Technical Report
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A Geomorphic Interpretation of the Orari – Waihi – Temuka – And Opihi River Floodplains

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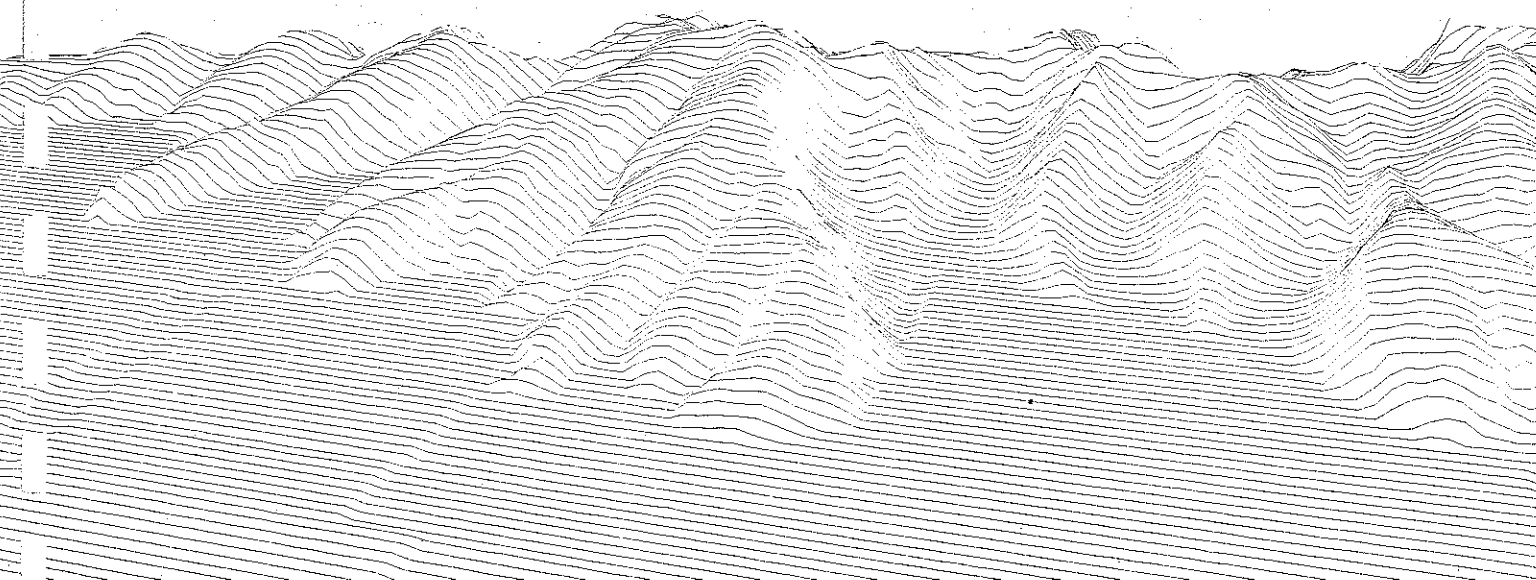

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1. Summary

1.1 Project and Client

Landcare Research, Lincoln undertook an aerial photograph interpretation-based assessment of the Late Quaternary and present day geomorphic setting of the Orari, Waihi, Temuka, and lower Opihi river floodplains for the Canterbury Regional Council in 1997.

1.2 Objectives

- Define the geomorphic characteristics of the Orari, Waihi, Temuka, and lower Opihi river floodplains.
- Prepare a detailed geomorphic map (scale 1:25 000) in hard copy and digital format and a report detailing the geomorphology of the Orari, Waihi, Temuka, and lower Opihi river floodplain area and the potential influence of the geomorphology on future flood flows.

1.3 Main findings

The coalescing floodplains and older alluvial fan surfaces of the Orari, Waihi, Temuka, and lower Opihi rivers form the Canterbury Plains south of the Rangitata river. These rivers whose headwaters extend only a short distance into the mountains, are weakly incised into their fan heads and flow on the surface of their fans from the mountain front to the sea. Along their courses they are confined between low boundary banks. Consequently, overbank flood discharge may occur over considerable stretches of river.

Fan surfaces away from the rivers have considerable areas with textural features that indicate abandoned river channels, and overbank discharge. These are especially conspicuous in the middle reaches where gradients are relatively steep and where abandoned channels are incised into coarse gravelly alluvium. However, such features are often subtle in the lower reaches, especially east of SH 1, where gradients are less and where subsequent fine overbank deposits or agricultural activities have buried and masked former channels.

Potential avulsion zones include:

- Coopers Creek, which exits the Orari River 3.5 km above SH 72 bridge and rejoins the Orari 6 km from the sea.
- The channel which exits the Orari near the SH 72 bridge and links the Orari, Waihi, and Temuka Rivers with the Opihi River system.
- Channels which exit the Tengawai River and direct flood waters through the Pleasant Point township.
- A channel which exits the Opihi River near Roaring Camp Road and which can be traced to the coast.

Barriers to potential flood flows include:

- The embankment of the Main South railway line.
- State Highways 1 and 8, and a number of bridge approaches.
- The coastal sea wall stretching north from the Washdyke lagoon to the Opihi River mouth.
- The sea wall parallelling the coast from the Opihi to Orari River mouth.

Areas of impeded drainage and former swampland in low lying flood basins and potential ponding areas were also identified, predominantly in the lower reaches of the Orari and Opihi Rivers and along the coastal margin.

1.4 Recommendations for further work

- **Orari-Waihi-Temuka avulsion channel entrance**
  Priority should be given to more detailed geomorphic mapping of the area surrounding the entrance to the Orari-Waihi-Temuka avulsion channel.

- **Tengawai River, Pleasant Point, and the Tengawai / Opihi confluence**
  Channel activity and bed level dynamics should be closely monitored and managed in the reach from west of Chisholms Ford to the eastern boundary of the Hammonds Road relict channel.

- **Coopers Creek diversion channel entrance**
  The ability of the entrance to operate as proposed requires careful monitoring.

- **Temuka River**
  Distributary channels identified aerial photographs should be investigated on the ground.

2. Introduction

Landcare Research, Lincoln undertook an aerial photograph interpretation-based assessment of the Late Quaternary and present day geomorphic setting of the Orari, Waihi, Temuka, and lower Opihi river floodplains as background for flood risk analysis by the Canterbury Regional Council in 1997.

3. Background

Geomorphic floodplain studies are a rapid and cost effective means of identifying areas that may be prone to flooding. As part of the Canterbury Regional Council's (CRC) flood hazard investigation programme, a detailed geomorphic study of the Orari, Waihi, Temuka, and lower Opihi River (OWTO) floodplain area was commissioned. The information will be used to :

- verify flood hazard computer modelling work that has already been completed by the CRC;
- identify areas requiring further more detailed flood hazard analysis.

Although it is a stand alone qualitative flood hazard assessment, this reconnaissance study is not a substitute for detailed planning or site specific investigations.

4. Objectives

- Define the geomorphic characteristics of the Orari, Waihi, Temuka, and lower Opihi river floodplains.
- Prepare a detailed geomorphic map (scale 1:25 000) in hard copy and digital format and a report detailing the geomorphology of the Orari, Waihi, Temuka, and lower Opihi river floodplain and the potential influence of the geomorphology on future flood flows.

5. The Study Area

The study area includes the floodplains of the Orari, Waihi, Temuka, and lower Opihi rivers which form the Canterbury Plains south of the Rangitata River (Fig. 1). The Canterbury Plains comprise major coalescing alluvial fans covering some 8000 km^2 lying between the eastern foothills of the Southern Alps and the Pacific Ocean (Haast 1864, Wilson 1985, Fitzharris *et al.* 1992). The major river systems, the Rangitata, Ashburton, Rakaia, and Waimakariri, originate along the main divide, from where their flow and sedimentation regimes are strongly controlled by precipitation events. During successive glaciations their glaciers supplied the debris from which the plains have largely been constructed. The higher parts of the Plains are formed by outwash of early glacial advances while the distal parts of the fans constructed during those advances were buried by later deposits of outwash gravel. During interglacial periods, when ice receded and sea levels rose, the rivers incised into the fans. Gravels removed during these periods were redeposited along the seaward edge of the Plains, interfingering with marine deposits in interglacial periods of high sea level (Brown and Wilson 1988). The major rivers are incised into their fans near the mountain front and emerge onto the surface of the Plains in a zone of minimal erosion (Leckie 1994). In contrast, the headwaters of the smaller rivers e.g., Ashley, Selwyn, Hinds, Orari, Waihi, and Opihi extend only a short distance into the mountains. These rivers experienced limited glaciation, occupy depressions or margins of the main fans forming the Plains, and are weakly incised, or flow on their fan surfaces from the mountain front to the sea.

This study covered the series of small rivers from the Orari to the Opihi. The north-east boundary of the study area is formed by the intersection of younger deposits from the Orari River onlapping older deposits of the Rangitata River fan. The study area is bounded to the north-west by the eastern foothills and fringing downlands, to the south-west by the South Canterbury downlands and to the south-east by the Pacific Ocean.

The Orari River rises in the eastern front ranges and foothills. The upper catchment is underlain by indurated sandstones and siltstones of the Torlesse Supergroup. The catchment downstream of Silverton, is composed of unconsolidated Burnham aged glaciofluvial outwash sediments, recent alluvium and swamp deposits (Gair 1967).

