BEFORE THE MANAWATU-WHANGANUI REGIONAL COUNCIL HEARINGS PANEL

IN THE MATTER OF	**the Proposed One Plan of the Council**

STATEMENT OF EVIDENCE

Dr. Ian Christopher Fuller

On behalf of Fish & Game New Zealand

1. Introduction

Qualifications and relevant experience

1. My name is Dr. Ian Christopher Fuller. I am a Senior Lecturer in Physical Geography, School of People, Environment & Planning, Massey University, Palmerston North.
2. I hold the degrees of Bachelor of Science with First Class Honours in Geography, University of Wales, Aberystwyth, UK, 1992 and have a Ph.D. in respect of which I completed a thesis dissertation: “Alluvial response to environmental change”, University of Wales, Aberystwyth, UK, 1996.
3. I was Lecturer in Physical Geography, University of Northumbria, UK, from 1996-2003 and Lecturer in Physical Geography, Massey University, 2003-2006. I have been Senior Lecturer since January 2006.
4. At advanced level, I teach a 200 level paper on Rivers & Slopes, a 300 level paper on River Dynamics, a 300 level paper on Applied Field Geomorphology and a 700 level paper on Fluvial Geomorphology: Dynamics & Management.
5. I am actively engaged in researching river channel dynamics in New Zealand and the UK. I am a member of the British Society for Geomorphology, the Australian and New Zealand Geomorphology Group and the New Zealand Geographical Society.
6. I have over 16 years of international research experience. My area of research expertise is in river channel dynamics. I have published a total of 32 peer reviewed research articles in my career to date, of which 23 relate to river channel dynamics.
7. I have published five peer reviewed articles on river channel behaviour in connection with the February 2004 floods in the Manawatu region.
8. I authored a Technical Report for Horizons Regional Council on Measuring and Monitoring Channel Morphology (Report 2007/EXT/773), following my involvement in a workshop on this topic at the invitation of HRC in November 2006.
9. In 2008 I was commissioned by Fish & Game (Wellington Region) to produce a Technical Report on channel change in the lower Rangitikei, co-authored with my student, Jane Richardson.
10. I have been subcontracted by Landcare Research (Nelson) since 2004 to work on reaches of the upper Motueka River to assess morphological change and bedload fluxes using repeat detailed GPS survey and GIS analysis. This research forms part of the Motueka Integrated Catchment Management Programme.
11. In 2008-09 I supervised an Honours project on bank erosion and channel change in the lower Pohangina River.
12. I am currently supervising an Honours project on channel change in the lower Oroua River, a PhD project on Holocene flood histories in Northland, a PhD project on Holocene infilling of the Manawatu estuary. I am co-supervising a PhD project on bedload disturbance of invertebrate communities in mountain streams in the lower North Island.

13. I have been commissioned by the Wellington Fish and Game council to provide expert advice and evidence on the Beds of Rivers and Lake provisions of the One Plan, and the Environmental Code of Practice for River Works. In this evidence I will provide an introduction outlining definitions concerning river morphology and natural river character; my own findings informed by research on rivers in the region and farther afield in New Zealand; and recommendations for river management in the region.
14. I confirm that I have read the Environment Court's Code of Conduct for Expert Witnesses and that I agree to comply with it.

2. Executive Summary

1. Rivers comprise unique assemblages of morphological units (e.g. bars, pools, riffles, which are defined in section 3 Introduction), which are formed in response to the interaction between key channel forming variables including flow regime, sediment regime, channel gradient, and bank composition.
2. In this evidence I report findings from two rivers in the Horizons Region: Rangitikei and Pohangina.
3. These findings inform the identification of natural character in these rivers and identify the geomorphological components associated with rivers in this region.
4. These findings also identify the impacts of flood and erosion protection activity on the natural characteristics of these rivers.
5. Results are presented which demonstrate significant narrowing of river channels in response to River Scheme activity over the last 50 years with a commensurate loss in morphological diversity and degradation of natural character in these rivers.
6. The impacts of width reduction and morphological change are examined in the light of research undertaken in a similarly narrowed, engineered reach of the upper Motueka River.
7. Recommendations for future river management are made in the light of evidence presented. In particular I endorse an integrative scientific approach f future river management.

Scope

8. I present this evidence on behalf of Fish and Game (Wellington Region).
9. I provide definitions of alluvial rivers and natural character in the Introduction. This is followed by evidence drawn from research I have been involved with in the Rangitikei, Pohangina and Motueka Rivers. I offer recommendations on the basis of this research and background information.
10. Work presented on the Rangitikei was undertaken by Jane Richardson under my supervision. Work presented on the Pohangina was undertaken by Sheryl Paine under my supervision. Work on the Motueka was undertaken by myself in conjunction with Landcare Research (Nelson).

3. Evidence

Introduction

Definitions

1. Alluvial rivers, which include gravel-bedded and sand-bedded rivers, typify rivers within the Horizons region. The principal morphological components in alluvial rivers are: bars, riffles, pools and runs. Bars are the principal bedform arising from deposition within the active channel (defined as bank toe to bank toe). They may be classified according to their morphology into a range of types (Figure 3.1; Report 2007/EXT773). Riffles, pools and runs represent topographic highs, lows and intermediate zones respectively within the wetted channel. Wetted channel morphology is intrinsically linked with barforms, e.g. riffle crossings may form as the thalweg (main flow thread) flows from side to side in a straight channel across alternate lateral / diagonal bars (Figure 3.2). Pools and riffles should be considered together as a continuous bedform, i.e. as a pool-riffle unit / sequence. Pools and riffles do not tend to occur in isolation.

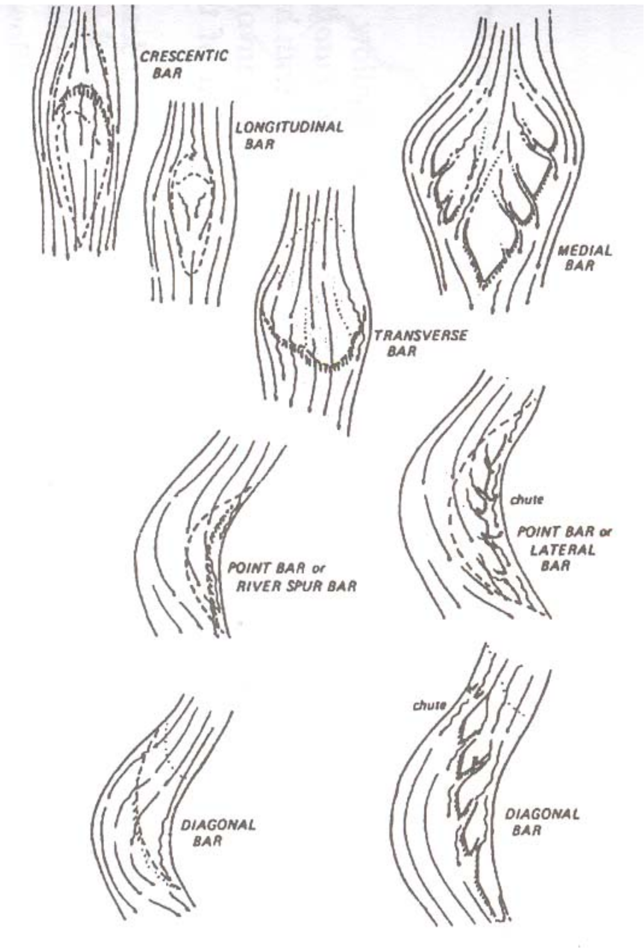


Figure 3.1: Types of channel bars.
Source: Figure 9.6 Thorne *et al*. (1997)

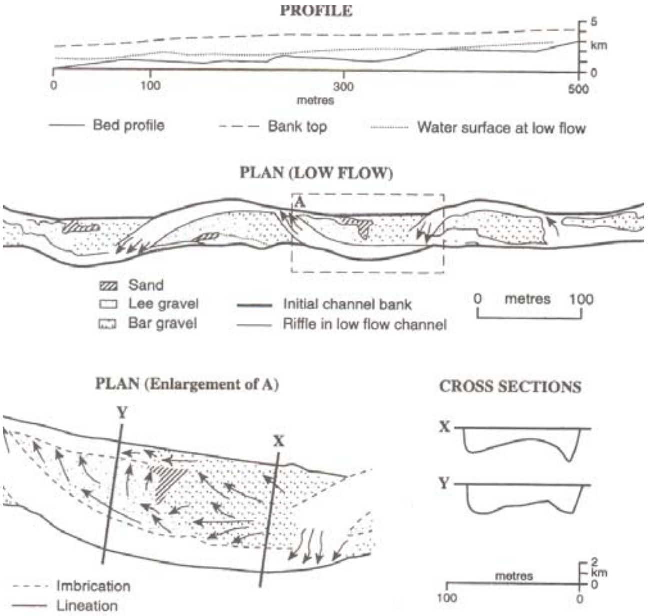


Figure 3.2. Formation of asymmetrical pools, alternate bars and riffle crossings in a straight alluvial channel (after Richards 1982). Source: Figure 7.7 Thorne *et al*. (1997).

Natural channel character

2. Each river comprises a unique assemblage of morphological components (bars, riffles, pools, runs), reflecting the unique flow regime conditioned by runoff from the catchment; unique sediment supply, both in terms of volume and calibre (size); and unique channel boundary conditions, notably bank composition and channel gradient. The precise morphology and character of a reach reflects the unique combination of these variables.

3. River channels which have adjusted to an equilibrium form within their framework of sediment and flow regime within the boundary conditions of a catchment should not be considered to be absolutely stable. Stability is relative and natural systems are dynamic, responding to discrete flood events in particular. Well-adjusted river systems are best understood as operating within a dynamic equilibrium.

4. River morphology adjusts to subtle changes in flow and sediment supplied to the system from the catchment. Whilst boundary conditions (gradient and bank composition) could be considered as being relatively constant, discharge and sediment supplied to a river is highly variable, responding to discrete natural events (e.g. storms, landslides). Rivers are therefore naturally dynamic and responsive systems, adjusting their form in response to changes in key channel forming variables on an event basis. The natural character of rivers is dynamic.

