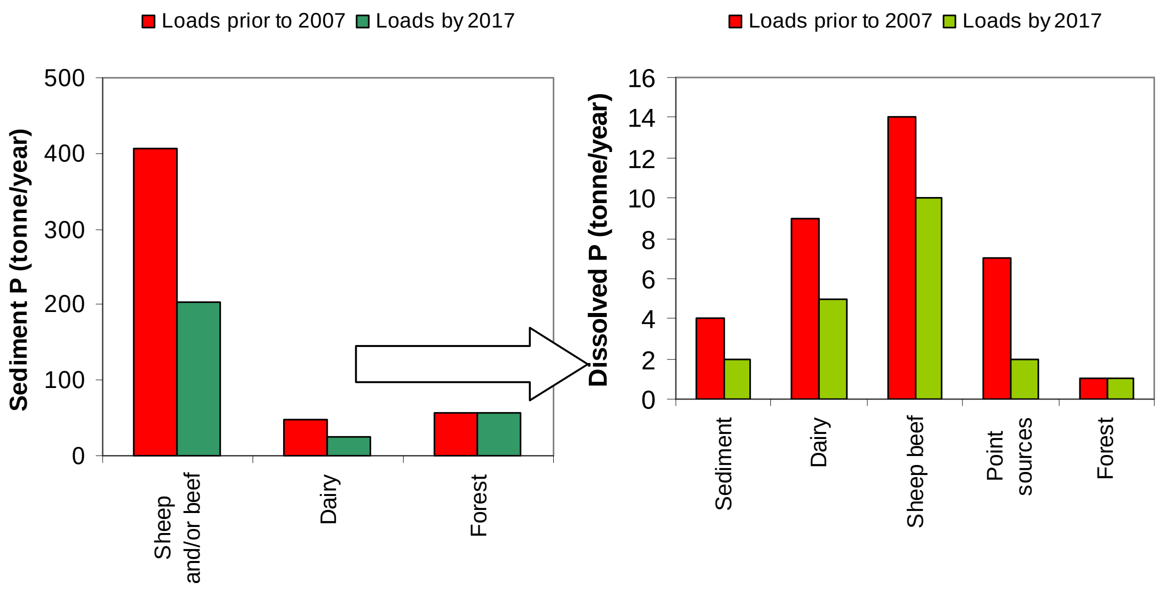


Figure A. *Estimates of sources of particulate phosphorus in the Manawatu River at Hopelands in 2007, and loads achievable by 2017 if recommendations are implemented (tonnes phosphorus per year).* ***Figure B.*** *Estimates of sources of dissolved phosphorus in the Manawatu River at Hopelands in 2007, and loads achievable by 2017 if recommendations are implemented (tonnes P per year). Note: Some of the 511 tonnes of particulate phosphorus remain on the bed of the river and generate about 4 tonnes of dissolved phosphorus per year*" *Parfitt et. al. 2007*.

SLUI outcomes - Aggradation in rivers

62. Soil loss from eroding hill country in the 2004 storm event contributed to the material that was deposited in the flood plains of the lower catchments of the Regions river systems and the active river channels, reducing the level of flood protection provided by the existing flood protection schemes. It is noted that there are other processes that contribute to aggradation in rivers other than hill country erosion. The evidence of Allan Cook of Horizons addresses this in further detail. The comments in my evidence below provide a brief overview of some recently completed or ongoing projects that are underway for/by Horizons around the relationship between SLUI and aggradation in flood plains and the active channel of the river.

63. In 2008, Graeme Smart of NIWA was commissioned via an Envirolink project (HZLC31) to review Horizons' Fluvial Science and Monitoring programme. To clarify my role in this, I manage the fluvial monitoring programme of Horizons, and commissioned and project managed this project. I also sought the envirolink funding. The aim of the project was to

improve the monitoring programme and reporting to meet the outcomes required by Horizons. Smart (2008) noted "*While many aspects of HRC fluvial science are progressing satisfactorily, this report concentrates on the areas which could be improved".*

64. Smart (2008) states in relation to SLUI. "*Hopes are being placed on SLUI work to reduce fine sediment delivery to the Manawatu River. Diamond and Shepherd's (2006) model shows there could be a 45% reduction in sedimentation from stabilising the sediment yield from 500 farms. However, it is not a foregone conclusion that the clay sediments are causing aggradation in the lower river reaches. Cross-section analyses could indicate what volume of sediment is accumulating on the river berms. This would answer whether the reduction in flood capacity is primarily due to channel aggradation, or is the deposition of fines on river berms a significant factor? Much of the aggradation may be sand-sized particles not sourced from SLUI catchments. Particle size distribution analysis of sources and deposits could help resolve this issue. The Oroua River has the most serious fine sediment aggradation problem but no SLUI work is being carried out in this catchment.*"

65. In making those statements, it is unclear as to whether the author (Graeme Smart) was aware that the predictions of the Schierlitz et al. (2006) report, which he refers to as Diamond and Sheppard (2006), was predicting a change in mean sediment discharge to the ocean rather than amounts of material deposited in the river channel.

66. Smart (2008) does document other sources of material causing a reduction in flood-carrying capacity eg. "*A lot of lost capacity (in the Manawatu in particular) is due to banks forming on insides of bends. Rivers meander by eroding the outside of bends and depositing on the insides. Protecting the outside of a bend doesn't prevent the continued growth of the inner bank*". Further to this, the report identified that other sources of material that contribute to aggradation, including redistribution of material from upstream (eg. from degrading upstream reaches to reaches that are aggrading), lateral erosion and sources of gravel from the ranges.

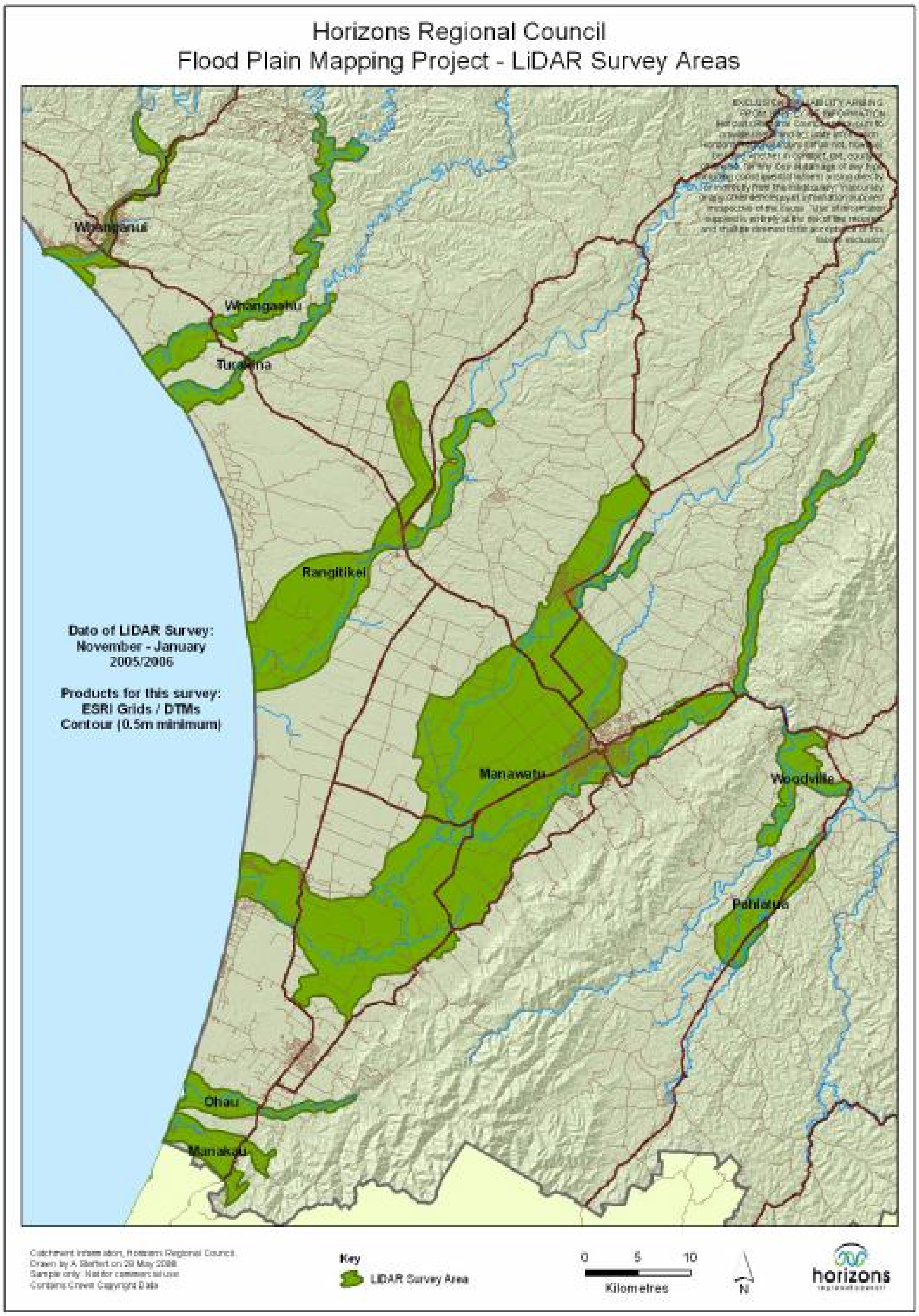
67. The silt and other material deposited into the floodplains was clearly observable following the 2004 storm event. Quantifying the exact proportion of this deposited material that comes from hill country erosion is not achievable. Allan Cook of Horizons provides estimates of this for various river systems.