The headwaters of the Waihi, Hae Hae Te Moana and Kakahu Rivers are also underlain by Torlesse Supergroup rocks. Their middle reaches drain considerable areas of Cretaceous-Tertiary aged weakly indurated sandstone, siltstone and mudstone, and limestone. The lower floodplains comprise unconsolidated Burnham aged alluvium, with recent alluvium and swamp deposits. The Waihi River joins the Hae Hae Te Moana River to form the Temuka River at the northern end of Temuka settlement. The Kakahu River enters the Hae Hae Te Moana 5.5 km above this confluence. The Temuka River flows to the west and south of Temuka settlement and discharges into the Opihi River.

The lower catchment of the Orari and adjoining coalescing Waihi and Temuka Rivers form the geomorphically active 'Orari fan' extending from Clandeboye in the north to Temuka in the south. An 1849 map by Torlesse, [Torlesse (1849), cited in Raeside *et. al.* (1959), Williams (1968), and Connell (1993)], showed the Orari River, (named Umukaha), joining the Waihi-Temuka River system north-west of the present township of Winchester. Williams (1968) states that "prior to pakeha settlement, about 1852, the Orari left the Temuka system and carved out a new, 17.7 km course to the sea."

The southern sector of the study area is the lower floodplain of the Opihi River which rises in the Hunter Hills and Two Thumb Range. The upper catchment is underlain by Torlesse Supergroup rocks, the middle reaches by Cretaceous-Tertiary sediments, and the lower plain by outwash sediments, recent alluvium and swamp deposits. Recent alluvium, swamp and estuarine deposits occupy former channels of both the Orari and Opihi Rivers along the coastal margin.

6. Methods

- We searched library databases using the SCITEC index on Kiwinet, the catalogue of Crown Research Institute libraries, the New Zealand bibliographic network and a NIWA in-house database.
- We under took detailed mapping of the floodplain and geomorphic changes in the active river bed systems from aerial photograph analyses.
- We undertook limited field investigations to verify aerial photograph interpretation and to map any other significant additional features.
- We prepared an appropriate classification of geomorphic features based on existing information, air photograph interpretation and field work.

6.1 Mapping procedure

Mapping involved detailed aerial photograph interpretation of river beds (21 km^2), floodplains (209 km^2) and older geomorphic surfaces within the 568 km^2 study area (Fig.1). Previous flood breakout paths and abandoned river courses that carried flood flows were identified. Some of the latter are also potential avulsion channels. Higher older fan surfaces were studied in less detail. The Sweetwater Creek tributary of the Orari River was not assessed.

The study area is covered by NZMS 260 series 1:50 000 topographic map sheets J37 Mount Peel, J38 Geraldine, J39/K39 Timaru, K37 Hinds, and K38 Temuka. Topographic bases on which our data is compiled are the 1:25 000 scale NZMS 270 series Topoplot sheets J37 B; J38 B, D; J39 B/K39 A; K37 A; K38 A, and C (Fig.1).

Details of the aerial photographs used in the study sourced from New Zealand Aerial Mapping and the South Canterbury Catchment Board archives, (now CRC), are given in Appendix 13.1.

The location of river control structures plotted on enlargements of the South Canterbury Catchment Board river flights (SN 38, 103A and C) were provided to the consultant by the CRC.

Information from interpretation of aerial photographs was compiled on to the 1:15 840 scale semi-controlled mosaics to provide an overview and then transferred manually onto the 1:25 000 scale transparent topoplots.

The river bed and floodplains have been divided into geomorphic mapping units. Each unit is characterised by the perceived level of flood risk when compared to adjacent units. Linear features such as stopbanks, terrace risers, road, or rail embankments were mapped where these function as actual or potential barriers to flood flow.

6.2 Constraints to mapping

The length of channel assessed and the area of floodplain evaluated were limited by the resources available. Recommendations for more detailed work are included in this report.

The 1:25 000 scale topoplot base data was compiled from 1977, 1978, and 1986 aerial photographs. Since the time of field checking of the topoplot base data by the Department of Survey and Land Information, (Appendix 13.1), some major engineering works and structures have been built, relocated, or removed e.g., the oxidation ponds at Temuka and Geraldine, and stopbanks at K37/718823. Every effort was made to identify variations in the location of structures as indicated on the topoplot base maps, and to record 'new' features where present.

The length of channel ways and fairways and their positions were taken as those shown on the topoplot base maps with limited modifications where major changes have taken place e.g., the Temuka-Opihi and Tengawai-Opihi confluences. All topoplot base map photography predates the 13 March 1986 flood event.

We undertook limited field checking and confirmed that the aerial photograph interpretation was of a high standard although significantly more field input would be required to verify all mapped features. The availability of high quality aerial photographs at different scales and a range of ages and seasons enabled the main geomorphic features of the floodplains to be identified within the terms of the study brief.

7. Review of Available Information

Little scientific information has been published on the geomorphology of the OWTO floodplain area. Our searches identified 64 articles. Most were documents by the South Canterbury Catchment Board and Region Water Board and dealt with water resources, low flow conditions and in-stream values. Sheriff and Evans (1986) depict generalised flood hazard maps at 1:50 000 which include the area. Connell reviewed the flood hazard posed by the Orari, Waihi, Temuka, and Opihi Rivers in a series of flood plain management studies and discussion documents (Connell 1988, 1990, 1991, 1992, 1993). Stopbank overtopping, breaching, outflanking and lateral bank erosion at high discharges were identified as the major sources of flood water delivery to the adjacent countryside. He also considered that there were some areas on all river systems that were vulnerable to lateral bank erosion and therefore at risk of flooding at lower discharges. No publications specifically addressed geomorphic aspects of flood hazard, or the imprint of flooding on the landscape.

7.1 Quaternary geology and geomorphology

Geological mapping at 1:250 000 scale (Gair 1967) distinguished 'Burnham aged' glaciofluvial outwash sediments over most of the study area. Undifferentiated alluvium swamp and beach deposits are mapped adjacent to the main river channels, including the abandoned Orari-Waihi-Temuka channel, and the northern half of the Levels Plain (Gair 1967, Wellman 1953). No surface or subsurface materials from the area have been dated and all age designations are based on correlation with dated sections outside the area. Discrepancies exist with adjoining 1:250 000 mapping (Sheet 21, Suggate 1973) where the Holocene Springston Formation is extensively mapped on younger surfaces. No Springston Formation is mapped in the study area. Barrell *et al.* (1996) map Rangitata fan surface ages which they equate to Springston and younger Burnham Formations ('RG2'), and older Burnham deposits ('RG3', and 'RG4'), and Windwhistle

Formation ('RG5). Orari fan surfaces are not differentiated by Barrell *et al.* (1996) but onlap 'RG3', 'RG4' and 'RG5' surfaces.

Leckie's 1994 synthesis of the current geomorphology of the Canterbury Plains indicates the presence of a 'zone of minimal erosion' separating landward and seaward zones of river valley incision (Fig. 2). He postulates that river valley incision is driven by tectonic and isostatic uplift in the west and coastal retreat in the east. A southeastern extension of the concept of a 'zone of minimal erosion' would coincide with where the rivers of the OWTO floodplain are weakly incised or flowing on their fan surfaces with low channel banks, although these rivers are not incised in their lower reaches.

7.2 Soils

The study area is covered by reconnaissance soil mapping (Kear *et al.* 1967, Raeside *et al.* 1959). The Levels Plain area has been recently reassessed and the maps of Kear *et al.* (1967) were 'upgraded' where new information was available (Landcare Research unpublished data, Webb *pers. comm.*). The relationships between soils and inferred ages of underlying deposits can be used to further refine the relative age of the geomorphic surfaces. Basher *et al.* (1988) summarised the relationships between soil age groups and geological formations for the more intensively studied lower Waimakariri River floodplain (Table 1). Such correlations would be expected to broadly hold for the OWTO floodplain. Yellow-grey earth Lismore-age soils (>14 000 yrs) are mapped on the Burnham Formation, with Templeton-age soils (recent yellow-grey earth intergrades) mapped on intermediate aged deposits, (3 000 to 10 000 yrs). Waimakariri-age soils are formed on low terraces that are generally above the limit of present flooding on 700-900 to 2400-year-old deposits. On the OWTO floodplain the Waimakariri-age soils were NOT differentiated from the younger Selwyn-age soils in the reconnaissance soil mapping. Selwyn-age soils comprise very weakly developed recent soils on low terraces barely above the present floodplain. They have formed within the last 300 years and include those mapped as Selwyn soils and some mapped as Kaiapoi and Taitapu soils. Recent work that has differentiated Selwyn-age soils has been incorporated where available.

Inconsistencies exist between the ages of mapped Quaternary deposits and the soils and soil patterns that are formed on them, especially on land adjacent to some of the smaller rivers, such as the Opihi, (Webb 1996). Frequently only small areas of post-glacial alluvium and recent soils are associated with the younger river channels or former overflow channels.

In spite of the limitations and lack of precision outlined above, the soil pattern mapped on the OWTO floodplain provides an illustration of its flood history and is a valuable tool in the understanding of its geomorphic history (Fig. 2).

7.3 River characteristics

7.3.1 Hydrology and flood history

Connell (1991) analyses the hydrology of the Orari, Waihi, Temuka and Opihi Rivers, and their flood discharge characteristics are summarised below:

River	Return Period (yrs)		Discharge (m^3/s)	
Orari*	50 yrs		1083	
	100		1252	
		above Geraldine	at Geraldine	at Te Awa
Waihi*	50	200	278	316
	100	232	322	366
Temuka*	50		1166	
	100		1378	
		Saleyard Bridge	at mouth	
Opihi†	50	2700	3500	
	100	3170	4100	

† from Connell 1992, *from Connell 1993.