5. Within a constantly fluctuating channel morphology it is possible to identify general channel patterns. Braided channels are characterised by multiple channels and braid bars. Wandering channels, also defined as semi-braided or pseudo-meandering, comprise morphological units present in both braided and meandering rivers e.g. irregular pool-riffle sequences, bends, bifurcating channels around occasional medial or longitudinal bars. Channels are only classified as meandering where sinuosity (channel length / straight line valley length) exceeds 1.5 and the river is single threaded and dominated by point bars and well developed pool-riffle sequences. Meandering channels are characterised by a cycle of development from cutoff which straightens the channel to regained compound meanders. The dominant process is lateral accretion on the inside of bends and localised erosion on the outside of bends. Avulsion in the form of cutoff occurs when the meander neck is breached (neck cutoff) or point bar is cut (chute cutoff). Wandering channels are also characterised by similar processes, although avulsions are more significant and may cut across large parts of floodplain as opposed to narrow channel necks or point bars. Avulsive behaviour produces rapid and sudden channel switching in such systems. Braided channels are characterised by multiple channel bifurcations around multiple medial and transverse bars in an unconstrained active channel. For a full review of braiding mechanisms, see Sambrook-Smith *et al*. (2006). Each planform type is characterised by constant adjustment of precise form.

6. This planform classification is inevitably generalised. The diversity of morphological units within alluvial channels must be recognised. There is no 'one size fits all'. Each system or reach is unique, reflecting the precise combination of channel-forming variables (discharge, sediment load and character, bank composition and stability). Effective management and maintaining natural character requires a clear understanding of natural channel characteristics and should work with these processes. I recommended this in my report to HRC (Report 2007/EXT773). Failure to recognise the diversity of form in natural rivers or the

dynamics of that form will result in design of channels which are not in equilibrium with natural processes, which will always seek to adjust towards the equilibrium form. This adjustment will mean constant intervention and maintenance of such schemes is required, accumulating cost and at the expense of natural stream characteristics.

7. The natural character of a river, defined in terms of its morphology, is therefore the dynamic assemblage of morphological units which adjust to the changing flow regime, sediment supply and boundary conditions within a discrete catchment.

Research

Assessment

8. Aerial photos dating to the 1950s provide the basis for assessment of river channel change in the Rangitikei and Pohangina.

9. Analysis of aerial photos was undertaken by students under my direct supervision, generating maps documenting morphological change in the active channel (defined as cut bank to cut bank), which were in turn analysed by the supervised students to quantify the extent and direction of changes observed.

10. Detailed ground survey using high-precision differential GPS receivers was deployed to map the active channel of the Motueka reaches. Topographic data were analysed within a GIS using digital elevation models constructed from each survey dataset.

11. Ground survey was beyond the scope of assessment in the Rangitikei and Pohangina reaches examined.

Rangitikei

12. Three reaches in the lower Rangitkei River were examined (Figure 3.1). These reaches were selected on the basis of aerial photograph availability which provided greatest temporal coverage.

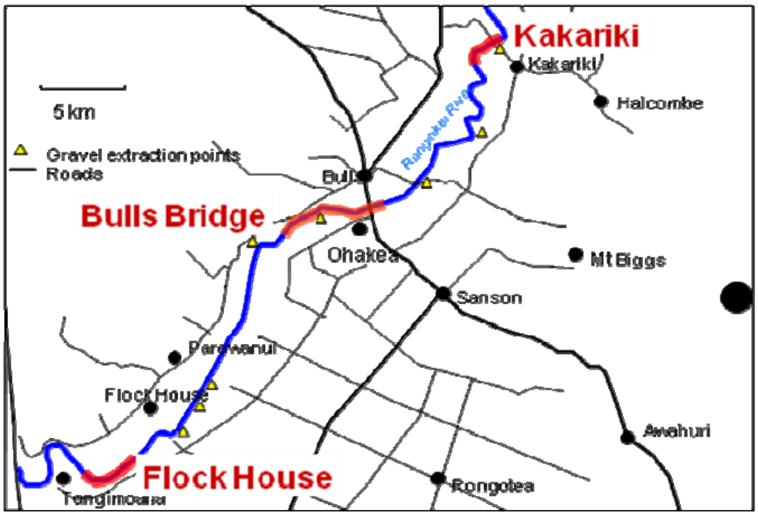


Figure 3.1. The three study reaches in the lower Rangitikei defined in terms of their spatial extents: Kakariki, Bulls Bridge and Flock House.

13. Aerial photographs were scanned and rectified. A positional accuracy or 6.5 m was achieved, i.e. features on the rectified aerial photograph were accurate to within 6.5 metres. The morphology of each reach was mapped for each time period, with particular attention on the boundaries of the active channel, bar and wetted channel margins and delineating areas of active, semi-vegetated and vegetated sediment within the active channel (Figures 4.2-4).

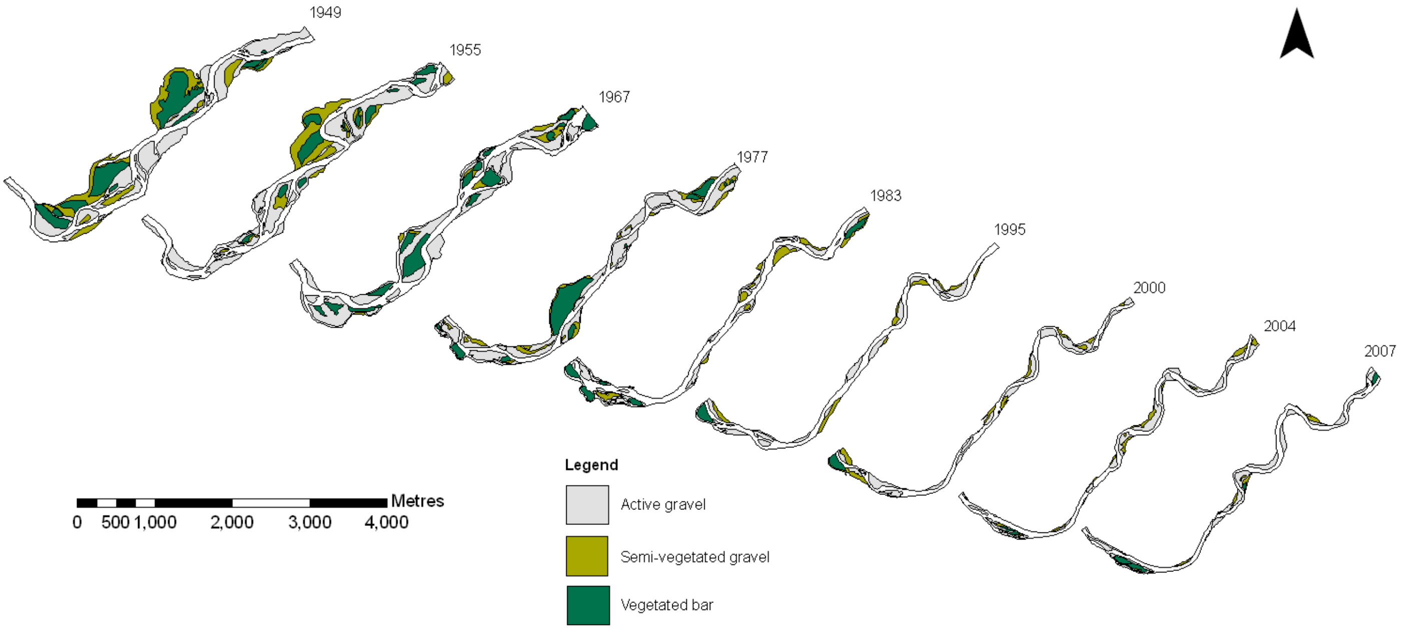


Figure 3.2. Channel change, Flock House reach, 1949-2007.

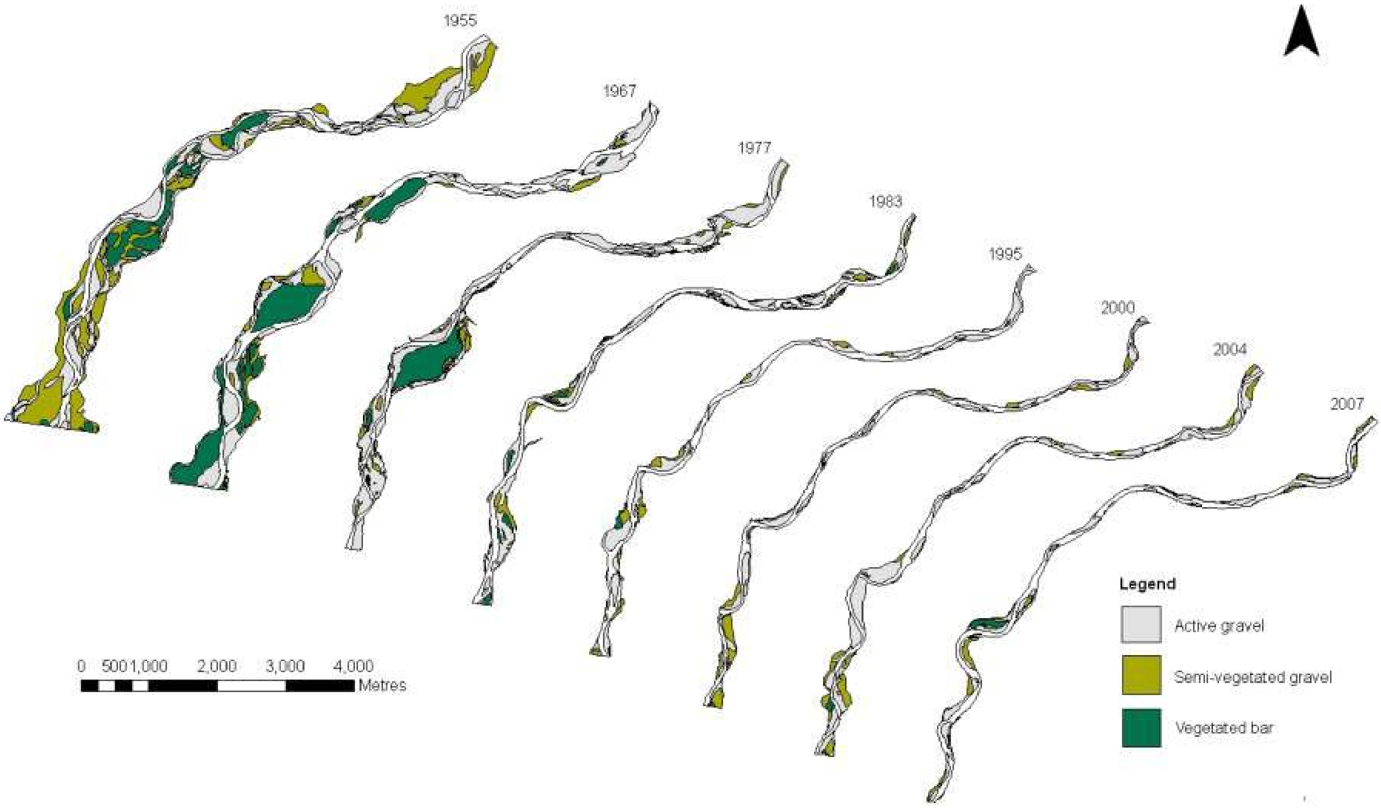


Figure 3.3. Channel change, Bulls Bridge reach, 1955-2007.