68. Smart (2008) provides some suggested methodologies to answer a number of the questions around what is causing the aggradation of material in riverbeds and on the flood plains, using cross sectional analysis and particle size distribution analysis. As addressed by Allan Cook, Horizons has addressed the more immediate question of what

is the reduction in channel capacity (and flood protection) from the combined sources of aggrading material in the scheme areas.

69. Ongoing analyses of the cross section data have been underway concurrently with the Smart (2008) report. In December 2007, Horizons had an assessment completed of the currently available cross section data in order to improve accessibility of this data for detailed analysis of river bed aggradation and degradation. A subsequent project has been commissioned to rework the cross section data into an easier form to analyse. This ongoing project is currently focused on the subset of the existing data for the river cross sections collected for the Manawatu River from the Ashhurst Bridge to the Oroua confluence. Analysis of this data is being undertaken trialing some of the methods from the Smart (2008) report. It is noted that Smart (2008) provides an overview of the historical programmes around this data and includes a bibliography of reports in relation to fluvial monitoring and research. The reports listed include studies into areas of aggradation and degradation. As a part of the fluvial monitoring programme in the next financial year, Horizons plans to undertake an assessment of the available information on particle size distribution to further address the questions around relative contributions and sources of material.

70. Horizons has a methodology for assessing, very accurately, relative changes in the flood plain capacity through the use of LiDAR. The Flood Plain Mapping project being undertaken by Horizons utilises high precision LiDAR data and 2D hydraulic models to determine where water will flow, to what depth and at what velocity, once it leaves the natural channel. The LiDAR data-sets provide high resolution topography of the natural stream and river channels. Subsequent acquisition of LiDAR data of the same areas following large scale flood events would provide highly accurate estimates of changes in channel morphology above the water surface. A map of the areas where Lidar data has been collected by Horizons is shown in Map 2.



Map 2. Location of LiDAR mapping surveys.

SLUI Prioritisation

71. My involvement in SLUI prioritisation has been through providing technical advice to the implementation group who make decisions in relation to where the priority zones are. The technical advice has related to using water management zones and water quality indicator results for prioritisation. More recently this has also included providing feedback from other studies including the fluvial review (Smart, 2008), and in discussion around which priority zones should be selected in relation to the contract requirements with MAF.

72. Prioritisation of where SLUI WFPs are completed is a key mechanism to achieving the sub catchment/catchment outcomes sought through SLUI. For example, the Schierlitz et al. 2006 report showed the benefits of targeting high priority farms in terms of outcomes relating to sediment discharge.

73. SLUI is in its third year of operation. These are referred to as “year 0”, “year 1” and “year 2” by Mitchell and Copper (2007). These naming conventions are used in my report below for consistency. In year 0, the six farms (Table 5) were hand-picked to have whole farm plans completed by AgResearch.

74. Prioritisation going into “year 1” aimed to complete 40 whole farm plans aiming for 30 of these to be completed in eight priority water management zones (Table 6) and 10 to be completed in other catchments (Mitchell and Cooper, 2006). Water management zones (and sub zones) are the geographic units on which Horizons’ integrated catchment management approach is based (McArthur et al., 2007).

75. In “year 2” of SLUI (Mitchell and Cooper, 2007) documented an expanded set of priority catchments from the previous year’s eight to a total of 14 water management zones (Table 6). The aim being to complete five whole farm plans in each of the eight, 2006/07 priority water management zones with three or four whole farm plans in the six catchments that had been added. The balance of the 80 Whole Farm Plans were targeted to be split, with 12 of them to be done in “other catchments” and eight to be completed on Ati Hau Corporation properties (Table 6).

76. For details of the actual farms completed in these years please refer to the evidence of Alan Kirk of Horizons.

Table 5. Whole Farm Plans completed in the 2005-06 financial year (Modified from Mitchell and Cooper [2006]).

Catchment	Property
Upper Pohangina	Gray
Para Para	Truebridge
Kokakonui (Kirikau)	Carter
Ongarue	Hikorangi B2
Makuri	Murfitt
Kawhatau	Rainey

Table 6. Whole Farm Plans targets in the 2006-07 and 2007-2008 financial years (modified from Mitchell and Cooper [2007]).

Catchment Name	Target WFPs 2006-07	Target WFPs 2007-08
Ongarue	3	5
Matarawa	3	5
Makohine	3	5
Upper Rangitikei including Kawhatau/Makopua	3	5
Middle Pohangina	5	5
Middle Rangitikei including Pakihikura	5	5
Upper Tiraumea	3	5
Whangaehu	5	5
Sub Total	**30**	**40**
Te Mairie		3
Punga Punga		3
Tokomaru West		3
Mangawhero		3
Mangamahu / Whangaehu		4
Turakina		4
Ati Hau Corporation		8
Other Catchments/Priority Properties	10	12
TOTAL	**40**	**80**

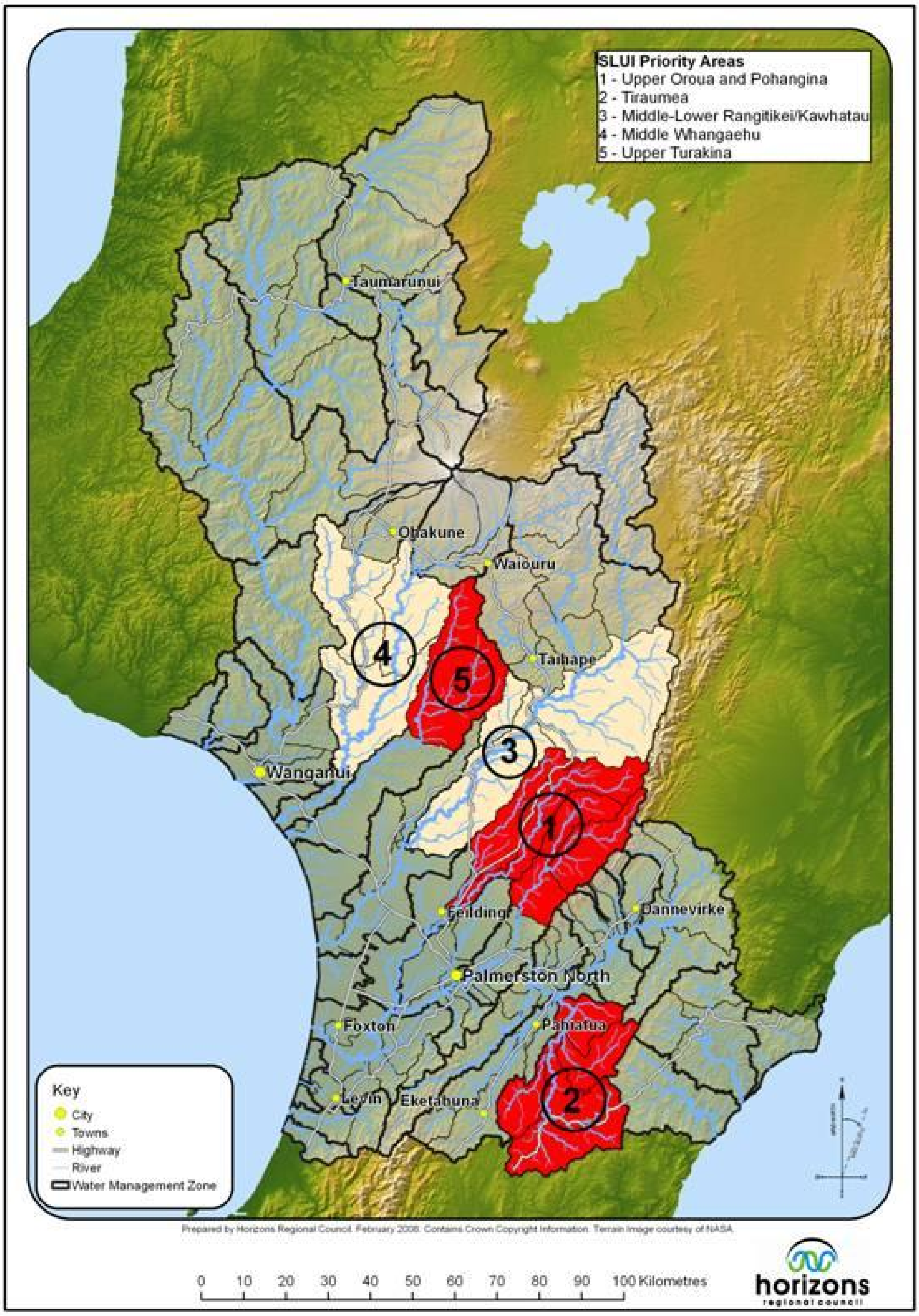
77. Horizons has committed as a part of the funding arrangement with MAF "to deliver 75% of WFP by area to the five most at risk sub catchments within the Region (As individual sub catchments reach saturation either through full coverage of WFP or landowner resistance new sub catchments will need to be introduced)".