Since European settlement, significant floods have been recorded on all river systems (Geraldine County Council 1927, Davey 1952, Soil Conservation and Rivers Control Council 1957, Williams 1968, Connell 1991, 1993). Major events include:

1852 - The Orari River diverted from the Waihi-Temuka system and established a 'new' course to the sea (referred to by Williams 1968).

1868 - The Orari River nearly washed away the Orari Gorge homestead on 3 February (Acland 1930); flooding badly affected Temuka and the lower country in general (Geraldine County Council 1927, Davey 1952). In Temuka the water was level with the bar counters in the Crown and Royal Hotels. The Waihi is reported to have risen 17 feet and 'spread out over a great deal of country the appearance of which more resembled a sea than land'.

1871 - The Orari River overflowed its banks and flooded all land south the of river between the railway and the sea (Connell 1991).

1902 - In March, extensive damage to roads and bridges was reported to be 'no doubt nearly as heavy as the record flood of 1868..'. The Orari River overflowed west of Winchester into the Waihi-Temuka system (Davey 1952 p 66). By this time river training works were in place at the Rolleston Road and the main road bridge. The county engineers recognised in retrospect that aggradation upstream from the main road bridge (SH 1) as far as the upper bridge (SH 72) was excessive (2 feet in 5 years at the main road bridge).

1911 - Heavy flood recorded, no data.

1924 - One pier subsided on the Orari River traffic bridge on 27 December (SCRCC 1957).

1925 - The upper Orari River bridge lost one span on 2 July and the Opihi River was in high flood (SCRCC 1957).

1929 - The Opihi River flooded Temuka and Arowhenua.

1930 - On 15 January the Orari River was high and land was flooded.

1940 - The Orari River overflowed and flooded large areas of land on 7 May (SCRCC 1957).

1941 - In March, the Orari River was in heavy flood.

1945 - Widespread flooding, worse than 1902 event occurred from 20-21 February. Floods affected Geraldine and Temuka settlements, and the northern half of Levels Plain. The Orari River overspilled southwards at several points and flowed into the Waihi watershed.

1945 - The Orari River overflowed at Orari bridge on 5 December.

1946 - The Opihi River overtopped stopbanks at Saleyards Bridge, and flooded farmland.

1950 - The Orari River overflowed stopbanks in Clandeboye area on 21 August.

1951 - The Orari River broke its banks at Clandeboye on 23 January and flooded large areas of farm land.

1951 - Widespread flooding of similar dimensions to the 1945 event occurred on 17 April. Orari River submerged Clandeboye and Milford areas under several feet of water. Some paddocks were left with thick layers of silt and /or heaps of gravel (Davey 1952). Northern half of Levels Plain flooded.

1952 - The Orari River stopbanks overtopped from Badhams Bridge to mouth, and on the north bank from Coopers Creek junction, Clandeboye flooded on 8 November, the upper Opihi River flooded.

1957 - The highest flow since 1951 in the Orari River several overflows in unprotected reaches occurred on 20 May.

1961 - The Opihi River broke out above Saleyard Bridge and flooded the Pleasant Point flooded the northern half of Levels Plain.

1972 - Major stopbanks were constructed in the 1970s on the Opihi river system. The stopbanks were designed to handle the 50 year return period flood.

1975 - Orari-Waihi-Temuka scheme was severely damaged at Coopers Creek entrance.

1986 - On 13 March, 37 km^2 of the Levels Plain was flooded, [up to 45 km^2 in the 1945 event], including Pleasant Point, Waipopo Huts, Waihi farmland, Temuka industrial area and Milford Huts.

1994 - On 19 March, the Temuka River flooded from upstream of the Opihi / Temuka confluence, 5 km^2 near Milford affected.

1997 - On 6 February, a flood wave came down the Opihi River from the breached Opuha dam while under construction.

The frequency of major floods is high in all seasons, with most flood breakouts occurring in the mid or lower reaches of the river systems.

River management has significantly changed local river gradients and centres of erosion and deposition by constricting and shortening river channels. Major localised works were undertaken on the Orari and Opihi during the 1880s mainly in association with bridge construction (Davey 1952). Major construction of the Orari-Waihi-Temuka River flood control scheme was initiated in 1954 and largely completed by 1968 (Williams 1968, see below). Small scattered control works existed on the Opihi prior to 1945. The construction of a 'stopgap' control scheme was initiated in December 1951 in response to the April 1951 floods (Herd and Powell 1964). Major stopbanks designed to handle the 50 year return period flood were constructed on the Opihi in the 1970s (Herd and Powell 1964, Connell 1992). Consequently in many places the natural, unstable, wide, braided channel morphology of these systems has been reduced to a single thread.

No bed level data were available for this study, but the results of recent bed level surveys of the Orari are currently undergoing analysis (Connell *pers. comm.*). Bed level aggradation has been recognised as a problem in the Orari since 1902 (Davey 1952). Bed level data are critical for the identification of potential breakout points and avulsion zones especially on the Orari and Opihi Rivers.

7.3.2 The Orari-Waihi-Temuka flood control scheme (Williams 1968)

The design flood for this scheme is 1260 m^3/s at the lower Orari River gorge. The design is for 250 m^3/s to be diverted northwards down the Coopers Creek channel with the remaining 1010 m^3/s, plus 28 m^3/s, from Sweetwater Creek diverted down a 180-m wide fairway to SH 1. The fairway has been gradually narrowed to 100 m through the aggraded reaches below SH 1 and was to be progressively restricted by training works, poplars and willows to form a 100-m fairway from Coopers Creek to the sea. Coopers Creek and Ohapi Creek on the southern bank join the Orari 6 km and 1.5 km from the sea respectively. The designers considered flood peaks on these lower velocity tributaries unlikely to coincide with those of the Orari, and provision was made to discharge 1260 m^3/s at the mouth. A straight 1.6-km diversion at the mouth by-passes the former lagoon and is designed to transport of gravel to the sea.

Stopbanks were to have a 600-mm freeboard above the design flood. On the south bank above SH 1 this was to be increased to 760 mm. A freeboard of 300 mm was to be present on the north bank from the spillway to Coopers Creek confluence, to allow preferential flooding of the north bank area. By 31 March 1968, degradation in the Orari was evident below SH 1, with aggradation on the lower reach berms. The Waihi, Temuka and north bank of the Opihi Rivers were stop banked for 50-year return period floods.

7.4 Implications of the literature review

The literature review has established the geomorphic background of the study area. The area is an active and dynamic depositional environment. The rivers are weakly incised or flow on their fan surfaces with low or non-existent bounding banks over much of their length. Flood frequency is high with flooding by stopbank overtopping, breaching, outflanking and lateral bank erosion at high discharges, and by lateral bank erosion causing breaching at lower discharges. Human intervention has significantly changed local river gradients and centres of erosion and deposition by constricting and shortening river channels. Consequently, in many places the natural, unstable, wide braided channel morphology of these systems has been reduced to a single thread which may well be out of equilibrium with the current geomorphic conditions. The extensive modifications and prevailing natural conditions must be considered when identifying and interpreting geomorphic features through aerial photograph interpretation or field observation on the OWTO floodplain.

Soils provide a stratigraphic record of depositional events and alteration of alluvial deposits through time by soil forming processes. In this depositional environment soils can be used to interpret recent geomorphic history by providing a relative index of flood vulnerability.

Combinations of surface geomorphic expression, surface materials, relative soil development, and recorded flood water paths were therefore used to establish the geomorphic mapping units.

8. Map Key

Based on existing information, aerial photograph interpretation and field work, the geomorphic features of the OWTO floodplain were classified and mapped. The map key has been based on McPherson (1997). This has helped to provide a consistent regional approach. Mapping units are listed in the Map Key in order of their proneness to flooding considering their position in the landscape and relative elevation with respect to the fairway. Map unit A1 is the 'first-to-flood', succeeded by A2 to A4. Within the confines of the boundary banks, where present, floods could be expected to spread out to occupy the potential width of the floodplain to include unit B1. Flows which peak above the capacity of the boundary banks will lead to overbank discharge, or even to avulsion of the river course.

A - FLOODPLAIN UNITS WITHIN THE RIVER CONTROL SCHEME

Fairway

1 - Low flow stream channels containing non-vegetated gravel and shingle. The river bed where sediment is actively transported downstream. The first area to submerge under flood conditions.

Vegetated Berms (established for flood control)

2 - Vegetated berms, flood protection trees (willows, poplars) and minor scrub.
3 - Vegetated berms, dense scrub (gorse, broom etc.) with grass, minor tree cover.
4 - Vegetated berms, mixed trees, scrub, or grass cover.

River Control Works

5 - Stopbanks (where constructed).

B - REMAINDER OF FLOODPLAIN

1 - Pasture or cropped areas of river bed and low degradation terraces marginally higher than the fairway, lying within or outside of the River Control Scheme.

C - BOUNDARY BANK

1 - A terrace riser which marks the outer limits of the current floodplain and will be overtopped if discharge exceeds 'bank full' capacity of the floodplain below.