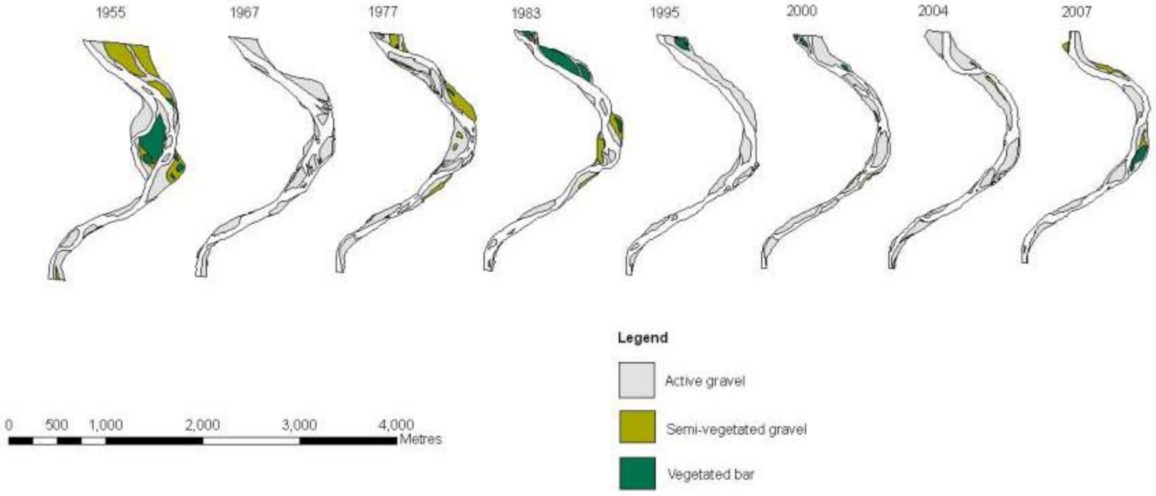


Figure 3.4. Channel change, Kakariki reach, 1955-2007.

14. A clear directional change is evident in these sequential maps (Figs 2-4). The river has changed from a morphologically diverse multi-thread braided planform to a more uniform single thread planform. Interrogation and analysis of the maps produced from sequential aerial photographs (Figs 2-4) was performed within ArcMap GIS® in order to quantify the extent of change evident in these maps.
15. Areal extent of active gravel (defined as being unvegetated due to frequent reworking of sediment), semi-vegetated gravel and vegetated bar was assessed for each reach over the time period examined (Figure 3.5). This demonstrates a reduction in morphological diversity within the reaches over time as well as a reduction in active bar area.

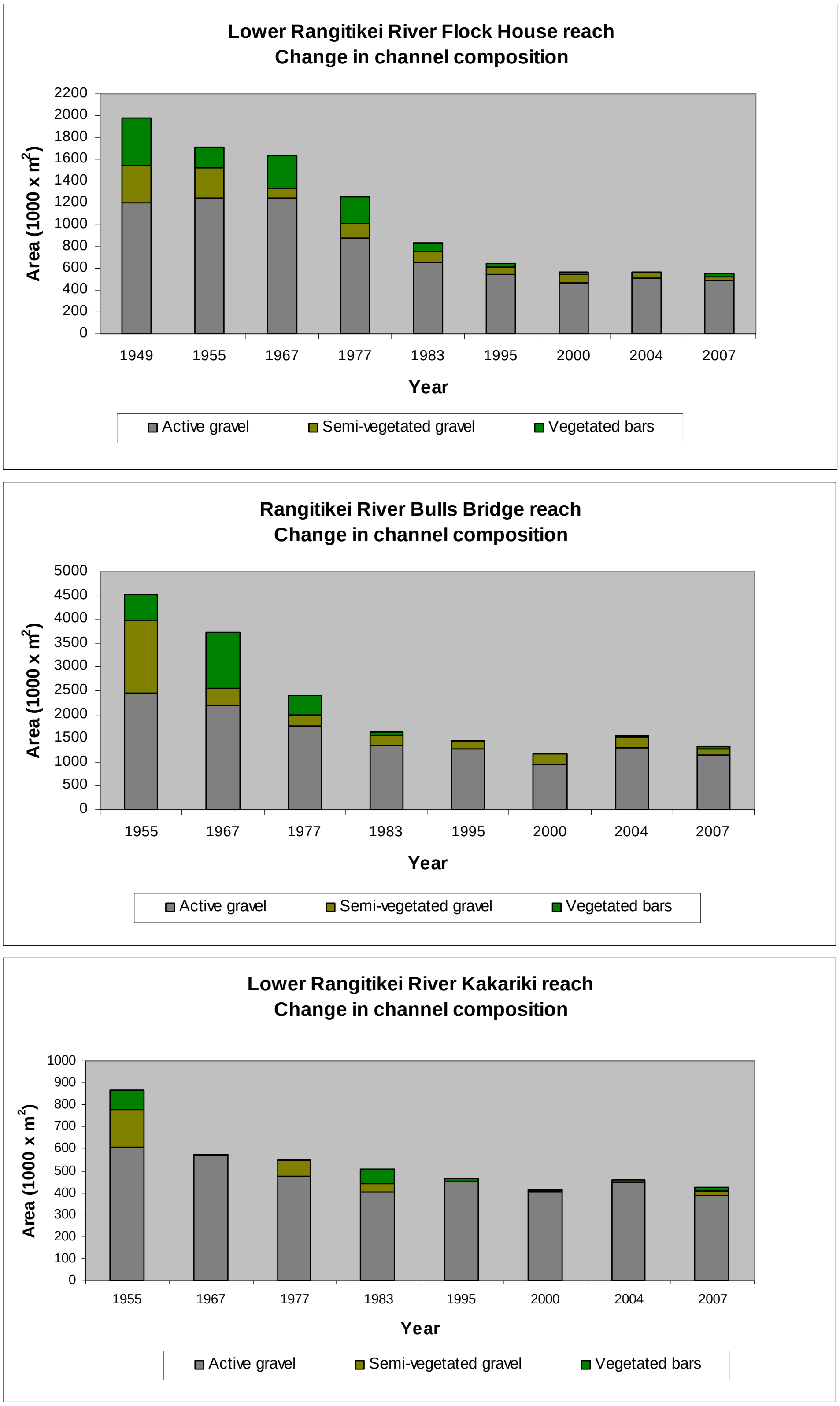
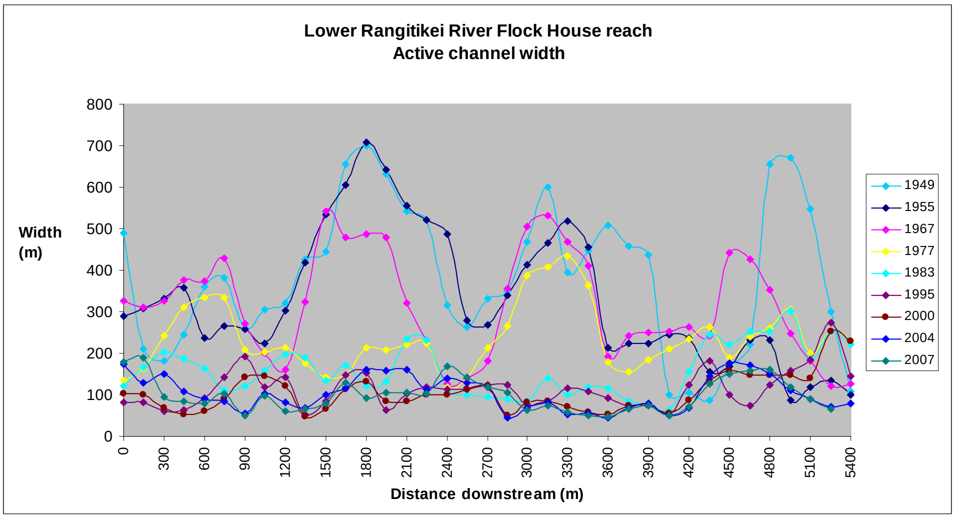
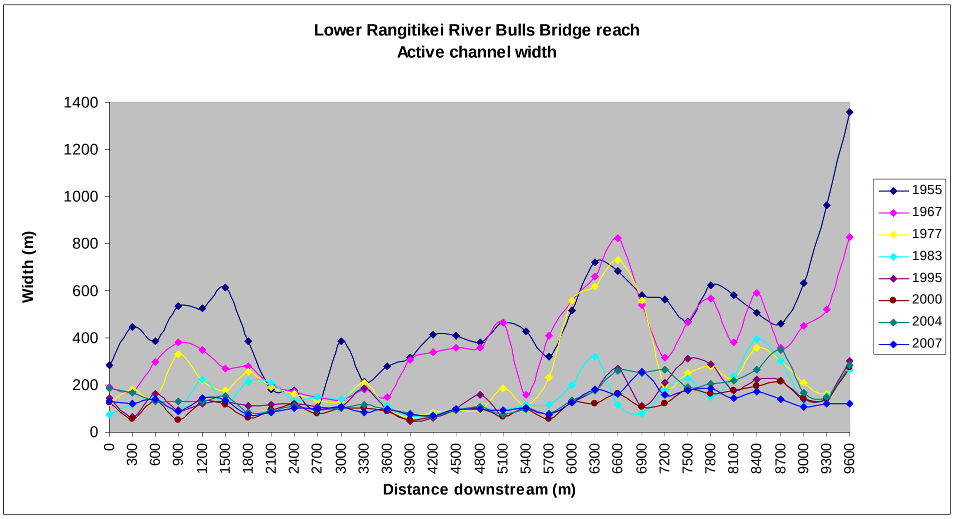


Figure 3.5. Areal extents of active gravel, semi-vegetated gravel and vegetated bars within each study reach.