78. To meet the requirement of the MAF contract and to build in findings from other studies Horizons has reassessed the priority catchments in 2008 as shown in Map 3 and Table 7.

79. Horizons has changed some of the SLUI prioritisation in relation to the Smart (2008) comments in relation to SLUI. These include adding the Oroua catchment as one of the highest priority catchments along with the Pohangina for SLUI work. Also within the Oroua, an emphasis is being placed on farms with sandy type soil types and geology.

80. These changes came about following discussions that included the members of the Horizons Operations team during and following the preparation of the Smart (2008) report. Smart (2008) states *"it is not a foregone conclusion that the clay sediments are causing aggradation in the lower river reaches"* and "*Much of the aggradation may be sand-sized particles not sourced from SLUI catchments".* These statements were backed up via the observations during the field trip as a part of the fluvial review project where it was observed that a large proportion of the deposited material was sand-sized ad that there were high levels of aggradation in the Oroua which was not a SLUI Catchment at that time. In the case of the Oroua at the River Road site, the aggrading material was primarily sand and had considerably reduced the flood-carrying capacity of the river. Observations of particle size distribution at other sites in the Oroua, including areas that are aggrading and degrading also showed a high percentage of sand. Sand within these river systems can only originate from a few sources: these include breakdown of the gravel within the river system, sand stored within the river system, and from the sand type geologies and soil types in the catchment. These findings were passed through to the SLUI implementation team who are now targeting farms in this catchment that have sandy soil types and geologies. A continued emphasis on farms to address silt and clay inputs into the Oroua River will have benefit in terms of water clarity and will likely have benefit into reducing the silt depositions from larger storm events into the river system and wider floodplain.

81. In assessing the fluvial processes occurring in the Manawatu catchment, a key finding of Smart (2008) has been that little fluvial material (gravel or sand) will transport through the Manawatu Gorge during high flow events. This essentially means that the source of any aggradation from gravel and sand in the Lower Manawatu River Scheme is sourced on the western side of the Manawatu Gorge from tributaries such as the Pohangina and the Oroua Rivers, and from degradation and lateral erosion within main-stems of the Pohangina, Oroua, and Manawatu Rivers. Horizons have also applied this finding to the SLUI prioritisation programme by placing the highest level of priority on the Oroua and Pohangina systems.



Map 3. SLUI priority zones as specified in the MAF contract.

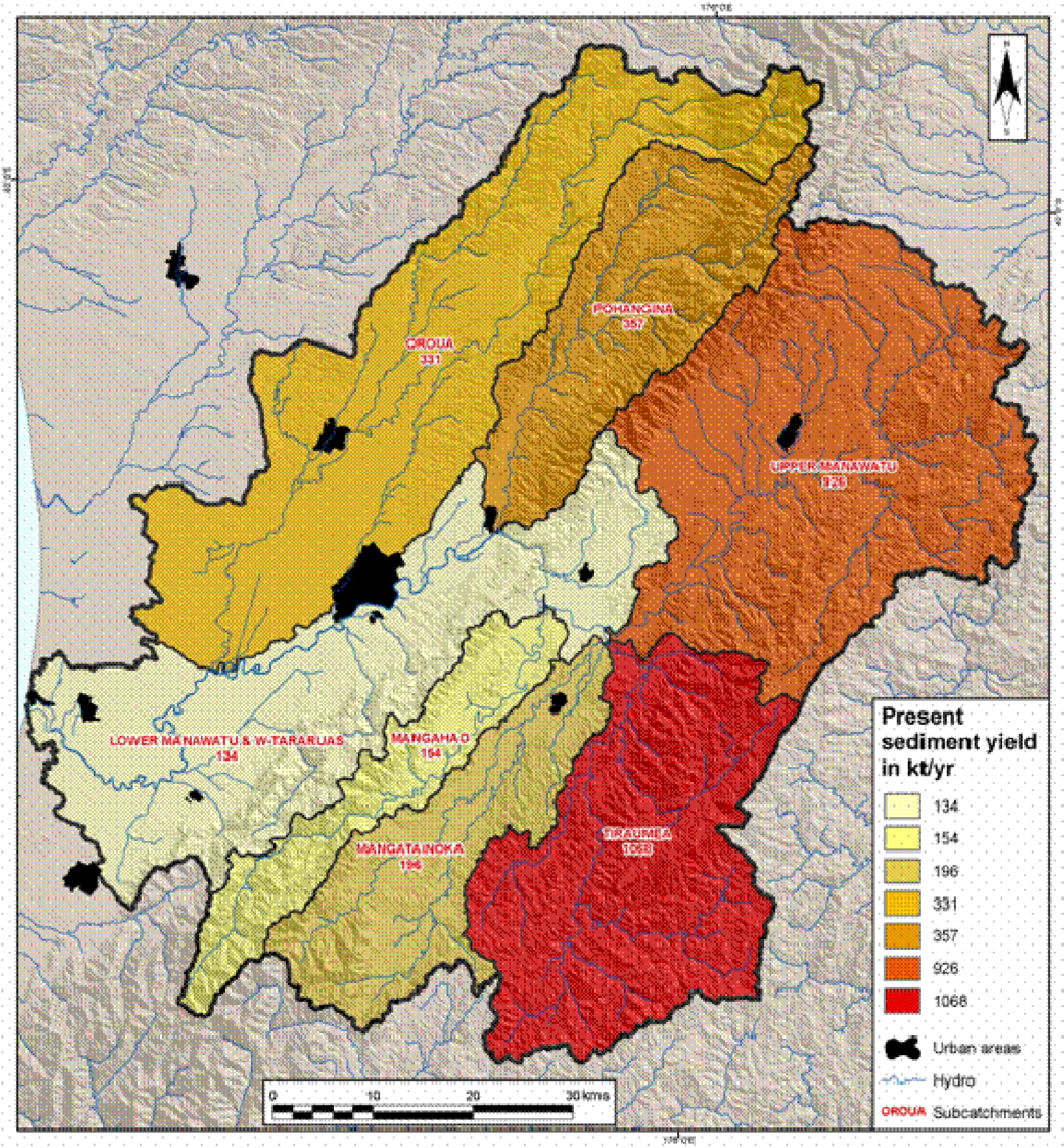
Table 7. Priority Zones for SLUI as specified in the MAF contract. It is noted that the whole of a water management zone is not necessarily included. The sub-zones identify the priority areas.

Catchment	Name	WMZ Zones	Sub-zones
Manawatu	Oroua/ Pohangina	Oroua, Middle Manawatu	Upper Oroua (Mana_12a) Kiwitea (Mana_12d) Upper Pohangina (Mana_10b) Middle Pohangina (Mana_10c)
Manawatu	Tiraumea	Tiraumea	Upper Tiraumea (Mana_7a) Lower Tiraumea (Mana_7b) Mangaone River (Mana_7c) Makuri (Mana_7d)
Rangitikei	Middle - Lower Rangitikei/ Kawhatau	Middle Rangitikei Lower Rangitikei	Pukeokahu - Mangaweka (Rang_2b) Lower Rangitikei (Rang_3a) Makohine (Rang_3b)
Whangaehu	Middle Whangaehu	Middle Whangaehu Lower Whangaehu	Middle Whangaehu (Whau_2) Lower Whangaehu (Whau_3a) Lower Mangawhero (Whau_3e)
Turakina	Upper Turakina	Upper Turakina	Upper Turakina (Tura_1a)