D - OVERBANK UNITS

1 - Abandoned river courses, some of which are potential routes for avulsion from the present river system.
2 - Flood discharge imprints:
(a) - Weaker imprint, probably late Holocene to historic in age;
(b) - Stronger imprint, probably late Holocene to historic in age;
(c) - Relict channelling, on 'Burnham-age' surfaces.
3 - Former swamps or areas of impeded drainage.

E - SUBORDINATE MAPPING UNITS

1 - Downland.
2 - Minor fans.

F - OTHER SYMBOLS

1 - Stream.

2a - Fluvially cut edge (terrace riser).

2b - Degraded, discontinuous or uncertain terrace riser.

3a - Well defined boundary to mapping unit (readily apparent from aerial photograph interpretation and field observation).

3b - Less well defined boundary to mapping unit (e.g., masked by younger deposits, destroyed by farming practises etc.).

4 - Directions either of flood flow or depositional slope.

5 - Road, rail or other embankment which may form a potential barrier to flood flow.

6 - Oxidation ponds.

7 - Estuary, or former estuary as indicated by saline gley recent soils.

9. Findings

9.1 Overview

Aerial photograph interpretation of the fan surfaces away from the rivers shows considerable areas with textural features that indicate abandoned river courses, channel ways, and overbank discharge. These are especially conspicuous in the middle reaches where gradients are relatively steep and where abandoned channels are incised into coarse gravelly alluvium. However, such features are often subtle in the lower reaches, especially east of SH 1, where gradients are less and where subsequent fine overbank deposits or agricultural activities have buried and masked former channels. Detailed analyses with intensive field investigation, beyond the scope of this study, would be required to accurately delineate former channels and flow directions in this terrain. Areas of impeded drainage and former swamp land in low lying flood basins are detected from darker tones on aerial photographs. Such features have not been comprehensively mapped because of resource constraints and the effects of drainage activities especially around the margins. Detailed interpretation of the soil pattern, soil stratigraphy and profile characteristics indicative of present and past drainage characteristics would provide a more accurate delineation of these former and potential flood basin areas.

9.2 Orari River floodplain

On exiting the mountain front at Orari Gorge (J37/635952) the river is entrenched about 10-15 m below the north bank by a prominent terrace riser that gradually reduces to be intersected by river protection works at J37/697880. The former 500-1500 m wide floodplain is restricted by stop banking from J37/688923 which parallels Silverton Road to the Coopers Creek overflow channel entrance.

9.2.1 Coopers Creek

Coopers Creek, a former northern course and potential avulsion channel of the Orari River, exits the present course 3.5 km above SH 72 bridge. The channel is well defined over most of its length and rejoins the Orari 6 km from the sea. It is spring fed in the upper reaches and collects surface water from the Rangitata fan, most of which is lost to groundwater by seepage. Recent shallow and stony Waimakariri-aged soils are mapped along its upper reaches although considerable areas of Selwyn-aged soils are also present. The north eastern bank displays a channel bank varying from 1-2-m high over considerable lengths predominantly west of SH 1. In other areas there is a subtle sedimentary onlap boundary with the Lismore-aged surface. Lower reaches of the channel present a more subtle geomorphic imprint and are mapped with Recent poorly drained Kaiapoi and Taitapu soils.

Coopers Creek has been designated as a flood diversion channel (capacity 250 m^3/s) as part of the Orari-Waihi-Temuka river control scheme (Williams 1968). It would be readily re-occupied by flood waters following river aggradation or destruction of the control works (which were severely damaged by floods in 1975). The overflow channel and current river course are separated by a subtle bounding bank from the end of the control works at K37/702869 to K37/708858 which is crossed by a strong discharge imprint. Weaker discharge imprints exit the river to K37/710845 and downstream of the SH 72 bridge. In the Palmers Road area K37/735810, discharge imprints indicate the return of some floodwater from Coopers Creek to the Orari channel.

A major problem with the operation of Coopers Creek as a flood diversion channel is presented by the elevated embankment of the Main South railway line between K38/748758 and 755775. The embankment which is 3-4 m-high in places, crosses the flow direction at an acute angle and has culverts which would struggle to handle 250 m^3/s. Flood flows would be diverted in a south-westerly direction to be impounded behind stopbanks, and may breach the river control works in low lying areas near the railway bridge.

Downstream of the railway crossing a strong discharge imprint from Coopers Creek returns to the Orari in the vicinity of the SH 1 bridge. Weaker discharge imprints are evident on slightly higher surfaces crossing Farm Road to K38/755735. Further weak discharge imprints leave the Coopers Creek channel way in the vicinity of Chalmers Road and west and east of Milton Road.

Downstream of Burnham Road discharge imprints exit Coopers Creek to the east at K37/780720 and /791700. Although partially stop banked and entrenched from this point to its confluence with the Orari, overbank discharge to the east and south is evident. All land from Badhams Road to the coast is vulnerable to flooding from both the Orari River and Coopers Creek (e.g., during 1945, 1950, 1951, 1951, 1952) due to its low lying position with respect to these flow channels.

9.2.2 Current Orari River channel

For the northern bank to SH 72 bridge see Coopers Creek section above. On the southern bank from the inland edge of the study area the river is contained by a stopbank to J37/690880, a degraded terrace riser to K37/703844, and stopbanks to the confluence of Sweetwater Creek. The fairway and berms have been reduced from 1000 m to <250 m immediately upstream of the SH 72 bridge where in 1967 a major active river channel was adjacent to the Keen Road / Orari Back Road junction. The stopbank in this location, the bridge approach immediately downstream, and the stopbank to K37/718823 are vulnerable to lateral erosion. It appears that a section of stopbank from K37/716824 to 718842 that is indicated on the 1:25,000 topoplot map has been removed.

The southern bank downstream from K37/716820 to the Orari Racecourse at K38/734746 shows a strong discharge imprint exiting the Orari and flowing south to the Waihi-Temuka river system through a well defined avulsion channel. We consider that the true western bounding bank for the Orari through this reach is to the west of Orari Back Road (see map K38A). From Orari Station Road the bounding bank can be traced south in the vicinity of Williams and Elmslie Roads to intersect the Waihi river at K38/713723. The eastern bounding bank of this avulsion channel can be traced as a terrace riser west of the Orari Racecourse to Bates Street. Between Bates and Opuha Streets an overflow channel can be traced firstly in a south easterly direction and then south along SH 1. In the vicinity of Beeby Road it swings south east in the direction of the swampy area at the head of Ohapi Creek near Muff Road. South from the overflow exit weak discharge imprints can also be traced east of SH 1, crossing to the west in the vicinity of College Road. At this point they intersect the strongly channelled imprint of the main avulsion channel which is traceable to the west of Winchester and along Dobies Creek to the head of the Temuka River.

The youthfulness of the main Orari / Waihi-Temuka avulsion channel is confirmed by the sharp channel relief, extensive occurrence of shallow and stony Selwyn and Waimakariri-aged soils along its length, and its use by flood waters in historical times (e.g., 1902, 1945).

The Orari River control works protecting the entrance to the Waihi-Temuka avulsion channel have significantly reduced the current fairway from some 900 to <210 m. They are vulnerable to overtopping or destruction through a combination of aggradation and/or erosion. This reach should be subjected to detailed study, especially to determine the elevation differences between the fairway, stopbanks, and adjacent land surfaces and the presence/absence and dynamics of any aggradational gravel waves in the fairway.

9.2.3 Ohapi Creek and the southern Orari lowlands

On the southern bank of the Orari River 2.5 km east of SH 1 the spring-fed northern branch of the Ohapi Creek rises. Ohapi Creek follows a course roughly parallel with the Orari river about 2 km to the west and rejoins it 1.5 km from the sea through an artificial cut into the diversion. In high flood the Orari River spills south into the Opahi Creek and spreads over the adjoining floodplain (Raeside *et al.* 1959). No strong flood discharge imprint was evident during this reconnaissance study but the pattern of poorly drained Recent soils and the subtle traces of overflow channels further down Opahi Creek confirm the likelihood of flood discharges. Numerous distributary imprints from Opahi Creek to the Orari, e.g., in the vicinity of The Stumps Corner and Bain Road/Clandeboye Road intersection; and south west across Muff Road to the middle branch are evident.

Most of the land on the southern bank downstream from 2-3 km east of SH 1 is vulnerable to flooding from over-topping or breaching of the Orari stopbanks. Extensive flooding of this area occurred in 1871, 1951, and 1952. Rise Road, a large gravel ridge extending from SH 1 to Milford some 3-5 m higher than the general landscape, and of unknown age, forms a south western barrier to flood discharges east of SH 1.

9.2.4 North bank of the Orari River channel

No major discharge channels leaving the Orari River on the north bank downstream of the SH 72 bridge were identified, although minor channels exit at K37/728808 and return to the main channel at K38/734790. Downstream of the Penney Road /Badhams Road area, all land is vulnerable to flooding from the Orari River and Coopers Creek (e.g., during 1945, 1950, 1951, 1951, 1952) due to its low lying position with respect to these flow channels.

9.2.5 Orari River mouth

A straight 1.6-km diversion has been constructed at the mouth of the Orari to bypass the former lagoon-river mouth-bar complex. Strong longshore currents have formerly pushed the river mouth some 5 km northwards along the coast and currently obstruct the discharge of gravel to the sea except when the bar is breached in extreme events. The sea wall parallelling the coast southwards to the Opihi River mouth provides a barrier to the intrusion of sea water but also serves as a barrier to flood flow from the land. The river channel stopbanks, below the Badhams bridge, and those of the diversion in combination with the sea wall serve to pond southern bank flood waters.