16. Active channel widths in each reach were quantified by measuring a total of 30 equally spaced sections spanning the active channel, perpendicular to its alignment (Figure 3.6). Spacing was scaled to reach length. Whilst there is some variability in widths, an overall narrowing of the channel over the period of study is evident (Figure 3.6).





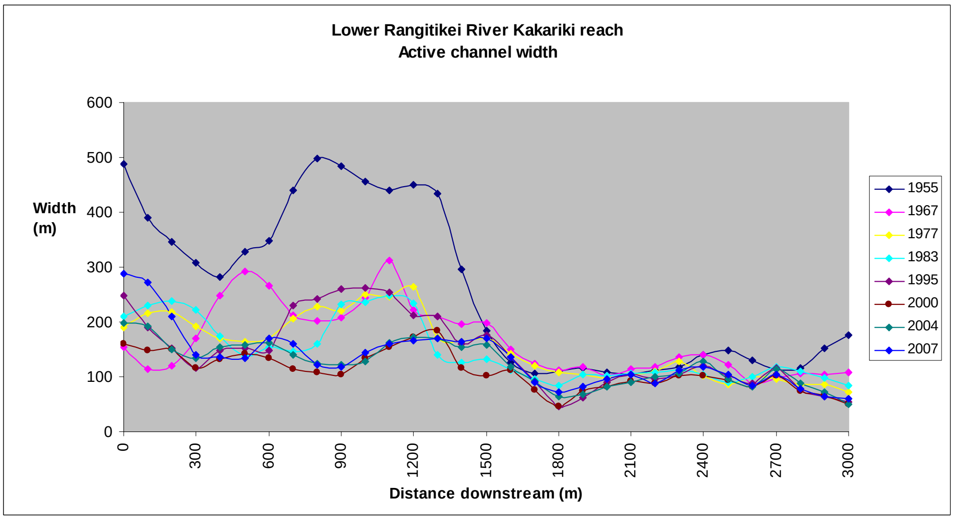


Figure 3.6. Active channel widths over time for each study reach

17. The statistical significance of the apparent changes over time was assessed using parametric analysis (t-test) of active channel width data derived from Figure 3.6. This demonstrates statistically significant narrowing of the active channel over the period of investigation, by as much as 74% (Figure 3.7).

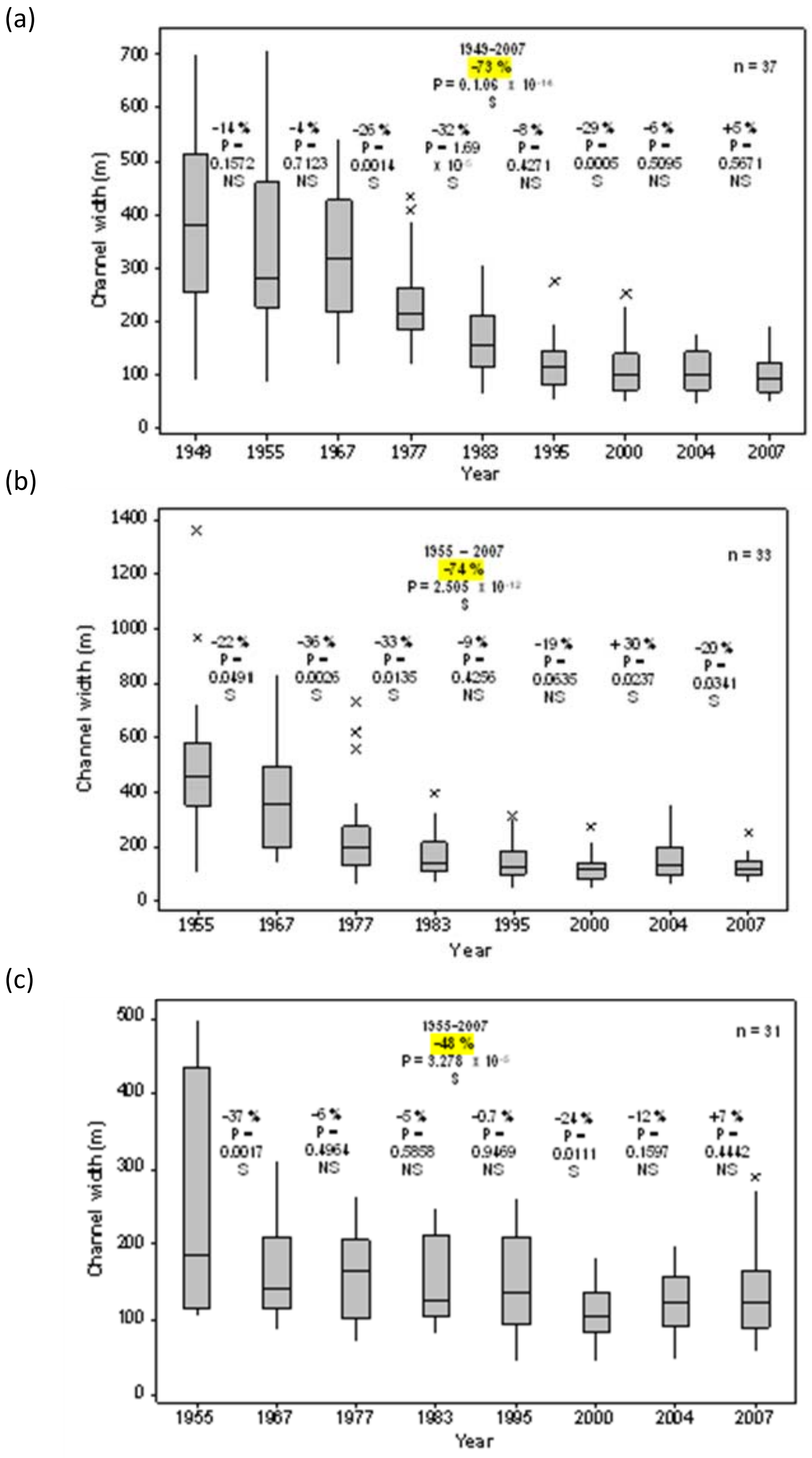


Figure 3.7. Statistical analysis of width changes in the active channel of the Rangitikei at (a) Flock House, (b) Bulls Bridge and (c) Kakariki. Overall change between the first and last years contributing to the analysis is highlighted.

18. The morphological character of the Rangitikei reaches was also assessed via determination of a braiding index (Figure 3.8). This is based on Brice's (1960) definition, where the index is twice the total length of bars within the reach divided by the mid-channel length of the reach. The result quantifies the reduction in braiding observed in Figures 4.2-4.

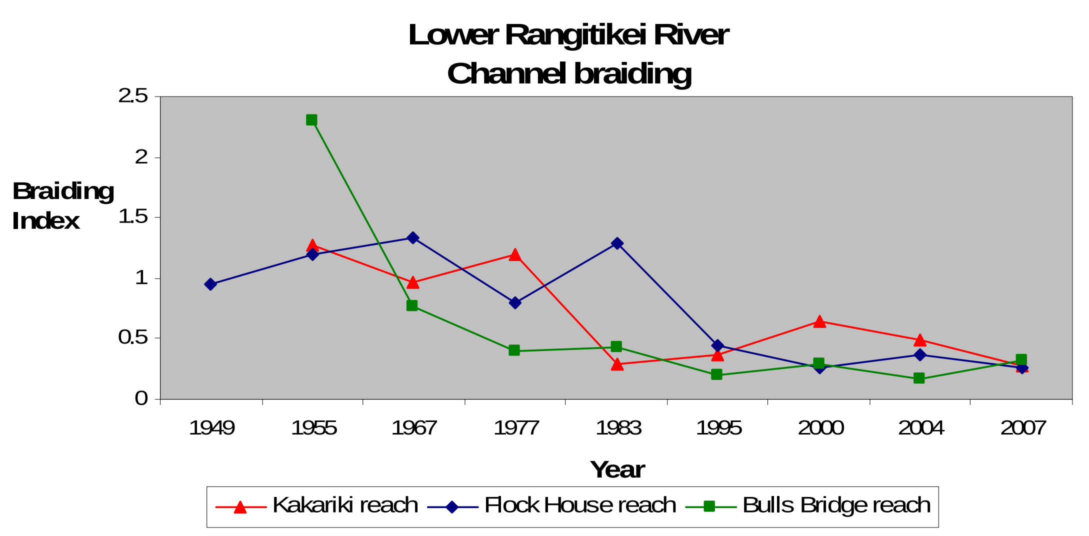


Figure 3.8. Braiding index change over time in the lower Rangitikei study reaches.

Synthesis

19. Assessment of channel change in the lower Rangitikei River at three discrete reaches demonstrates:
    a. Reduced morphological diversity and complexity in the active channel (Figures 4.2-5, 8)
    b. Reduced width, which is statistically significant (Figures 4.2-4, 6-7).
    c. Stabilisation of channel planform commensurate with (a) and a complete transformation from a multi-thread braided channel to a laterally-confined single thread channel.