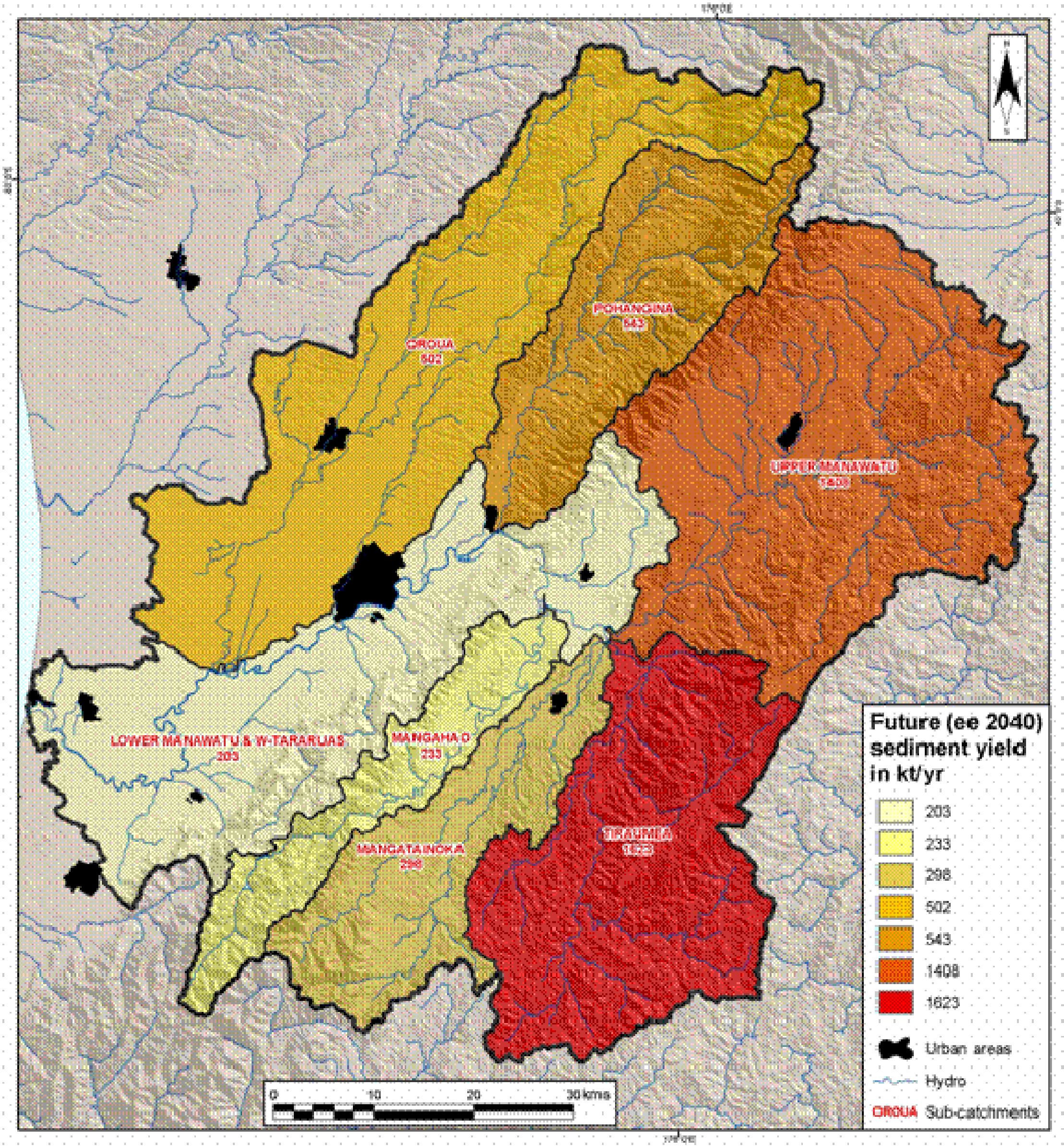
82. The findings of Smart (2008) which state that little gravel and sand will transport through the Gorge do not preclude the transport through the Gorge of silt and clay which require a lower levels of momentum to stay suspended the water column. It is noted that using the using the NZEEM® model Scherlitz (2008) predicted two thirds of the sediment yield of the whole Manawatu catchment 3.2 kt/year is sourced from the Tiraumea and the upper Manawatu Catchment (Map 4). This modelling combined with the turbidity indicator from the state of environment monitoring programme (see the land chapter and SLUI monitoring section below) and the modelling re climate change scenarios by Scherlitz 2008 (see below) contributed to the decision to include the Tiraumea as further priority subcatchment in the Manawatu. It is noted that Scherlitz (2008), refined the model used in the earlier work, Scherlitz et al. 2006, which predicted the catchment sediment yield was 3.8 kt/year.

83. Scherlitz (2008) analysed in the impact of climate change on mean erosion rate and sediment yield in the Manawatu catchment (Map 5). The study stated "*Model results lead to the conclusion that climate change expressed in a change in mean annual rainfall, will not affect mean erosion rates and sediment yield dramatically.*" A second approach was also modelled to analyse the impact of extreme events under a climate change scenario in the Manawatu catchment "*this approach projected a 52% increase in the mean erosion rate. Projected changes of sediment yield due to increased storminess (555 kt/year), differed greatly from the projected changes due to changed mean annual rainfall (30 kt/yr).*" It is noted the increase in sediment yield is a 17% increase (555/3200 kt/year). The study also clarified these findings with the statement "*Uncertainties for projected mean erosion rates and sediment yield due to increased storminess were -24%/=105%.*

Along with these uncertainties the approach faces two issues: only storm magnitude was considered, rather than both magnitude and frequency; and the erosion threshold for landslide was uncertain." The report also concluded "*The extreme event approach is more suitable than the mean annual rainfall approach because geomorphological processes in the Manawatu catchment are driven by mass movements triggered by major storms*".



Map 4. Modelled present sediment yield of Manawatu sub catchments. Sourced from Schierlitz 2008.



Map 5. Modelled future (2040) sediment yield under increased storminess for the Manawatu Catchment. Sourced from Schierlitz, 2008.

Within catchment prioritisation

84. Further prioritisation within sub-catchments is now possible through the roll-out of erosion models from Landcare Research to the Regional Councils. The Ministry of Agriculture and Forestry has funded Landcare Research to roll-out two erosion models (Dymond et al. 2008). The first model produces spatial maps of highly erodible land at 15 m pixel resolution. The second model gives erosion rates in tonnes/km^2/yr also at 15 m pixel resolution. The roll-out occurred on 18 March 2008 via a workshop attended by Regional Council representatives. This extends the concept of highly erodible land to the other Regional Councils and provides them with the tools developed by Landcare for defining highly erodible land and erosion loss rates.

85. With these tools available, Horizons are now able to assess within catchments and sub-catchments where the highest priority areas are. This is of considerable use to assess the highest priority farms without having to engage Landcare Research. These tools are proposed to be used in determining future priorities for SLUI within the priority zones identified above and for finding the priority farms outside of these zones.

86. In the notes provided by Dymond et al. (2008) two papers are included to provide background to the model. One of these has been published in the Journal Geomorphology (Dymond et al. 2006) and is titled “validation of a region model of landslide susceptibility in the Manawatu – Wanganui Region of New Zealand”. The second paper (Dymond and Betts 2008, submitted draft) had, as at the Dymond et al. 2008 documents circulation date (18 March 2008), been submitted to Journal Environmental Modelling and Software. This draft was titled “Description of New Zealand empirical erosion model (NZEEM®).”

Land Chapter and SLUI monitoring

87. The land research, monitoring and reporting programme is defined as a method in the Proposed One Plan. A key area of this will be the five-yearly assessment of the effectiveness of the projects, particularly the Sustainable Land Use Initiative (SLUI). The information and reporting from the SLUI is likely to cover a range of information that is being collected as a part of the whole farm plan development and monitoring. A primary part of this will be the whole farm plan monitoring programme that has been discussed above. Given Horizons’ current focus on SLUI and the proposed FARM strategy approach, the land research, monitoring and reporting programme is likely to centre on these initiatives and the monitoring of the anticipated environmental results.

88. The measurement of anticipated environmental results for the land chapter relies on reporting from Horizons’ water quality monitoring programme. Water quality monitoring in the Region is completed through State of the Environment (SoE) monitoring sites, compliance monitoring, and targeted science investigations. In relation to the land chapter of the Proposed One Plan, the discussion of this monitoring programme is limited to turbidity and phosphorus monitoring. A further component of the SoE monitoring programme is the monitoring network of turbidity sensors which measure the turbidity in the river every 15 minutes. The continuous turbidity monitoring network provides a more detailed turbidity data set than the monthly sampling of SoE data.