9.3 The Waihi River

The Waihi River, from the edge of the study area at Burdon Road to Geraldine, is contained by a combination of stopbanks and natural boundary banks. Weak overbank discharge imprints exit the river on the left bank in the vicinity of Flatman Road, J37/683843, to enter the creek and drain system east of the township. The elevated Woodbury Road bridge approaches form a barrier to flood flows. Flood waters could be impounded between the approaches and the terrace riser to the east but are unlikely to be diverted out of the floodplain because of the elevation difference.

South-east of Geraldine the river is largely confined by stopbanks built on the natural boundary banks. Some segments of the floodplain lie behind the river control works, e.g., at K38/706730. Flood discharges exiting the middle reaches of the river at J37/683843, re-enter the system between K38/700753 and 710733. The current sewage treatment ponds at K38/701753, form a potential barrier to the return of flood flows in this area.

The segment of stopbanks from the vicinity of Hawke Road K38/713723 on the eastern bank to the confluence of Dobies Stream K38/715654 form a potential barrier to Orari River flood waters discharging down the Waihi-Temuka avulsion channel. Depending on relative heights and volumes of flood flows from this source, the flows could be diverted eastwards across SH1 south of Winchester to be trapped behind the railway line and diverted into Temuka.

River control works from Hawkes Road to the confluence with the Hae Hae Te Moana River have severely reduced the former fairway from some 700 m to <100 m. Strong imprints of flood discharge on the 'protected' areas of the floodplains suggest that the bridge, bridge approaches, and roadway at K38/715647 are vulnerable to flood damage.

9.4 The Hae Hae Te Moana River

A combination of natural boundary banks and discontinuous stopbanks contain the Hae Hae Te Moana River from Speechleys Bridge to its confluence with the Temuka River. A subtle riser cut into a loess mantled terrace is present along most of the western bank. Along the eastern bank a riser bounds a higher, older (Templeton-aged) surface with a weak discharge imprint that trends in a southeasterly direction. In the lower reaches small relict channels exiting and rejoining the river are evident e.g., at J38/692690. At the confluence with the Waihi River, control works have reduced the channel way from 1400 to <500 m. There is potential for extensive ponding behind the control works in this area with the convergence of Orari flood flows from the Waihi-Temuka avulsion channel.

9.5 The Temuka River

The western boundary bank of the Temuka River is a riser cut into the loess-mantled downlands traceable from north of the Oxford Crossing Road to the Manse Bridge. From this point to SH1 and the railway the location of the true bounding bank is less clear. It appears that high flood flows may be able to be deflected by the railway embankment south to the Opihi. South of Oxford Crossing Road on the eastern bank a relict channel leaves the river between K38/716635 and K38/716626, and discharges into the stream that flows through the town. Other relict channel exit points are evident in the vicinity of K38/718619 and K38/713618. Further evidence of flow channels and directions detectable from aerial photograph interpretation have been masked by urban development. Major overflows occur in the southern 'industrial' section which has been built in the 'active' floodplain. In this section SH 1 and the railway form barriers to flood flows. East of the railway the lower level of the golf course and the 'new' sewage treatment ponds lie on the floodplain. Major flows of the combined Temuka and Opihi Rivers have entered Orakipaoa Creek and spread north-eastwards into the low lying swamps south of Boiling Down Road.

The relative elevations and potential flood flow directions from the Temuka River to the east, and south through to its confluence with the Opihi, need more detailed (ground based) investigation than was possible in this study because of masking of evidence detectable by aerial photograph interpretation by urban development. The 'Flood plain management study of Temuka Borough', Connell (1989), unsighted by the consultants, is assumed to address these issues. Hall (1997) evaluates the dispersal of Temuka River flood waters on the true right bank. There is a high flood risk for significant areas to a depth of 0.5 m as shown on his 500 year flood maps.

9.6 Opihi River floodplain

9.6.1 Tengawai and middle Opihi to Pleasant Point

The Tengawai from Sutherlands to its confluence with the Opihi at Pleasant Point is weakly incised into a narrow valley floor some 2 km wide. Weak flood discharge imprints are evident on the higher terrace surfaces which, although mapped as Lismore and Templeton-aged soils, were crossed by March 1986 floodwaters. Relict channels with strong discharge imprints leave the current river course at J38/530570 to re-enter at J38/565590. A series of relict braid channels with strong discharge imprints exit the river in the vicinity of Hammonds Road and are directed into Pleasant Point through the channel ways of Pleasant Point Stream. This stream and flood flows pass through the township either returning to the Opihi River at J38/675585, or are dispersed across the Levels Plain. The townships oxidation ponds impede flood flows down the Pleasant Point Stream channel way. They were overtopped and the rising main severed in the March 1986 event (Connell 1990). Flood waters overflowing to the south from Pleasant Point Stream are diverted into the township by SH 8. Between Hammonds and Maze's Road a lower elevation relict braid channel skirts Sherris Road with flows returning to the Opihi along the stretch from Tengawai Road to Bulters Huts. The current stopbanks along this section form a barrier to flood waters returning to the river if water enters this channel in its upper reaches.

River control works have reduced the active fairway in parts of this reach from 700 m to <200 m. Those on the southern bank west and east of Chisholms Ford are vulnerable to being outflanked. The stopbanks 'reclaiming' the floodplain at J38/570595 direct the river channel to the south-east against those stopbanks protecting the entrance to the Hammonds Road relict channel. Channel activity and bed level dynamics should be closely monitored and managed through this reach of the Tengawai River to prevent outflanking of the stopbanks and to identify potential avulsion locations.

Connell (1990) details analysis of flow patterns and volumes affecting the Pleasant Point township. He assesses the flood risk as high for areas in Pleasant Point to a depth of 0.5 m as shown in his 500-year flood maps. It would be prudent to refine this study and monitor the location and types of 'new' structures (buildings, fences etc.) that would impede flood flows.

The floodplain of the Opihi from 4 km downstream of the Hanging Rock Bridge to the Tengawai confluence is bounded to the north by a well-defined riser cut into the loess- mantled downlands. River control stopbanks abut this riser at J38/580645 and extend to the Saleyard Bridge to intersect the riser again at J38/623604. Strong discharge imprints are evident on the floodplain behind the stopbanks. Very strong imprints are present on the lower floodplain surface which comprised mainly scrub covered berms in 1969 before stopbank construction. Through this reach the fairway and berms have been reduced by some 50%. A subtle terrace riser separates the active floodplain from an overflow surface with a strong discharge imprint on the southern bank. Another terrace riser east of Hanging Rock Road bounds an older surface on which there is no obvious geomorphic evidence of overbank activity.

Sequential photography indicates that channel migration at the confluence of the Opihi and Tengawai Rivers has been highly variable. No attempt has been made to accurately map the current fairway morphology in this region. Channel activity and bed level dynamics should be monitored through this reach as the stopbanks from east of Tengawai Road to Saleyard Bridge are susceptible to lateral erosion.

Additional barriers to flood flows in this region include the approaches to the Saleyard Bridge, on both sides of the river. Ponding of flood waters will occur between the stopbanks, bridge approach, and downlands riser on the north bank.

9.6.2 North bank from Saleyard Bridge to the coast

On the north bank from the Saleyard Bridge to the Arowhenua homestead, the floodplain is bounded by a continuation of the riser cut into the loess mantled downlands. Stopbanks link this riser from J38/299601 to J38/68595. Through this reach the fairway and berms have been reduced from >1000 to <400 m by stop banking. Strong discharge imprints are evident on the floodplain behind the stopbanks. Very strong imprints are present on the lower floodplain surface which was largely scrub covered fairway and berms in 1967, before stopbank construction.

Sediment from the Opihi River onlaps the downlands surface east of K38/706595, indicative of past flood events. A subtle terrace riser bounds the Opihi from K38/713596 to approx. K38/737596. The lower floodplain surface behind the stopbank has a strong discharge imprint while on the overflow surface only weak discharge imprints are evident. Major barriers to flood flows through this region include the SH 1 bridge approaches and the railway embankment. The railway is elevated some 3-4-m from the Temuka to the Opihi River channels. Potentially, flood flows could be directed northwards from the Opihi to the Temuka River, or southwards from the Temuka to the Opihi in some breakouts. Hall (1997) maps potential flood levels and flow directions from the Temuka River in this region supplemented from breaches in the Opihi River stopbanks.

From the Temuka confluence to the sea on the north bank of the Opihi the land is susceptible to flooding from stopbank failure or overtopping. It is extremely low lying, being less than 2 m above sea level 7 km inland from the coast. Major overflows from the Opihi have been directed down Orakipaoa Creek and have spread northwards towards the coast. The presence of extensive areas of drainage impeded soil, swamps, saline gley recent soils and truncated estuaries northwards from the present river mouth to within the vicinity of the Orari mouth, are evidence of former river courses and flows in that direction.

9.6.3 Levels Plain east of Pleasant Point

Flood flows passing through Pleasant Point are either directed down the Pleasant Point Creek channel or are dispersed across the higher, older Levels Plain surface through and across German Creek. Weak discharge imprints are evident on the older plains surface (Lismore and Templeton-age), and subtle relict channels direct flows south-east. Major preferential channel zones were not evident. The actual flow path would be determined largely by the where the flood flow intersects with the plains surface.