20. The majority of channel transformation occurred prior to 1983 and is attributable to river management associated with the Scheme on this river. In particular, bank stabilisation works have narrowed the active channel (Figure 3.9).

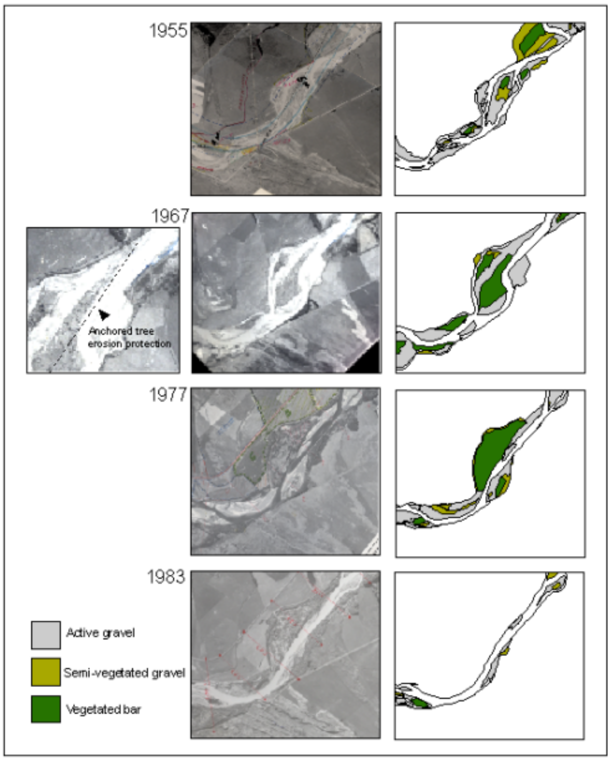


Figure 3.9. The influence of bank protection works (here a line of anchored trees) on channel planform in the lower Rangitikei. Stabilised vegetated bars are subsumed into the floodplain and cease to be defined as part of the active channel.

21. There was some limited adjustment to the February 2004 flood event on this river evident in the Bulls Bridge reach (Figures 4.3, 4.7b). However change was small in comparison with the trends evident over the 50 years assessed by this study.

Pohangina

22. Three reaches in the lower Pohangina River were assessed (Figure 3.10). Aerial photograph availability determined the dates used

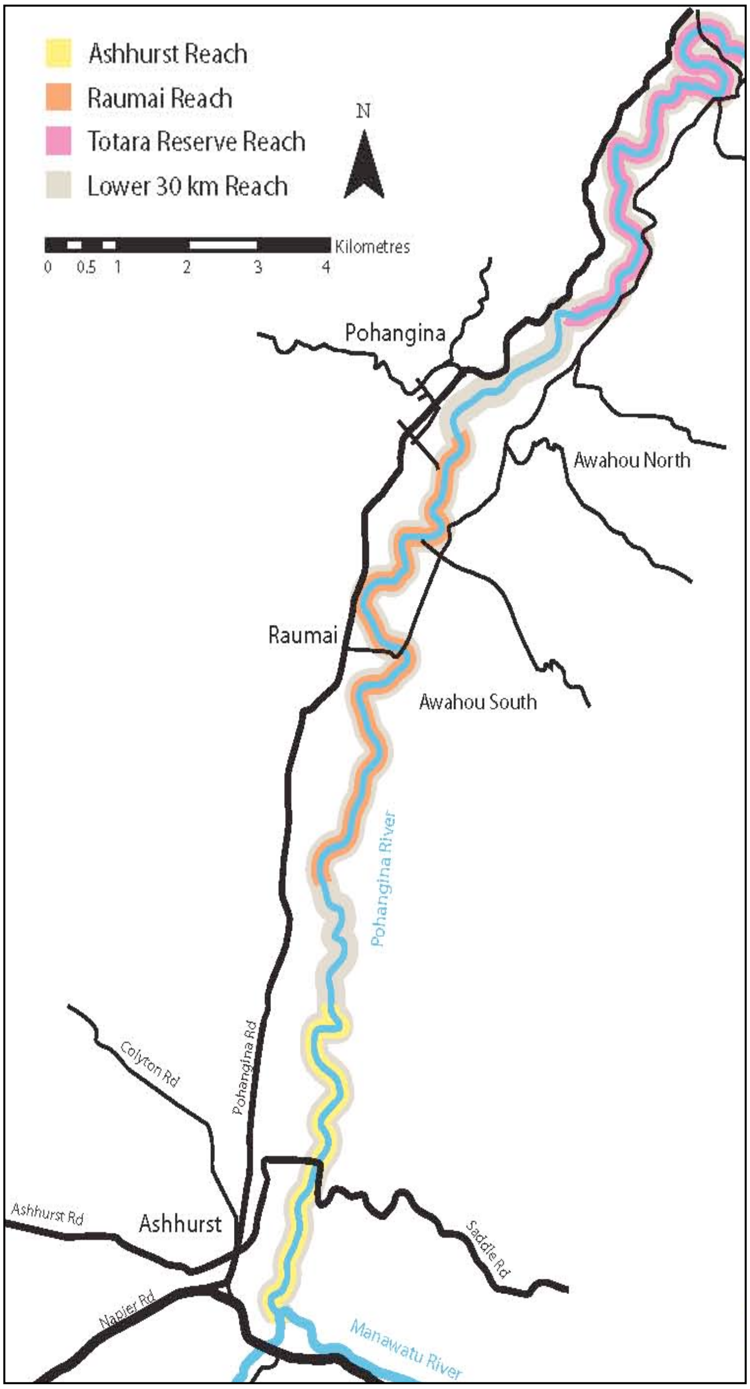


Figure 3.10. The three study reaches in the lower Pohangina defined in terms of their spatial extents: Ashhurst, Raumai and Totara Reserve.

23. Aerial photographs were scanned and rectified. A positional accuracy or 6 m was achieved, i.e. features on the rectified aerial photograph were accurate to within 6 metres. The

morphology of each reach was mapped for each time period, with particular attention on the boundaries of the active channel, bar and wetted channel margins (Figures 4.11-13). Vegetated areas of gravel were not mapped in this project.

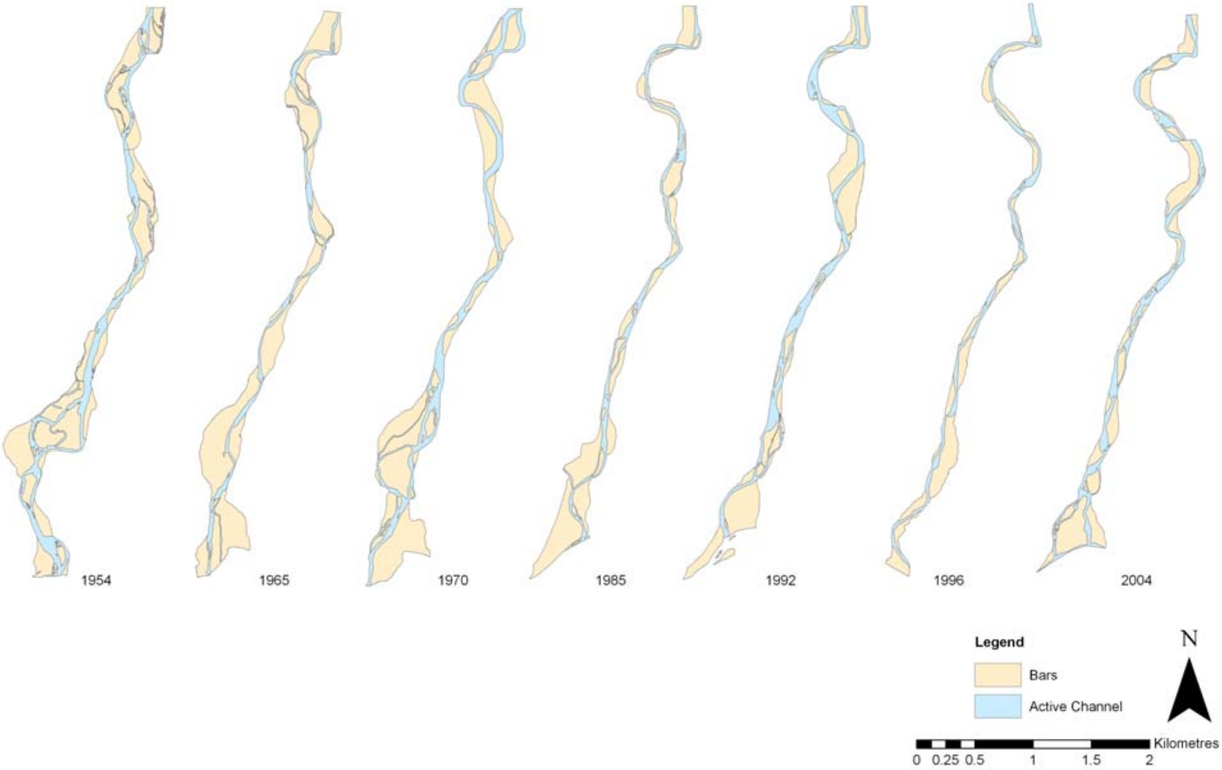


Figure 3.11. Channel change, Ashhurst reach, 1954-2004.