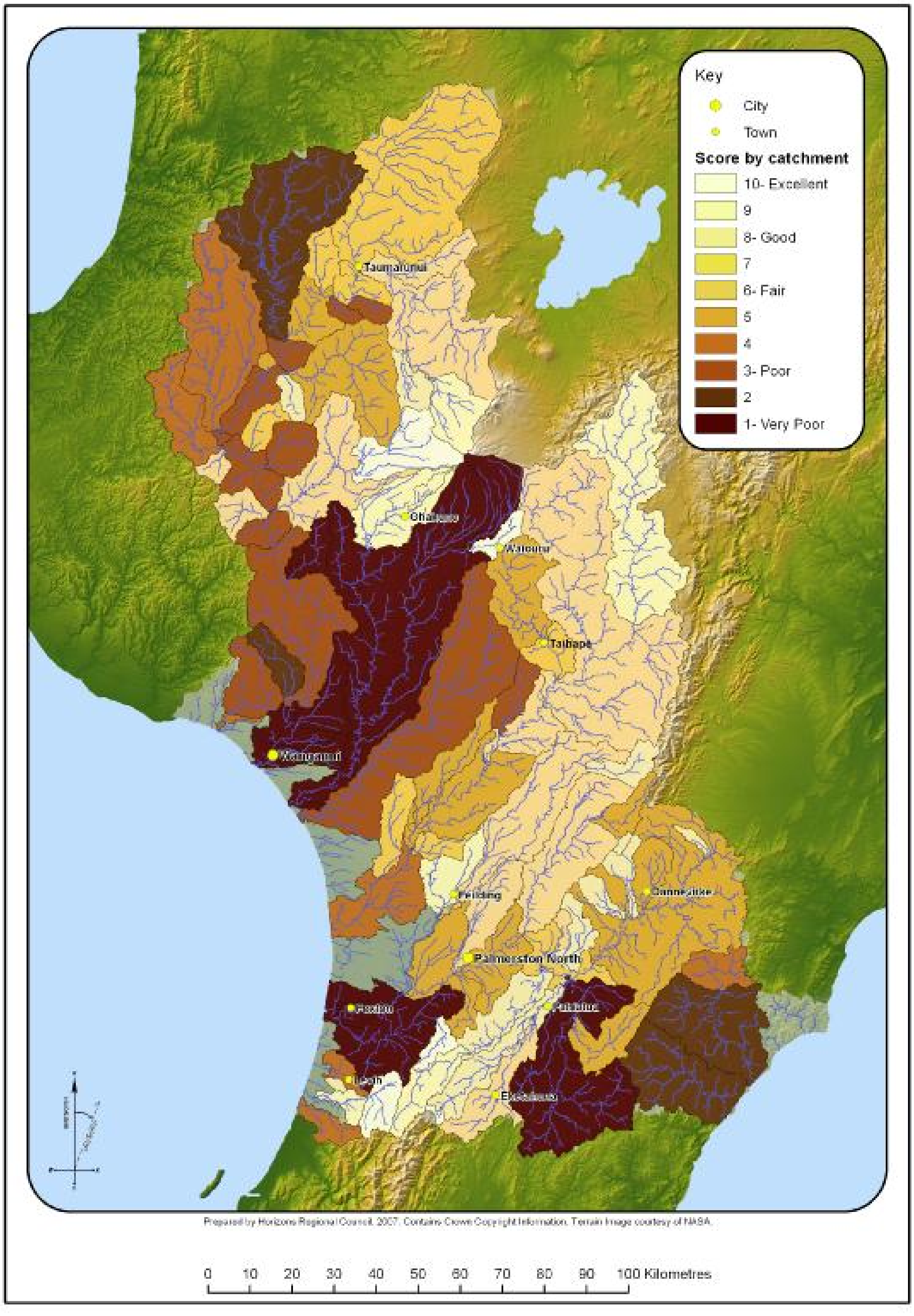
89. Horizons’ SoE monitoring programme samples more than 50 sites on a monthly basis. A range of parameters is measured as a part of this programme, including turbidity and

dissolved reactive phosphorus (DRP). The Horizons SoE Report (2005) compared measurements of turbidity and phosphorus from the monitoring programme to the ANZECC (2000) lowland trigger values (5.6 NTU for turbidity and 0.010 g DRP/m^3 for phosphorus) to develop a water quality indicator. The water quality indicator represents the percentage of samples that meet the standard, eg. a site where between 0 and 10 percent of the samples meet the standard has an indicator value of 1. Another example is a site where between 60-70 percent of the samples meet the standard has an indictor value of 7. The SoE maps provide an indicator of where turbidity and phosphorus are an issue; they do not specify the reason for the issue. The maps from the SoE Technical Report (Horizons, 2005) are presented for turbidity (Map 6) and DRP (Map 4). To clarify my role in the reporting of these indicators, I developed these indicators, including completing the numerical analysis which produced the results. It is noted the maps were compiled by other science team members.

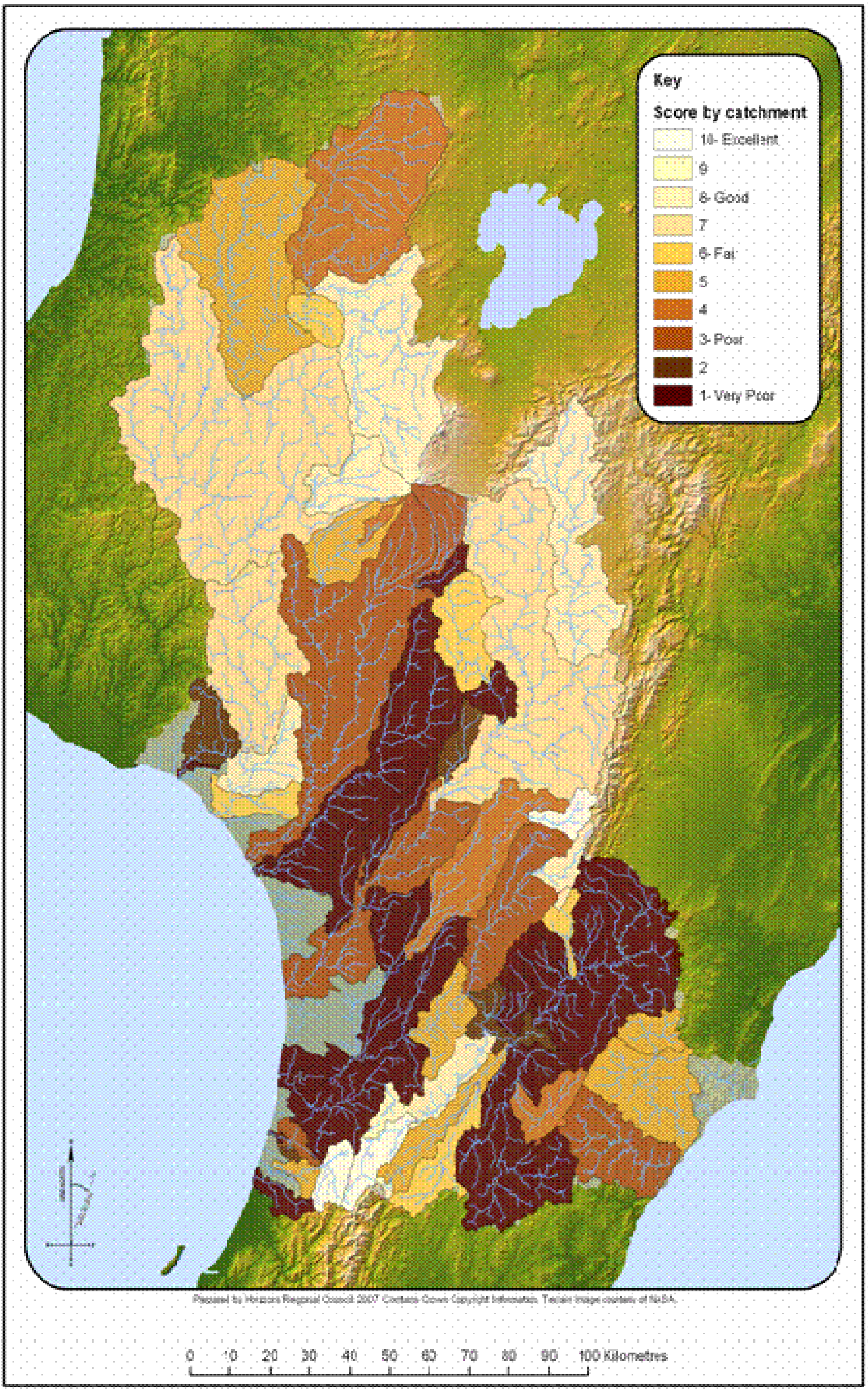
90. It is noted the maps for the SoE indicator maps were produced prior to the development of the water management zones (McArthur et al., 2007), and the areas represented in the water quality indicator maps may differ from the water management zones framework.

91. The turbidity water quality indicator (Map 6) shows a number of catchments are within the ANZECC guideline less than 20 percent of the time. These include the upper Ohura, Whangaehu, lower Whanganui, Tiraumea, lower Manawatu, Owhango and Akitio catchments.

92. The phosphorus water quality indicator (Map 7) shows a number of catchments are within the ANZECC guideline less than 20 percent of the time. These include the Turakina, lower Oroua, lower Manawatu, upper Manawatu, Tiraumea and Waikawa catchments.



Map 6. Water quality indicator for turbidity by catchment, Horizons' State of the Environment Technical Report (Horizons, 2005). *Note: a score of 10 indicates > 90 % of samples were </= the ANZECC guideline, a score of 1 indicates < 10 % of samples were </= the ANZECC guideline.*



Map 7. Water quality indicator for phosphorus (DRP) by catchment, Horizons State of the Environment Technical Report (Horizons, 2005). Note: a *score of 10 indicates > 90 % of samples were </= the ANZECC guideline, a score of 1 indicates < 10 % of samples were </= the ANZECC guideline.*

93. Trends analysis of the SoE water quality data was completed by Gibbard et al. 2006, a report which I co-authored. The trends shown in this analysis (Table 8) can be attributed to a range of reasons. The trends analysis, based on the monthly samples of water quality data, show for turbidity:

- § no trends for turbidity in the Rangitikei catchment;
- § some increasing trends (degrading water quality) for turbidity in the Manawatu catchment. This varied dependent on the use of non flow-adjusted or flow-adjusted methods. In my opinion, the flow-adjusted methods provide a more accurate assessment;
- § one decreasing trend (improving water quality), and some increasing trends degrading water quality in the Whanganui catchment. In my opinion this may be related to a reduction in inputs from point sources; and
- § some decreasing trends (improvement in water quality) in the Whangaehu catchment.