The Main South railway line crosses the Levels Plain at approximately 90 degrees to the mean flow direction. It is on an elevated embankment >1m above the ground surface from the Opihi River to Washdyke. It presents a major barrier to flood flows as it has few culverts and was breached in the March 1986 floods.

There are extensive areas of drainage-impeded land and swamps east of Seadown Road at the lower end of the Plains. These former swamplands merge with estuarine deposits on the coastal margin. A coastal sea wall stretches from the Opihi River mouth southwards to the Washdyke Lagoon. Flood waters crossing the older surfaces of the Levels Plain, and overflows from the Roaring Camp avulsion channel and south bank breakouts would eventually accumulate behind this coastal barrier.

9.6.4 South bank, Pleasant Point to the coast

From west of Mill Road to Roaring Camp Road a terrace riser separates the floodplain from the older surface. At J38/687587 a well defined avulsion channel exits the river and can be traced to the coast at K38/765555. Over much of its length the avulsion channel is bounded by a subtle channel bank and has strong surface channel morphology. Its path is also indicated by the presence of shallow and stony Waimakariri-age soils in the upper reaches. Channel morphology becomes increasingly subtle down stream where fine grained young drainage impeded soils are mapped. The elevated railway embankment crossing this avulsion channel is a barrier to flood flows as it is served by only one very small culvert.

East of SH 1 a channel exits the river at Grassy Banks and re-enters the river 2 km downstream. The confluence of the Temuka River from the north, deflects the main Opihi channel onto the southern bank at Waipopo. Here the stopbanks are vulnerable to failure or overtopping. Land seaward of this point, including the river mouth settlement, is susceptible to flooding as it is low lying, being less than 2 m above sea level.

10. Recommendations for Further Work

10.1 Orari-Waihi-Temuka avulsion channel entrance

Priority should be given to more detailed geomorphic mapping, at 1:15 000 or 1:10 000, of the area surrounding the entrance to the Orari-Waihi-Temuka avulsion channel. River control works through this section are vulnerable to overtopping or destruction through a combination of aggradation and/or erosion. Elevation differences between the fairway and adjacent land surfaces, especially the locations, profiles and dimensions of former channels leading down the avulsion channel, need to be accurately known. The location and effectiveness of stopbanks with respect to the topography needs to be assessed. Bed levels and aggradation and degradation in the fairway through this reach of the Orari River needs to be carefully monitored to identify potential avulsion locations.

10.2 Tengawai River, Pleasant Point, and the Tengawai / Opihi confluence

Channel activity and bed level dynamics should be closely monitored and managed in the reach from west of Chisholms Ford to the eastern boundary of the Hammonds Road relict braid channel to prevent outflanking of the stopbanks and to identify potential avulsion locations which would result in flood waters entering Pleasant Point. It would also be prudent to refine Connells (1990) study of the flood risk to Pleasant Point township and monitor the location and types of 'new' structures (buildings, fences etc.) that would impede flood flows.

Channel activity and bed level dynamics should also be monitored in the vicinity of the Tengawai River - Opihi River confluence as the stopbanks from east of Tengawai Road to Saleyard Bridge are susceptible to lateral erosion.

10.3 Coopers Creek diversion channel entrance

The ability of the entrance to operate as envisaged needs to be closely monitored. Channel direction and morphology, and the relative elevation difference between the fairway and the entrance lip, are critical. The impact of ponding of the proposed flood flows behind major obstructions e.g., the railway line embankment, should also be evaluated.

10.4 Temuka River

It is assumed that the 'Flood plain management study of Temuka Borough' Connell (1989), unsighted by the consultants, comprehensively addresses distributary channel depth and direction through the township. Geomorphic evidence of distributary channels and overbank discharge features normally detectable from aerial photographs have been masked by urban development. Ground based investigation would be required to confirm those distributary channels identified from aerial photograph interpretation.

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Table 1: Relationship between soil age groups (Cox and Mead, 1963; Cox 1978), and geological formations (Brown and Wilson 1988).

Soil Age Group	Soils			Geological Formations
	(well drained)	(mottled)	(gleyed)	
Lismore (>14,000 yr)	Lismore, Ruapuna Chertsey			Windwhistle Burnham
Templeton 3000-10,000 yr	Templeton Paparua Eyre	Wakanui	Temuka	Springston
Waimakariri 7-900-2400 yr	Waimakariri	Kaiapoi*	Taitapu*	Springston
Selwyn (<300 yrs)	Selwyn	Kaiapoi*	Taitapu*	Springston

* Note: Poorly drained soils are not distinguished separately in Waimakariri and Selwyn soil age groups. Selwyn aged soils were NOT distinguished in the earlier mapping being incorporated with Waimakariri aged soils.

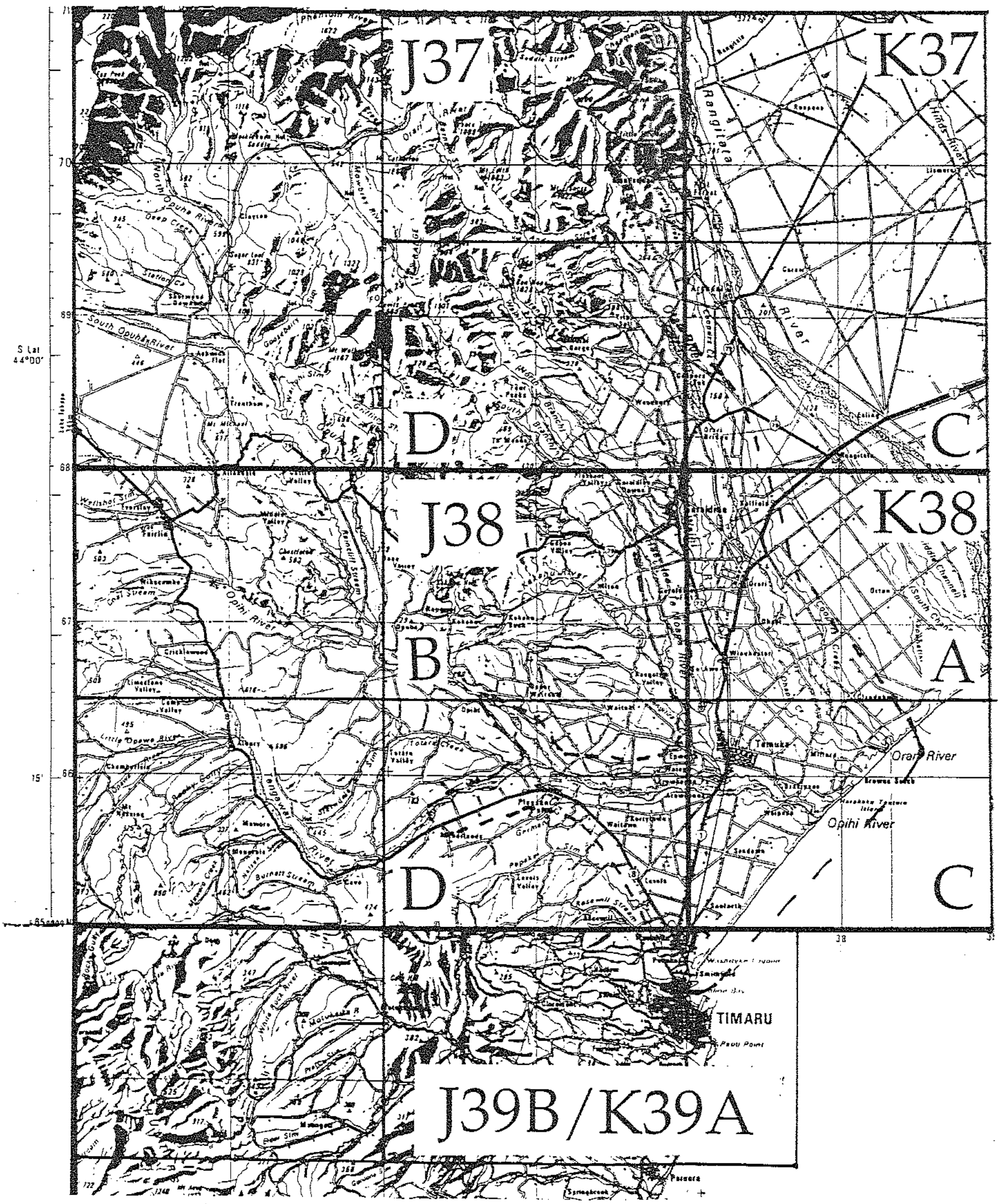

Fig.1 Outline of the study area and NZMS 270 Topoplots used to present data.