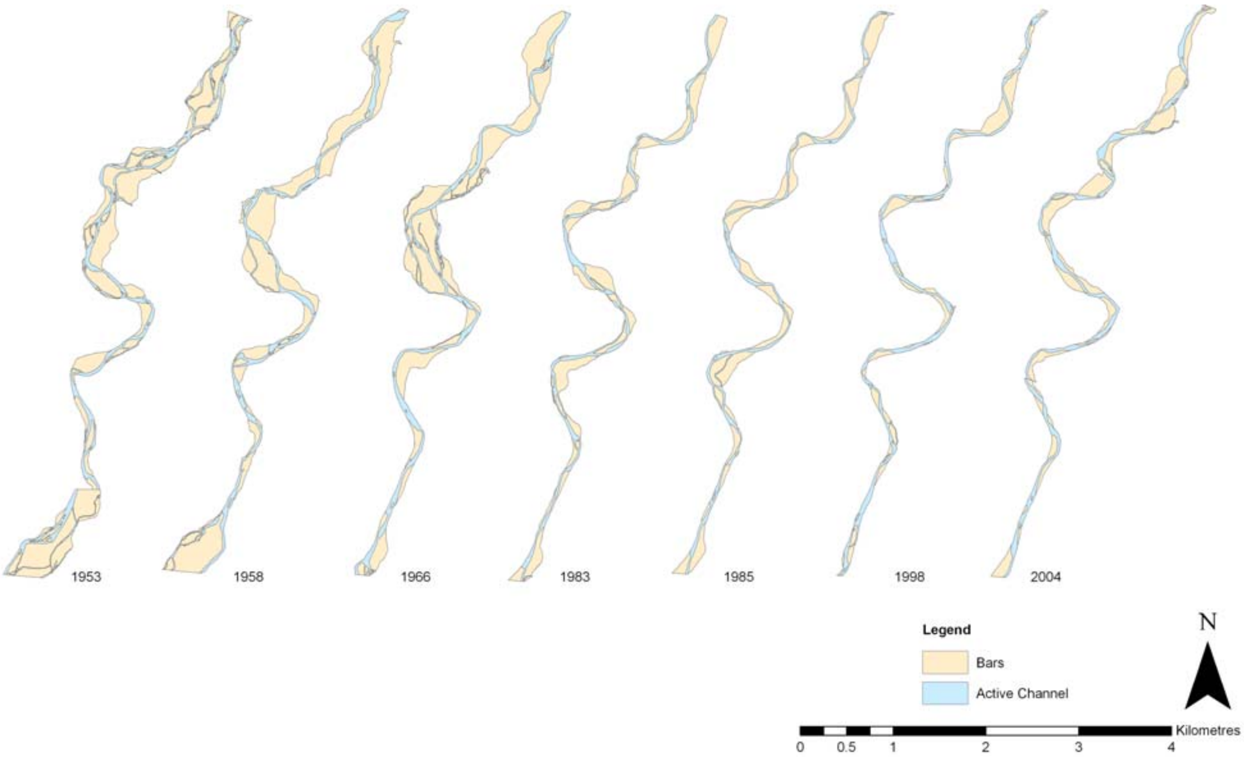


Figure 3.12. Channel change, Raumai reach, 1953-2004.

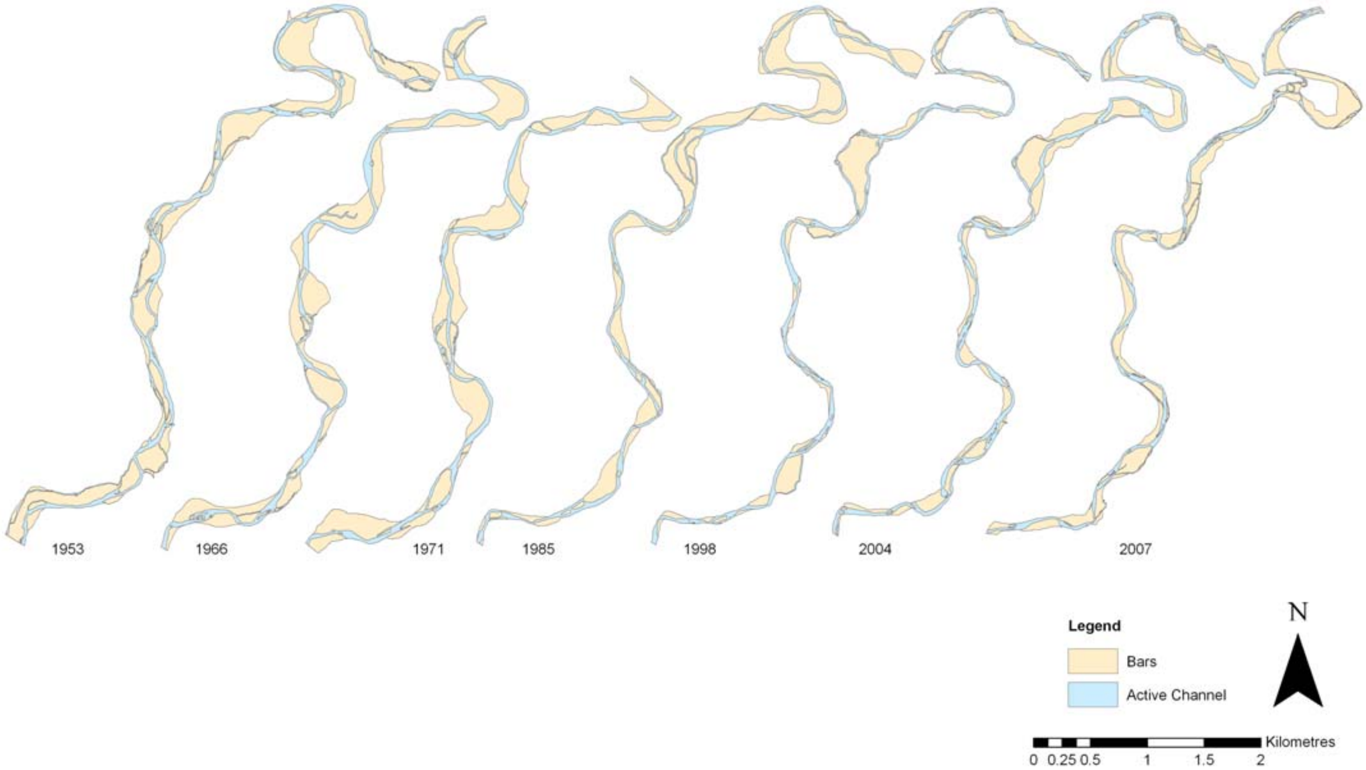


Figure 3.13. Channel change, Totara Reserve reach, 1953-2007.

24. Narrowing of the active channel in each of the reaches studied in the Pohangina is evident in Figures 4.11-13. A braided-semi braided planform is replaced by a single-thread laterally stable channel over the period of investigation. Interrogation and analysis of the maps produced from sequential aerial photographs (Figs 11-13) was performed within ArcMap GIS® in order to quantify the extent of change evident in these maps.

25. Active channel widths in each reach were quantified by measuring a total of 30 equally spaced sections spanning the active channel, perpendicular to its alignment (cf. Figure 3.6). Spacing was scaled to reach length. The mean widths are shown in Table 1. Statistical analysis on width data from the Pohangina quantifies the significance of changes observed (Figure 3.14). These figures quantify the progressive narrowing evident in Figures 4.11-13, demonstrating that width reduction of up to 46% is statistically significant (Fig 3.14).

Table 1. Pohangina mean active channel widths

Year	Mean active channel width (m)		
	Ashhurst	Raumai	Totara Reserve
1953		197.59	167.88
1954	193.5		
1958		191.54	
1965	177.96		
1966		173.02	152.84
1970	199.59		
1971			147.33
1983		102.5	
1985	124.78	104.5	129
1992	140.18		
1995	80.14		
1998		73.14	88.96
2004	129.45	105.77	110.85
2007			98.28

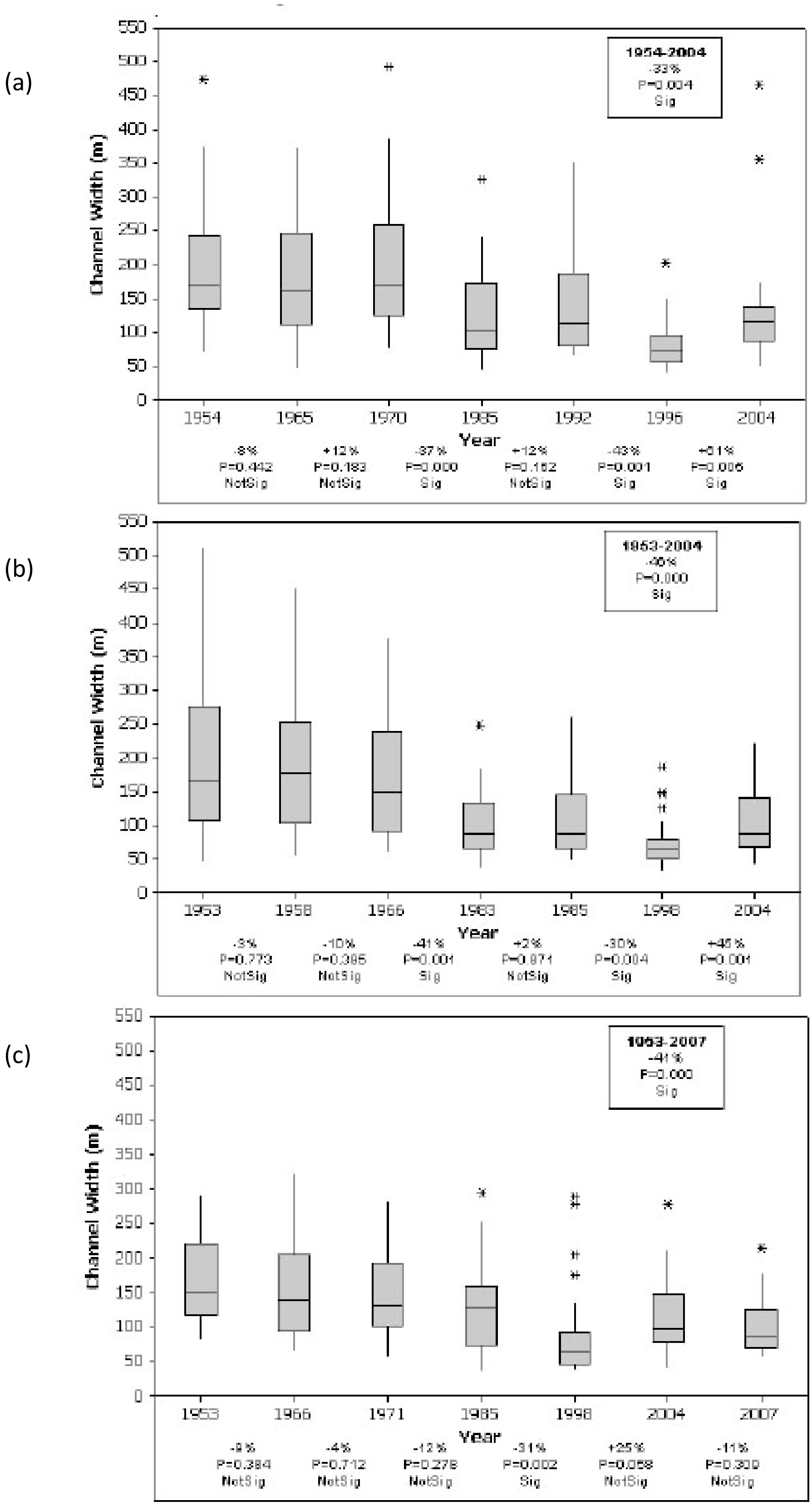


Figure 3.14. Statistical analysis of width changes in the active channel of the Pohangina at (a) Ashhurst, (b) Raumai and (c) Totara Reserve. Overall change between the first and last years contributing to the analysis is highlighted.