The trends analysis, based on the monthly samples of water quality data, show for phosphorus:

- § one increasing trend (degrading water quality) was observed in the Rangitikei catchment. This mainstem site was is located upstream of the other main stem sites in this analysis; and
- § the Manawatu sites showed some decreasing trends (improving water quality). It is noted that the Mangatera at Timber Bay is directly downstream of the Dannevirke sewage treatment plant discharge of treated wastewater to water. Other Manawatu sites showed an increasing trend for DRP:
- § the Whanganui showed some increasing DRP trends; and
- § the Whangaehu catchment showed one site with an increasing DRP trend.

Table 8. Summary of seasonal Kendall DRP, NO3 and TURB trend testing by site based on flow-adjusted or non flow-adjusted data (modified from Gibbard et al., 2006).

SOE Site	Non flow-adjusted			Flow-adjusted		
	DRP	NO_3	TURB	DRP	NO_3	TURB
Rangitikei Catchment						
Rangitikei at River Valley	↑			↑		
Hautapu upstream at Rangitikei						
Rangitikei at Mangaweka						
Rangitikei at Vinegar Hill						
Rangitikei at Kakariki						
Rangitikei at Scotts Ferry*						
Manawatu Catchment						
Mangatera at Timber Bay	↓↓↓	↑↑				
Makakahi at Konini		↑↑		↑↑	↑↑↑	↑↑
Mangatainoka at SH2		↑↑↑			↑↑↑	
Manawatu at Hopelands	↑↑↑	↑↑↑	↑↑	↑↑↑	↑↑↑	
Manawatu at Ashhurst Domain						
Oroua at Nelson Street	↑↑		↑↑	↑↑↑	↑↑↑	↑↑
Oroua at Awahuri Bridge				↑↑↑		↑
Manawatu at Maxwells Line					↑↑	↑↑↑
Manawatu at 42 Mile						
Manawatu at Whirokino*	↓	↑↑↑	↑↑↑			
Whanganui Catchment						
Whanganui at Retaruke						
Whanganui at Pipiriki	↑↑					↓
Whanganui at Kaiwhaiki	↑↑↑			↑↑↑		↑↑↑
Whanganui at Estuary opp. marina*			↑↑			
Whangaehu Catchment						
Mangawhero at DoC National Park			↓	↑↑		↓↓↓
Mangawhero d/s of Makotuku confl.						

* Tidal sites were not tested as part of the flow-adjusted analysis.
1. Some flow data has been supplied by Genesis Energy and NIWA.
2. Red arrows (↑) represent an increasing trend in concentration of a given water quality indicator (ie. a degradation in water quality). Green arrows (↓) represent a decreasing trend (ie. an improvement in water quality).
3. ↑/↓ indicates a significant trend (a probability of 90%)
↑↑/↓↓ indicates a very significant trend (a probability of 95%)
↑↑↑/↓↓↓ indicates a highly significant trend (a probability of 99%)

94. Horizons also measures turbidity via the turbidity monitoring network. Located at the river level/flow monitoring sites of the Regional Council, Horizons currently has 15 of these monitoring sites (Map 8).

Map 8. Location of continuous turbidity monitoring sites in the Horizons Region.

Continuous turbidity monitoring and sediment load calculation

95. All continuous turbidity stations in the Horizons monitoring network are installed in conjunction with long-term hydrometric stations. Water level is measured and logged and flow calculated from these stations on a continuous basis at intervals of less than 15 minutes, depending on the site.

96. The turbidity monitoring network has two components to measure 1) low-range turbidity, and 2) high-range turbidity:
    1) Low-range measurement (0 – 250 NTU) enables the determination of a highly accurate measure of turbidity at low levels; and
    2) High-range measurement (0 – 2500 NTU) enables the determination of a full turbidity record to build a relationship for sediment concentration over the entire range of sediment load.

97. The combination of these ranges enables the calculation of accurate sediment loads for a monitored catchment.

98. All sensors used in the network operate *in situ* within the river channel and recorded data is logged at 15 minute intervals. Grab samples of total suspended sediment (TSS) and turbidity are collected on a rotational basis at a maximum of every six weeks. These samples are analysed through an accredited laboratory.

99. After removal of any anomalies from the continuous turbidity data, the data is then rated to the laboratory samples. This correction process removes instrumentation bias and provides calibration of the sensors. Continuous turbidity data is then reviewed and stored in the hydrometric archive and periodically audited.

100. The rated turbidity series is used to build a relationship with suspended sediment (TSS) to determine catchment sediment yields. This relationship is non-linear due to the variation in underlying sediment type, chemical composition and particle size class. Because continuous turbidity data is collected simultaneously with continuous flow, the calculation of sediment load from turbidity via a rating curve is a more accurate method than load calculation from grab samples of suspended sediment and flow. It is noted the calculations of loads from programmes using monthly or quarterly samples have been shown to underestimate load estimates as much as 35-50% (Richards and Halloway 1987, as cited in Richards, 1998).

101. The continuous turbidity network has been established for over five years within Horizons. The data collection and processing is a significant commitment by the council. The

existing network has high in field maintenance requirements and processing of the data is very time consuming. In early 2008, some further trial work was undertaken with an aim of improving the data collection and processing procedures to reduce the maintenance requirements in the field, improve the quality of the raw data and to reduce the amount of time required to process the data through to sediment load. This programme was successful to the point where raw turbidity data is now provisionally rated to sediment load automatically for the site where the trail occurred. A roll out of this improved methodology is currently being planned. Additionally, turbidity stations are currently being realigned to better fit the measurement of SLUI initiatives in the long term, and to more accurately determine sediment yields from catchments at risk of erosion.

102. To demonstrate the data collected from this network. The following dataset shows calculations made from the trial at the Manawatu at Teachers College site earlier this year. The methodology is as follows:

- Grab samples are analysed by an accredited laboratory for Hark Referenced Turbidity (NTU).
- This information is used for the correction/calibration of the turbidity record (Figure 3).
- The corrected turbidity series becomes the Final Archived Data Series.
- The grab samples are also analysed in the accredited laboratory for Total Suspended Solids.
- Using the relationship between the turbidity data and the TSS data (Table 9) a rating curve is established (Figure 4) that converts the readings of turbidity from the corrected turbidity series into a continuous series of suspended sediment concentration (Figure 5).
- Combining the continuous suspended sediment series with the continuous flow series from the site a sediment load for period of measurement can be calculated (Figure 6).
- Applying this methodology to the Manawatu at Teachers College site, it can be calculated that for the period 8/4/2008 12:30:00 to 28/05/08 13:30:00, the total sediment load (tonnes) was 23777.090 Tonnes which converts to an average of 475.5 Tonnes/Day.
- From the data gathered via this methodology many further aspects of reporting can be completed. For example a frequency distribution can be generated to show how often the site was below the ANZECC guideline for Turbidity at a lowland river site (5.6 NTU). Table 10 shows that the site was above this threshold over 66% of the time during this period.
- Numerical indicators derived via the continuous turbidity network will provide considerable information about the state and trends in water quality in relation to both turbidity and sediment load.

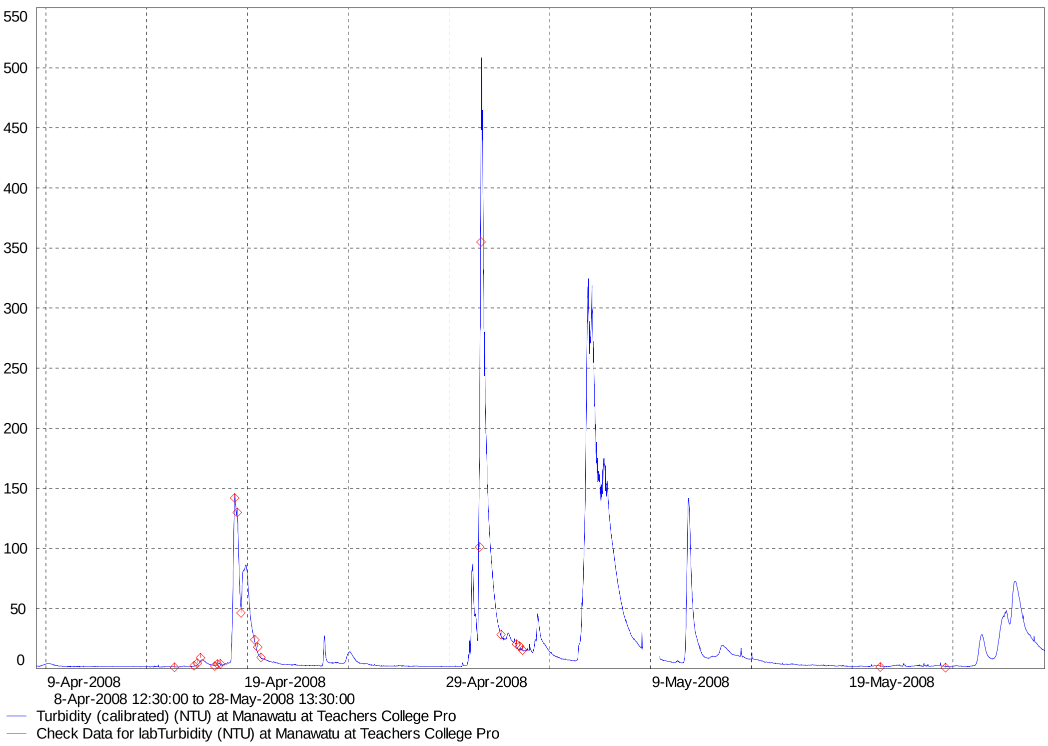


Figure 3. Grab samples (check data) are used to calibrate the raw data from the Turbidity Sensor.