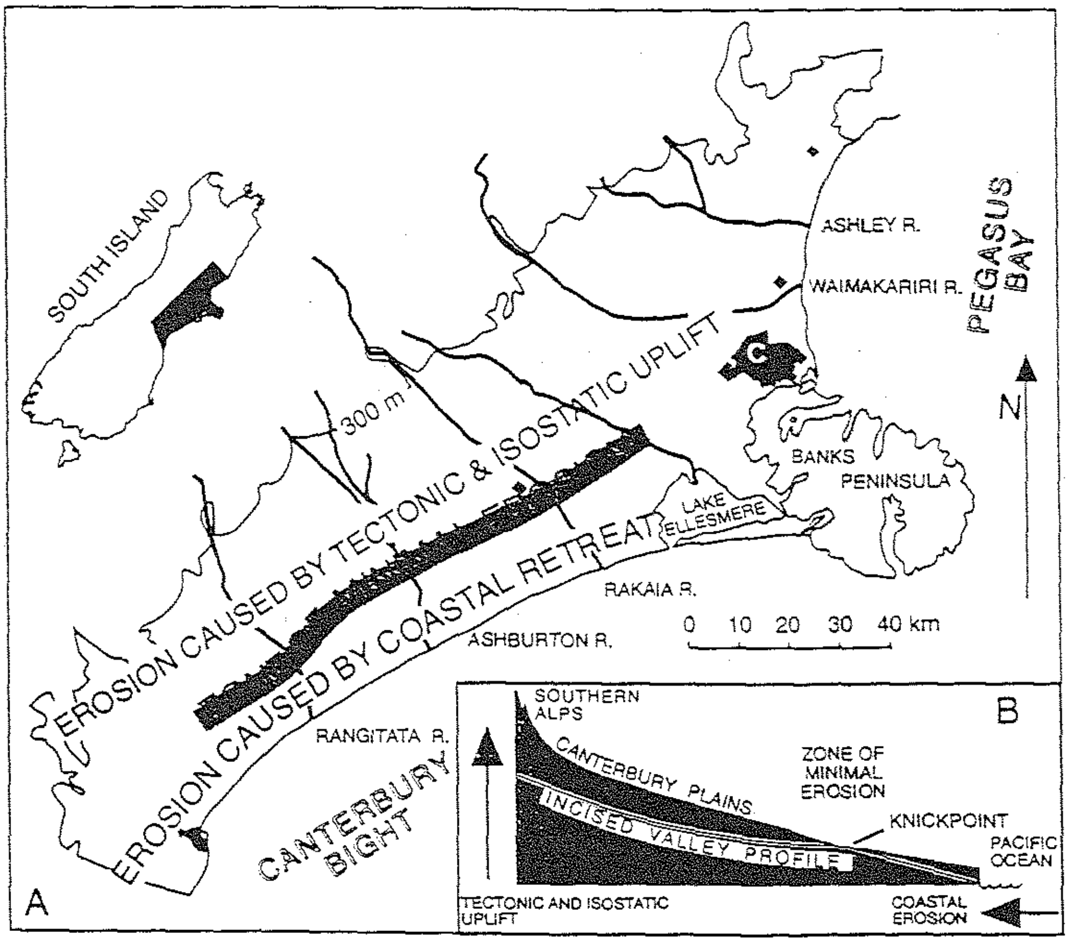

Figure 12—(A) Different zones of valley incision in the Canterbury Plains inland from Canterbury Bight. (B) Schematic illustration of valley incision on the Canterbury Plains. Valley incision occurs along the coast because of coastal retreat during modern sea level highstand. Incision occurs inland because of tectonic and isostatic uplift of the Southern Alps.

Fig. 2 Zones of valley incision in the Canterbury Plains from Canterbury Bright (from Leckie 1994, Fig. 12, pp1253).

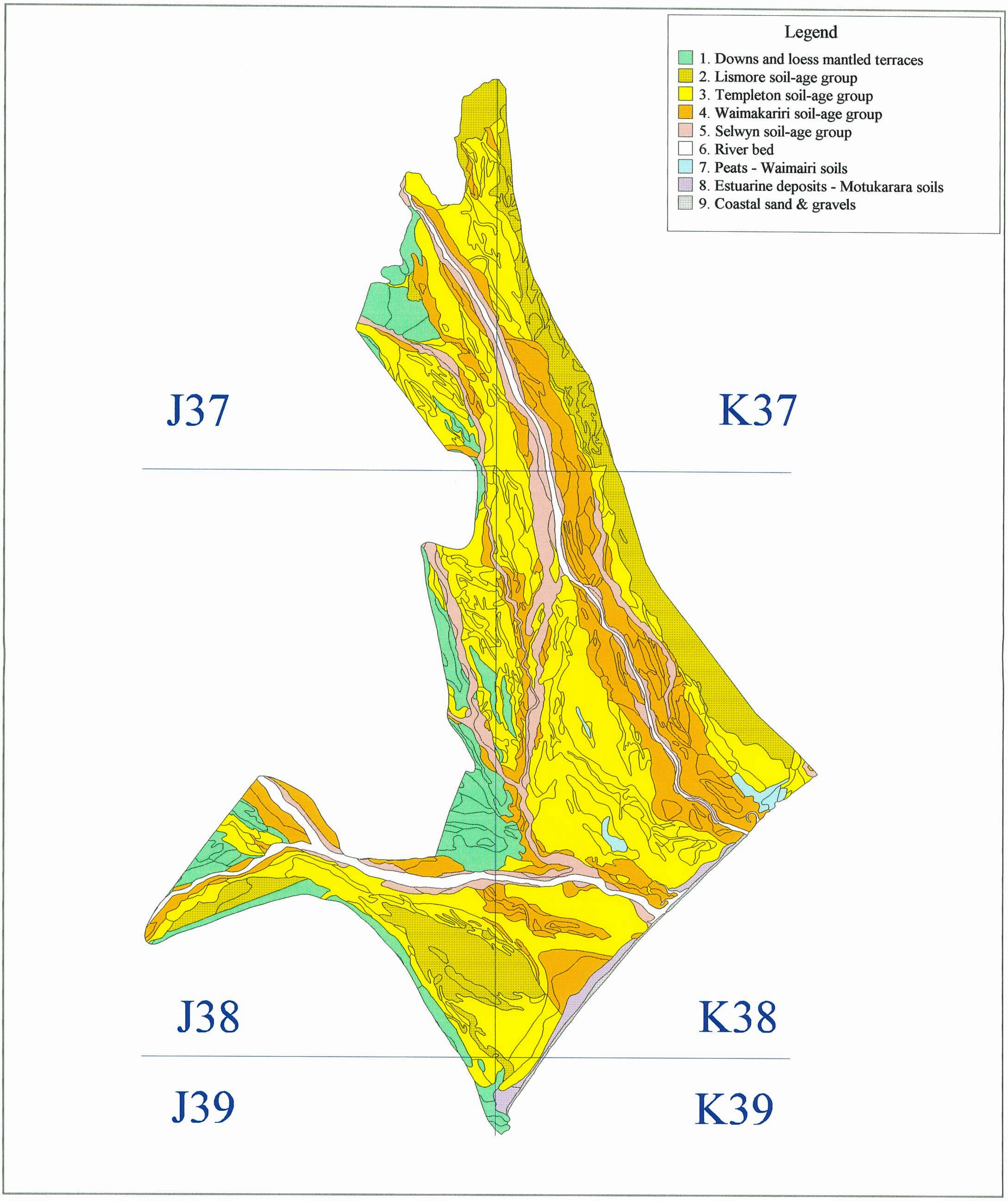

Fig 3: Simplified soil map showing soil-age groups. Map scale is 1:180 000. The blue lines and numbers refer to NZMS 260 series INFOMAP sheet boundaries.

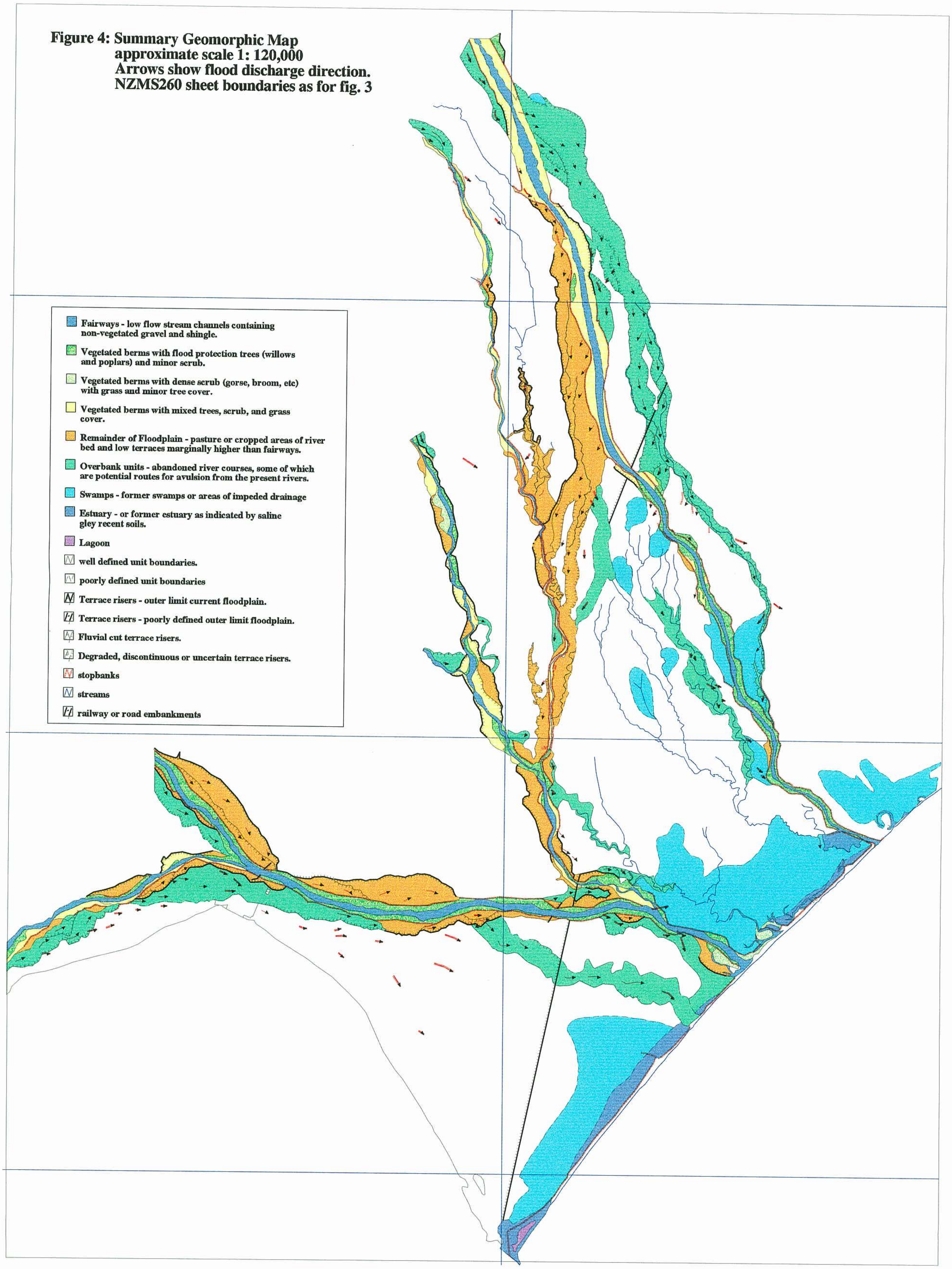

Figure 4: Summary Geomorphic Map
approximate scale 1: 120,000
Arrows show flood discharge direction.
NZMS260 sheet boundaries as for fig. 3