26. The change in braiding index for the Pohangina reaches during the period of study is given for each reach, together with the lower 30 km as a whole (Figure 3.15). This quantifies the reduction in braiding observed in Figures 4.11-13.

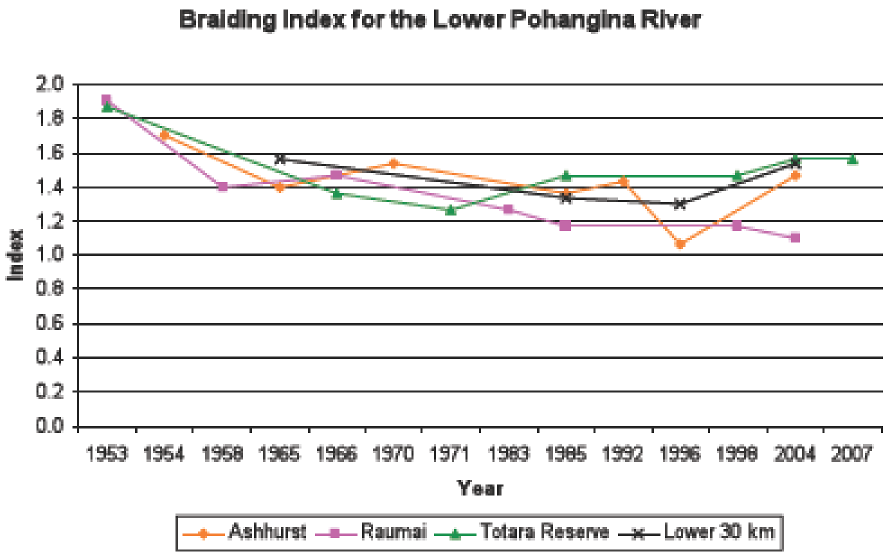


Figure 3.15. Braiding index change over time in the lower Pohangina study reaches and overall lower 30 km.

Synthesis

27. Assessment of channel change in the lower Pohangina River at three discrete reaches demonstrates:
    a. Reduced morphological diversity and complexity in the active channel (Figures 4.11-13, 15)
    b. Reduced width, which is statistically significant (Figures 4.11-14).
    c. Stabilisation of channel planform commensurate with (a) and a partial transformation from a multi-thread braided channel to a laterally-confined single thread channel.

Natural Character

28. The natural character of the Pohangina and Rangitikei Rivers is best understood as the channel morphology which is adjusted to the supply of water and sediment to the river. This equilibrium morphology under the current discharge and sediment regimes is that which is evident in the 1950s (Figures 4.2-4, 4.11-13).

29. A braided or semi-braided channel, laterally flanked by bars of active gravel and varying degrees of vegetated channel, which is reworked frequently (annually to decadal), is the natural character of the Rangitikei and Pohangina at present.

30. River flood and erosion protection work has reduced the morphological complexity and diversity in these rivers, such that they are no longer in balance / equilibrium with sediment loads and flow regime. The implications of this disequilibrium are considered in the light of higher resolution surveys completed in reaches of the Motueka River.

Motueka

31. Detailed, high resolution GPS survey has been deployed in the upper Motueka (Figure 3.16) to assess three dimensional channel change within a laterally-constrained, engineered reach. This assists in assessing some of the consequences of management in naturally laterally active gravel-bed rivers.

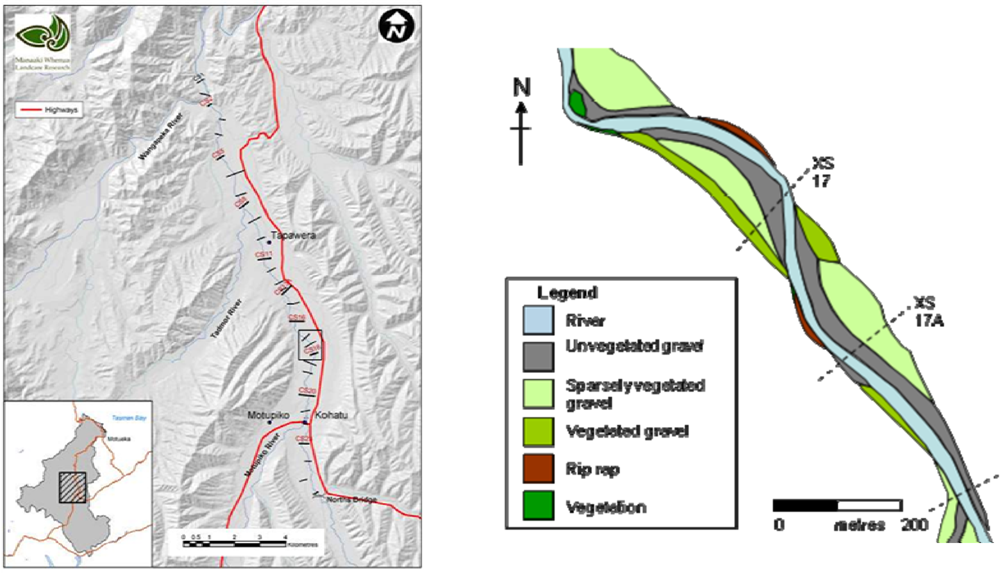


Figure 3.16. Location of Three Beaches reach, upper Motueka.

32. Detailed ground survey measures surface topography of all river morphology: sub-aerial and sub-aqueous. Data generated in annual surveys between 2004-2009 were used to generate digital elevation models (DEMs) of river bed and active bar topography (Figure 3.17). Assessment of three dimensional changes is facilitated using DEMs of difference. Difference DEMs are constructed by subtracting the surface at time 2 from the surface at time 1. Areas of negative elevation change represent net loss of sediment, whilst areas of positive elevation change represent net sediment gain. DEMs of difference for the Three Beaches reach in the upper Motueka demonstrate a net loss of sediment (Figure 3.18).

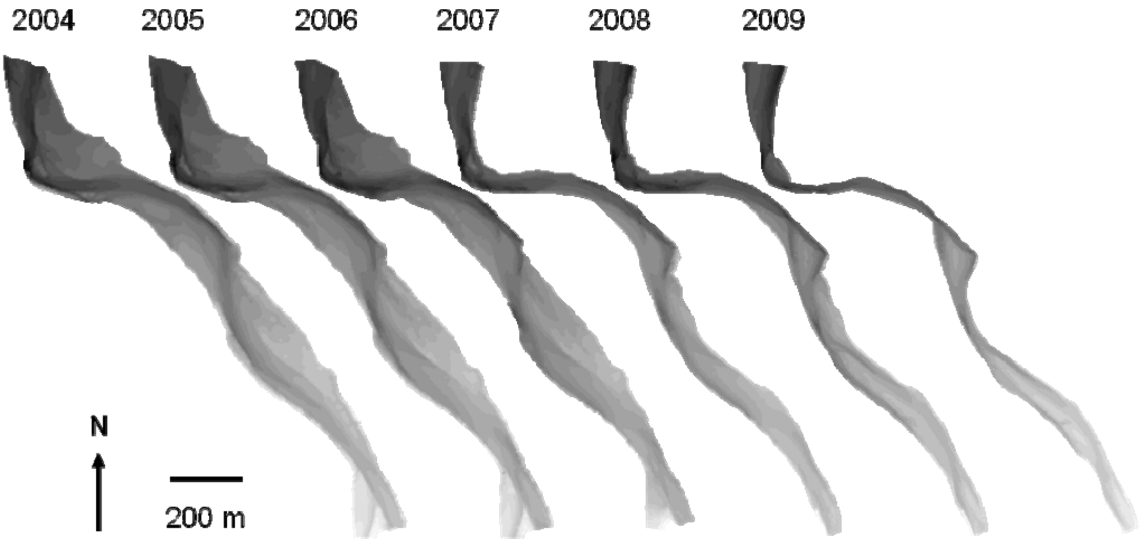
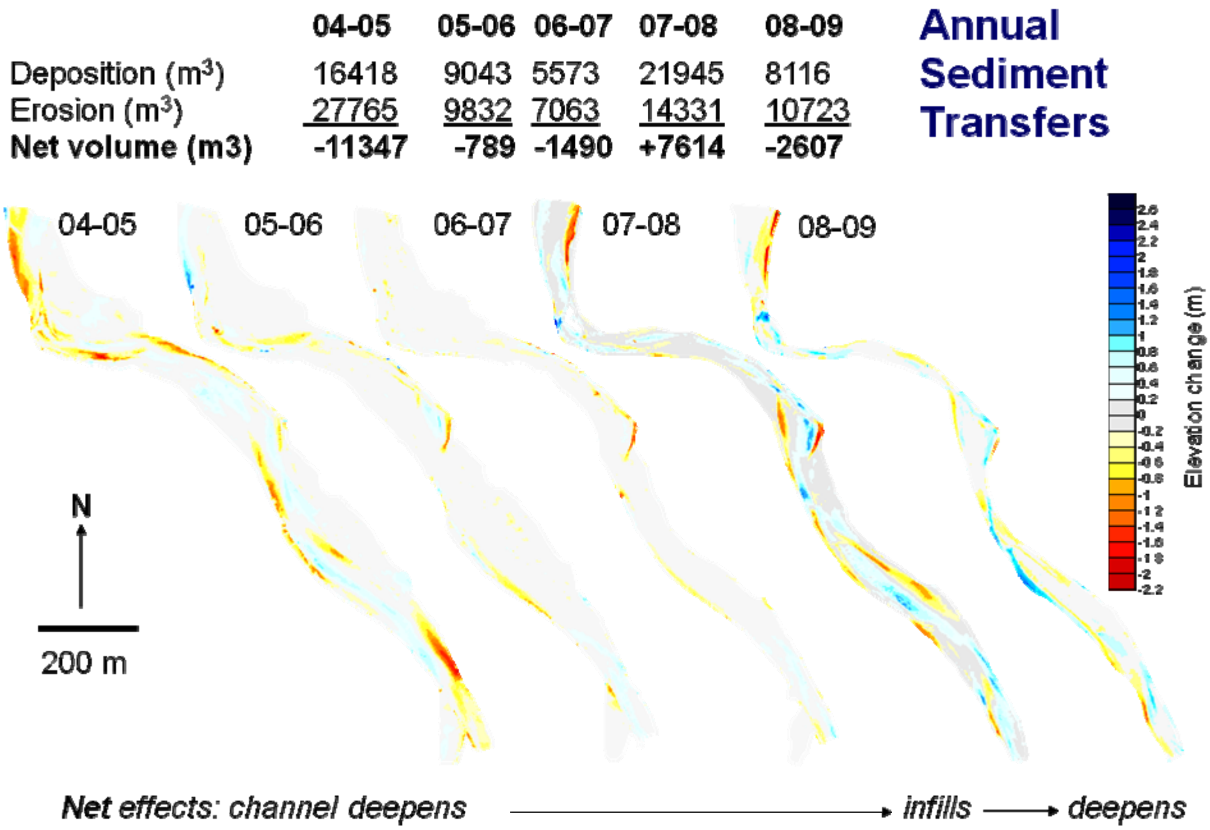