Table 9. Manawatu at Teachers College Grab Sample results for turbidity and total suspended solids

Time	Sampled Turbidity	Sampled Total Suspended Solids
	(NTU)	(g/m^3)
18/04/2008 08:45	141	275
19/04/2008 08:30	23.6	47
30/04/2008 14:15	445	864
23/05/2008 15:15	0.765	1
26/05/2008 11:30	30.7	71
Historical Samples		
21/01/2004 15:15	2160	4860
26/01/2001 15:45	1600	3500
19/10/2004 06:30	1070	2280

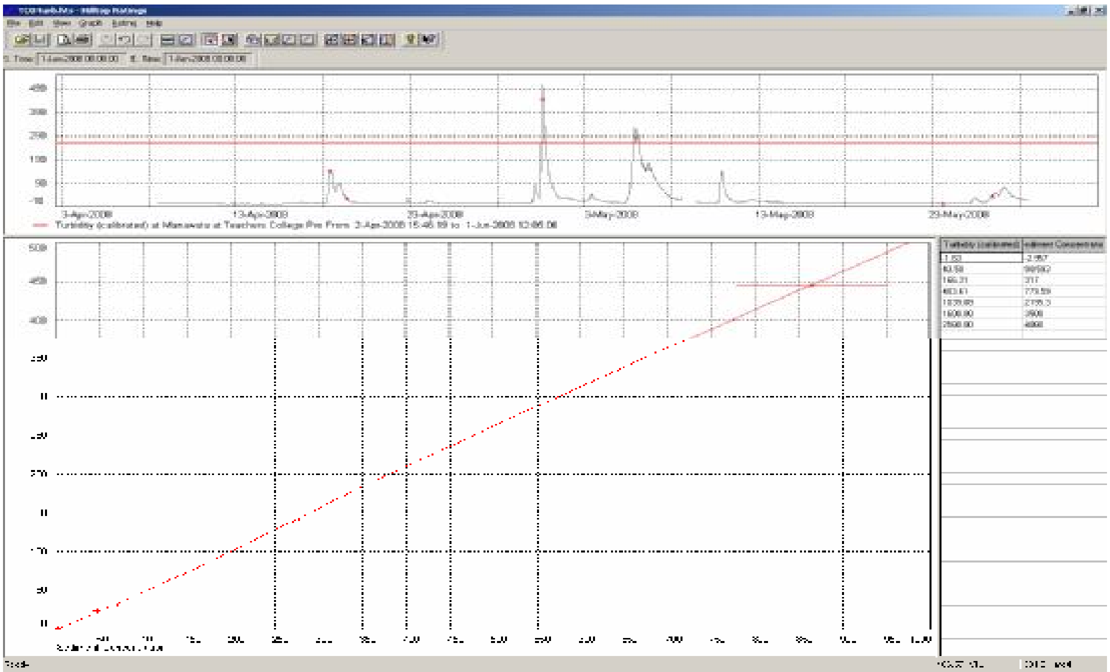


Figure 4. The Turbidity & TSS pairs enable reference points for a rating to be established. Pairs are plotted with +/- 8% error.

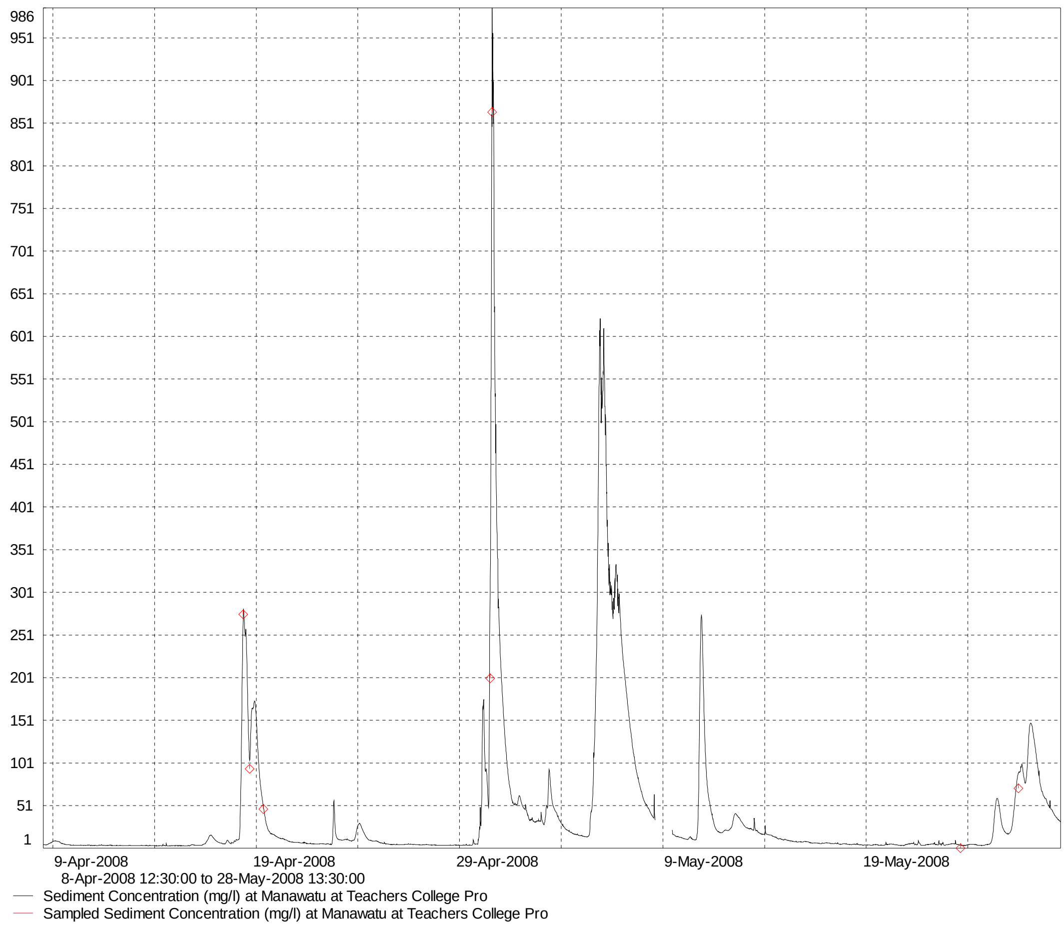


Figure 5. Plot of the calculated continuous total suspended sediment series. Showing the check data from the lab analysis of the grab samples.