Figure 3.17. DEMs of the Three Beaches reach, upper Motueka



	04-05	05-06	06-07	07-08	08-09
Deposition (m^3)	16418	9043	5573	21945	8116
Erosion (m^3)	27765	9832	7063	14331	10723
Net volume (m3)	**-11347**	**-789**	**-1490**	**+7614**	**-2607**

Figure 3.18. DEMs of difference showing locations of scour and filling of the active channel between 2004-2009. Volumes of sediment are derived from morphological budgeting (volumes of net gains and losses).

33. The Motueka active channel at Three Beaches has overall degraded its bed via scour between 2004-2009. This is a product of having constrained the channel laterally. Stream energy is focused on the mobile bed since banks are hardened by rock work or protected by willow planting. This net loss of bedload calibre sediment from the reach is exported to reaches downstream, where the effect is unquantified to date using the methodology described here, although Tasman District Council mean bed levels indicate a degradational trend is evident throughout the upper Motueka.

4. Recommendations

1. River management practice has demonstrably resulted in narrowing of the river channels and reduction in diversity of morphological assemblages within the reaches discussed in this evidence. This has resulted in change in the character of rivers from multi-threaded systems to single thread channels.

2. The main drivers of the changes observed in the rivers contributing to this evidence can be attributed to both natural and human factors. The natural processes of sediment transfer through the system are now operating within disequilibrium, narrowed channels, resulting in bed scour in many such reaches and commensurate undermining of many bank protection structures.

3. The degradation of morphological diversity in the reaches referred to in this evidence means that the assemblage of morphological units is not adjusted to the flow and sediment supply and boundary conditions within these catchments. These reaches do not display the natural character of the river under the prevailing climate-vegetation conditions. The current channel planforms are not sustainable within the present sediment and flow regimes.

4. Tasman District Council have imposed a zero extraction limit on gravel extraction from the upper Motueka due to the bed degradational trends. Gravel extraction must be sustainable if natural character is to be maintained. TDC are concerned that bed degradation is linked with unsustainable extraction of gravel from the Motueka. Bed degradation is certainly symptomatic of a reduction in sediment supply within a river system.

5. Furthermore, bed degradation reduces the connectivity between channel and floodplain and may enhance the scale of bank erosion in the reach because the channel becomes confined in a narrower, overdeepened cross section. Flood flows become confined between banks instead of dispersing across floodplains, exacerbating bank erosion, particularly on the outside of bends. I identified the role of channel confinement in the behaviour in the Kiwitea during the February 2004 storm (Fuller 2008). This research indicated that over-narrowed channels were especially adversely affected by this 100 year ARI event, marked by catastrophic channel widening in response to this event.

6. Prospects for success in river rehabilitation are enhanced when causes rather than symptoms of degradation are addressed (Brierley *et al*., 2008). Brierley *et al.* (2008) recognise that to achieve this requires an understanding of key controls on functionality for any given system, combined with, “meaningful and integrative assessments of river condition” (p.276). Thus to succeed in rehabilitating straightened and degraded reaches requires a recognition and understanding of the processes contributing to channel form in a given reach. Furthermore, each system should be understood within a historic framework, recognising that channel form and morphological assemblages adjust over time, including adjustment to management.

7. I would recommend that prior to river works being undertaken the natural character of the river be determined, since this is the planform and assemblage of morphological units within a reach which is adjusted to the sediment and flow regime within a catchment. In light of this recommendation, I support the amendment to Method 6.9, which states the requirement to define the state of natural character of a river by analysing habitat and morphological diversity.

8. In a previous report for Horizons Regional Council (2007/EXT/773) I recommend the following approach: Historic changes in exposed riverine sediment (ERS) (i.e. barforms and channels within the active channel) would provide valuable information on changes taking place in the region’s rivers over the last ~50 years. This provides context for the present channel configurations and any future changes (engineered or natural). Current ERS and river planform should be mapped from the most recent aerial photography. Linking geomorphic appraisal to ERS assessment would provide information on the relationships between ERS and morphological diversity. Re-mapping should take place at regular intervals, requiring a commitment to re-fly aerial photography of key reaches over the coming years. There should also be flexibility to acquire imagery in the aftermath of extreme events. Imagery should ideally be supplied rectified in digital format for use in GIS. Some investment will be needed to convert archive aerial photography to this format for analysis.

9. I note that in the HRC Code of Practice reference is made to maintaining sinuosity within a reach. However, as I indicated in 2007/EXT/773, maintaining sinuosity *per se* may not be desirable or effective in wandering rivers, which are naturally avulsive (Fuller *et al*. 2003). Habitat diversity may be better maximised by taking a holistic approach to assessing channel morphology, characterising reaches by taking into account variables such as sinuosity, channel bifurcation, nature of barforms, degree of entrenchment, gradient and sediment type. To this effect I agree with the evidence (paragraph 56) of Gary Williams in which an approach to reach characterisation is set out in terms of recognising key processes and channel form.

10. I also note that reference is made to maintaining the present pool-pool spacing / frequency in the HRC Code of Practice. However, again I recommend a more holistic approach. Protection and management of broader river corridors within which the river migrates and / or avulses provides for the maintenance of more natural river morphologies in the region which will ultimately be a state of equilibrium with natural sediment and flow regimes.

11. River channels which have adjusted to an equilibrium form within their framework of sediment and flow regime should not be considered to be absolutely stable. Stability is relative and natural systems are dynamic, responding to discrete flood events in particular. Well-adjusted river systems are best understood as operating within a dynamic equilibrium. Intervention, such as bank stabilisation will have a knock-on effect elsewhere in the system, such as facilitating scour at the stabilised bank, since river energy previously expended in bank erosion is now directed at the bed. Even straightened reaches have the propensity to rebel against their straightjacket, as referred to in the evidence of Gary Williams in paragraph 24 in connection with breakouts on the sections of the Rangitikei. This raises the point that adjustment normally takes place during flood events, when most geomorphic work is undertaken by river systems (Fuller, 2007). The larger the flood, the greater potential for geomorphic work in the form of sediment transport and erosion.

12. I recommend a more expansive and inclusive approach to river works and management, since success in river management is dependent upon clear, systematic and organised conceptualisation of river systems (Brierley & Fryirs 2008). I agree with Brierley and Fryirs (2008) in their recommendation of an integrative river science approach, which they define as, “holistic, cross-disciplinary analysis of aquatic ecosystems that integrates physical and ecological integrity as a platform to analyse controls upon ecosystem integrity.” (Brierley & Fryirs, 2008, p.9). This is in accord with RAMSAR’s definition of ecological character as, “*the structure and inter relationships between the biological, chemical and physical components of the wetland…These derive from the interactions of individual processes, functions, attributes and values of the ecosystem*”. Integrative river management should therefore be adopted by the One Plan and espoused in the ECOP.

13. Holistic understanding of geomorphic processes and their direction of change should underpin any river rehabilitation (Brierley & Fryirs, 2005), or any future river management in the region. This requires that the natural characteristics of a river and the channel forming variables conditioning river behaviour (past, present and future) be understood for each discrete reach. This is best met by undertaking research into catchment and river behaviour to better understand the dynamics of the system. I therefore recommend that river management be informed by research into channel dynamics. This includes gravel extraction, which should be sustainable, within limits understood by research into gravel supplies and transport within a catchment.

14. If natural character is to inform river management and river management is to be truly integrative, no reach of river should be permanently straightened.

15. In the light of my evidence and these recommendations I offer comment on Section 1.2 *Morphological Characteristics* of the Environment Code of Practice. The suggestion that the set of morphological characteristics identified should be maintained is to recommend maintaining unnatural, disequilibrium reaches. This is not in accord with recognising the natural character of these reaches.

16. As measures adopted to monitor river character I agree with the morphological indicators identified, namely pool & riffle spacing and frequency, sinuosity, braiding and channel widths. However, I refer to paragraphs 8-10 above and recommend a fully integrated geomorphic appraisal approach be adopted in connection with additional measurement of ERS.

17. Reference to a ‘significant shortage’ or reduction in the parameters being considered is being made with reference to already degraded channels.

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