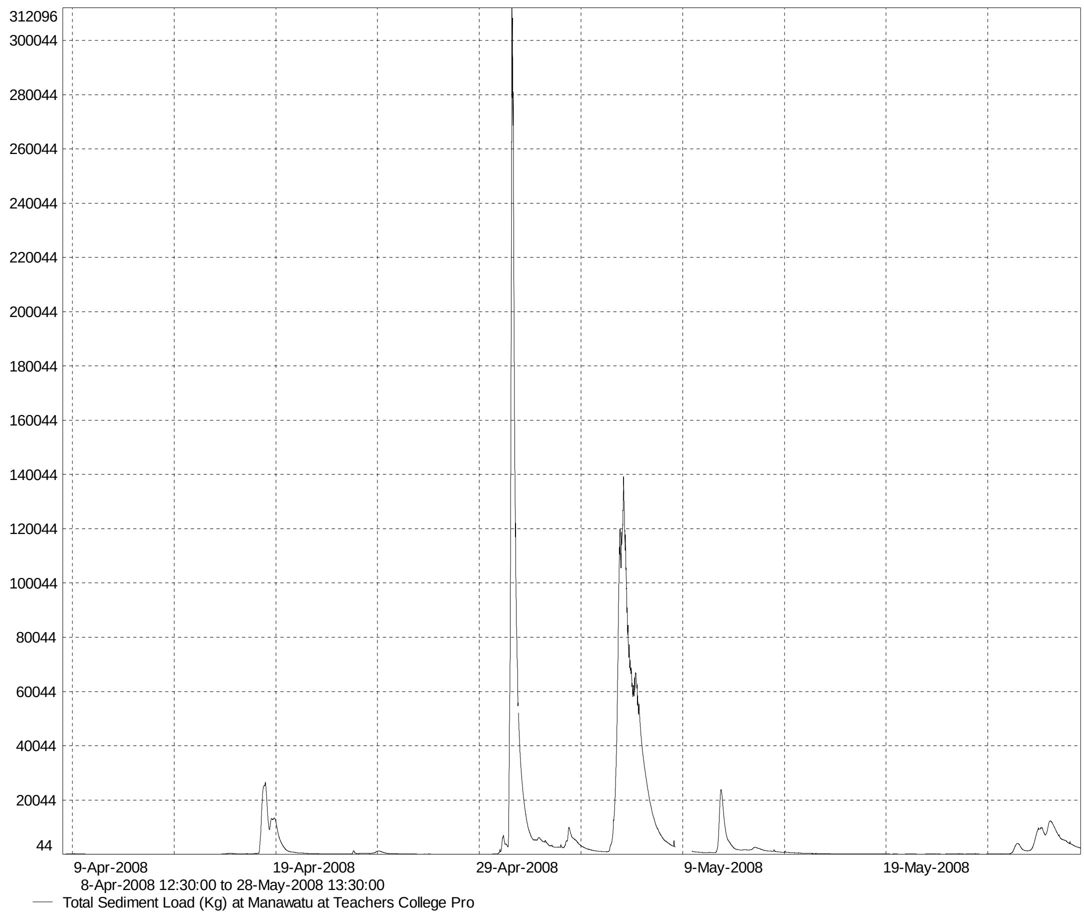


Figure 6. Continuous sediment load (kg) for the Manawatu at Teachers College site for the trial period.

Table 10. Frequency distribution for Turbidity at Manawatu at Teachers College for the period 8-Apr-2008 12:30:00 to 28-May-2008 13:30:00.

~~~ Hilltop Hydro ~~~ Version 5.56 30-May-2008

~~~ PDist ~~~

Sediment Concentration (mg/l) at Manawatu at Teachers College Pro
From 8-Apr-2008 12:30:00 to 28-May-2008 13:30:00

Exceedance percentiles

	0	1	2	3	4	5	6	7	8	9
0	992	520	325	282	247	196	165	146	128	110
10	96.2	89.1	80.5	71.4	62.8	58.7	54.6	52	49.1	46.2
20	42.5	39.8	37.1	34.6	33	31.7	29.1	26.6	24.4	23
30	21.9	20.8	19.5	18.4	17.6	16.9	16.1	15.3	14.6	13.8
40	12.8	12.1	11.6	11.2	10.7	10.5	9.88	9.52	9.27	8.8
50	8.51	8.09	7.82	7.57	7.2	7.04	6.89	6.76	6.54	6.36
60	6.25	6.15	6.07	5.99	5.92	5.85	5.67	5.54	5.48	5.42
70	5.36	5.3	5.24	5.19	5.13	5.07	5.01	4.92	4.81	4.69
80	4.66	4.62	4.58	4.54	4.5	4.46	4.42	4.39	4.35	4.31
90	4.27	4.23	4.19	4.15	4.11	4.05	3.99	3.93	3.87	3.75
100	3.55									

Mean = 40.144 Std Deviation = 90.186
49 days 04:45:00 hhmmss of data analysed
0 days 20:15:00 hhmmss of missing record
The distribution was calculated over 2000 classes in the range 3.5476 to 577.27 mg/l

103. Horizons will monitor the outcomes of SLUI and some of the methods of the proposed One Plan through an integrated monitoring approach. This will include pulling together information from a range of sources including the whole farm plans for SLUI farms, the

recording of operational details from implementing SLUI, whole farm plan monitoring programmes, and catchment monitoring via the state of environment monitoring programme, the fluvial monitoring and science programme and using data from the continuous turbidity network. There is currently some refinement of these monitoring programmes underway to align with the shift in the priority areas for SLUI.

Dr Jon Roygard

3 June 2008

References

ANZECC. (2000). Australian and New Zealand Environment and Conservation Council Guidelines for Fresh & Marine Water Quality. Ministry for the Environment website www.mfe.gov.nz.

Douglas, G., Dymond, J. and McIvor, I. (2008b). Monitoring and reporting of whole farm plans as a tool for effecting land use change. Prepared through Envirolink Fund (Contract No: 244HZLC26) for Horizons Regional Council by SLURI, the Sustainable Land Use Research Initiative.

Douglas, G., Harnsworth, G., and McIvor, I. (2006) Updating the Land Use Capability Handbook – A Scoping Report. Horizons Regional Council. AgResearch Client report prepared for Horizons Regional Council (June 2006).

Douglas, G., Manderson, A., Lynn, I., Harnsworth, G., and Page, M. (2008a). Updating the Land Use capability survey handbook. Envirolink tools contract AGRX604. AgResearch report (April 2008).

Dymond, J.R., and Betts, H.D. (2008). Description of New Zealand empirical erosion model (NZEEM®). Draft submitted to Environmental Modelling Software.

Dymond, J., and Shepherd, J. (2006). Highly erodible land in the Manawatu – Wanganui Region, Landcare Research, Report No. 2006/EXT/749

Dymond, J., Sheppard, J., and Page, P. (2008). Regional Council erosion rollout: Workshop notes (18 March 2008). Landcare report (March 2008).

Dymond, J. R., Ausseil, A., Sheppard, J.D., and Buettner, L. (2006). Validation of a region-wide model of landslide susceptibility in the Manawatu-Wanganui region of New Zealand. Geomorphology 74(70-79).

Gibbard, R., Roygard, J., Ausseil, O., and Fung, L. (2006). Water Quality Trends in the Manawatu-Wanganui Region 1989-2004, Horizons Regional Council Report No. 2006/EXT/702, ISBN: 1-877413-27-5.

Hicks, D. and Crippen, T. (2004). Erosion of Manawatu-Wanganui Hill Country during the Storm on 15-16 February 2004 - Calibration of bare ground measured from satellite images with bare ground measured from aerial photographs, for different landforms and vegetation covers. Prepared for Horizons Regional Council by Ecological Research Associates Inc. (September 2004).

Hancox, G.T., and Wright, K. (2005). Landslides caused by the February 2004 rainstorms and floods in southern North Island, New Zealand, New Zealand. Institute of Geological and Nuclear Science Report 2005/10 32p.

Horizons Regional Council. (2005). State of the Environment Report of the Manawatu-Wanganui Region. Horizons Regional Council Report No. 2004/EXT/608. ISBN: 1-877310-56-5.

Hawley, J.G., Dymond, J.R. (1988). By how much do trees reduce landsliding? Journal of Soil and Water Conservation 43: 495–498.

Hicks, D.L. (1995). Control of soil erosion. Ministry of Agriculture Publication 95/4. Wellington, Ministry of Agriculture.

Mackay, A., and Neild, J., (2005). Horizons Regional Council Sustainable Land Use Initiative Costings and Feasibility. AgResearch Client report prepared for Horizons Regional Council. (November 2005).

McArthur, K., Roygard, J., Ausseil, O., and Clark, M. (2007). Development of water management zones in the Manawatu-Wanganui Region. Technical report to support policy development. Horizons Regional Council Report No. 2006/EXT/733. ISBN 1-877413-47-X.

Mackay, A. (2007). Specifications of whole farm plans as a tool for effecting land use change to reduce risk to extreme climatic events. Horizons Regional Council. Envirolink medium advice grant 243-HZLC25.

Mitchell, G., and Cooper, G. (2006). Sustainable Land Use Initiative implementation plan 2006/2007. September 2006 ISBN: 1-877413-50-X. Report No: 2006/EXT/736.

Mitchell, G., and Cooper, G. (2007). Sustainable Land Use Initiative implementation plan 2007/2008.

Parfitt, R., Dymond, J., Ausseil, A-G., Clothier, B., Deurer, M., Gillingham, A., Gray, R., Houlbrooke, R., Mackay, A., and McDowell, R. (2007). Best practice phosphorus losses from agricultural land. Landcare Research Contract Report: LC0708/012.

Page, M., Sheppard, J., Dymond, J., and Jessen, M. (2005). Defining highly erodable land for Horizons Regional Council. Landcare research Contract report: LC0506/050.

Richards, R.P., and Halloway, J. (1987). Mote Carlo studies of sampling strategies for estimating tributary loads. Water resources Research 23:1939-1948.

Richards, R.P. (1998). Estimation of pollutant loads in rivers and streams: a guidance document for NPS programs, Project report prepared under Grant X998397-01-0, US Environmental Protection Agency, Region VIII, Denver, 108p.

Schierlitz, C. Dymond J., and Shepherd J. (2006), Erosion/sedimentation in the Manawatu Catchment associated with scenarios of Whole Farm Plans, Landcare Research Contract Report: 0607/028, Report No. 2006/EXT/748.

Schierlitz, C. (2008). New Zealand empirical erosion model: analysis, evaluation and application in climate change scenarios. Unpublished diplomarbeit (thesis), University of Bonn.

Smart, G. (2008). Review of fluvial science prepared for Horizons Regional Council NIWA client report: CHC2008-018. Envirolink project HZLC31.

Soil Conservation and Rivers Control Council (1971). Land use capability survey handbook. 2nd ed. Wellington, Water and Soil Division, Ministry of Works and Development. 138 p.