13. Appendices

Appendix 13.1 Details of aerial photographs and 1:25,000 scale topoplot base maps used in the study.

A Details of aerial photographs.

1. New Zealand Aerial Mapping aerial photographs;

NZAM Survey No.	Title	Date of photography	Approx. scale
SN 86	Downlands Water Supply	1938-39	1:10 000
SN 213	Geraldine-Temuka	1942-43	1:10 000
SN 5054	Timaru-Geraldine	1977	1:25 000
SN 5234	Sherwood Downs-Woodbury	1978	1:25 000
SN 8720	Geraldine-Temuka	1987	1:25 000

2. New Zealand Aerial Mapping semi-controlled mosaic map series NZMS 3 sheets

NZMS 3 sheet number	Name	Scale	Date of photography	Publication date
S102/2	Woodbury	1:15 840	1967	1969
S102/5	Geraldine	1:15 840	1967	1969
S102/6	Orton	1:15 840	1967	1969
S102/7	Blacker	1:15 840	1967	1969
S102/8	Winchester	1:15 840	1967	1969
S102/9	Clandeboye	1:15 840	1967	1969
S111/1	Pleasant Point	1:15 840	1967	1969
S111/2	Kerrytown	1:15 840	1967	1969
S111/3	Opihi	1:15 840	1967	1969

3. South Canterbury Catchment Board vertical aerial photographs of the river channels

SCCB Survey No.	Location	Date	Frames
SN 8	Orari River	1987	A1 to A85
SN 9	Opihi River	1987	A1 to A42
SN 10 (B/W)	Temuka - Te Moana Rivers	1987	A1 to A37
SN 12 (B/W)	Opihi River at Pleasant Point	1987	A1 to A10
SN 27	Waihi River from Temuka	1988	A1 to A55
SN 38	Orari River	1988	Run E, 1 to 37
SN 103	Waihi River	1993	Run A, A1 to A42
	Opihi River		Run C, C1 to C22
SN 119	Orari River	1993	A1 to A53
SN 133	Opihi River	1994	A1 to A39
SN156	Te Moana River	1995	A1 to A37

B Details of 1:25,000 scale topoplot base map photography and compilation

NZMS 270 Map sheet	Date of compilation and field checking	Date of photography	Date of publication
J37 B	1986	1986	1991
J38 B	1977	1977	1981
J39 D	1977	1977	1981
J39 B / K39 A	1977	1977	1981
K37 A	1980/81	1978	1982
K38 A	1977	1977	1979
K38 C	1977	1977	1979

Appendix 13.2 Glossary of terms

abandoned river course,	river channel recently abandoned by a change in the rivers course.
aggradation,	the process of building up a surface (river bed) by deposition. The opposite of degradation.
alluvium,	sediments deposited by streams and rivers.
avulsion,	an abrupt change in the course of a river, where a river deserts its old channel for a new one.
berm,	area of river bed inside the stop banked area, covered with vegetation e.g., river protection trees. It protects the stopbanks from fast flowing erosive water velocities.
boundary banks,	a terrace riser or other geomorphic feature which marks the outer limits of the current floodplain.
coalescing alluvial fans,	a series of confluent alluvial fans.
degradation,	the lowering of the surface of the land (river bed) by erosive processes, especially by the removal of material through erosion and transportation by water.
design flow,	the maximum flow for which the channel or structure is designed.
downland,	undulating to strongly rolling hill country.
fairway,	low flow stream channels and containing non-vegetated gravel and shingle. The river bed where sediment is actively migrating downstream
flood imprint,	the physical evidence of the passage of flood waters over the landscape, the erosion of channels, scouring, deposition of sediment and flood debris etc.
fluvial,	belonging to a river, produced by the action of a stream or river.
glaciofluvial,	pertaining to the meltwater streams flowing from wasting glacier ice and the deposits and landforms produced by such streams.
Holocene,	an epoch of the Quaternary period, form the end of the Pleistocene, approximately 11 thousand years ago to the present time, also the corresponding rocks and deposits.
loess,	a blanket deposit of silt-sized materials; usually carried by wind from dry river beds or outwash plains.
overbank discharge,	flood waters that cannot be contained in the stream channel.
onlapping	an overlap characterised by regular and progressive burial by younger deposits.
overbank deposit,	fine-grained sediment deposited from suspension on a floodplain by waters that cannot be contained in the stream channel.
Quaternary,	second period of the Cenozoic era, began approx. 2 million years ago and extends to the present. river control scheme,
stratigraphy,	the arrangement of strata (layers of sediment) especially their geographic position and chronological order of sequence.
stopbanks,	an artificial bank, or length of raised ground, constructed along a stream to confine flood water to the main waterway and so protect land further away.

terrace,	any long, narrow, relatively level or gently inclined surface (tread), generally less broad thana plain, bounded on one edge by a steeper descending slope (riser) and along the other by a steeper ascending slope (riser), and sufficiently elevated to be beyond the reach of the agent that formed it.
Tertiary,	the first period of the Cenozoic era, though to have covered the span of time between 65 and 2 million years ago.
Torlesse Supergroup,	moderately strong to extremely strong sedimentary rocks, largely interbedded sandstone (greywacke) and mudstone (argillite) and minor associated lithologies of Permian to Jurassic age of the South Island east of the Haast Schists.

Appendix 13.3 Simplified geological time-scale

Era	Period	Epoch	
CENOZOIC	Quaternary	Holocene	glaciations finished c. 11 000 years ago
		Pleistocene	glaciations begin c. 1 700 000 years ago
	Tertiary	Pliocene	
		Miocene	
		Oligocene	
		Eocene	
		Paleocene	*c.* 65 million years
MESOZOIC	Cretaceous		
	Jurassic		
	Triassic		*c.* 240 million years
PALEOZOIC	Permian Carboniferous Devonian Silurian Ordovician Cambrian		*c.* 570 million years
PRECAMBRIAN			

Appendix 13.4 Study brief

Geomorphic Study

Orari - Waihi - Temuka and Opihi Floodplain Area

Study Brief

1. INTRODUCTION

Geomorphic studies are a rapid and cost effective means of identifying areas that may be prone to flooding. Such studies now form an integral part of most flood hazard investigations carried out by the Canterbury Regional Council.

As part of the Regional Council's flood hazard investigation programme, detailed geomorphic and associated flood assessment information is required for the Orari - Waihi - Temuka and Opihi (OWTO) floodplain area. This information will be used to:

(1) Verify flood hazard computer modelling work that has already been completed by the Regional Council; and

(2) Identify areas requiring further more detailed flood hazard analysis.

2. AIM OF STUDY

The aim of the study is to define the geomorphic characteristics of the OWTO floodplain and to determine the influence of the geomorphology on future flood flows.

To achieve this aim the Consultant will complete the following tasks:

(1) Review of any available reports, publications and other documents on the geomorphology (and relevant associated topics) of the OWTO floodplain area;

(2) Detailed air-photo interpretation study of:

  (a) The geomorphology of the OWTO floodplain area; and

  (b) The geomorphic changes in the *active riverbed system*.

(3) *Walkover* field investigations to verify air-photo interpretations and to map any other significant additional features; and

(4) Preparation of an appropriate classification of geomorphic features based on existing geomorphic information, air-photo interpretation and fieldwork.

The geomorphic study will be a qualitative *stand-alone* flood hazard assessment. The study findings will be integrated by the Regional Council with other flood risk mapping techniques including existing flood hazard computer modelling results and historic flood information.

3. STUDY AREA

The study area is essentially the combined floodplain of the Orari, Waihi, Temuka and Opihi Rivers. The approximate boundary of the study area is shown in Figure 1.

The extent of geomorphic mapping within the area defined in Figure 1, will be determined in consultation with the Regional Council as mapping proceeds. All landforms that may have the potential to directly affect or influence flood events on the floodplain will be mapped. The study area does not include the upper catchment of the Orari, Waihi, Temuka and Opihi Rivers.

4. PRODUCTS

The Consultant is required to prepare two main products. These are:

(1) A detailed geomorphic map with appropriate flood hazard annotation; and

(2) A report detailing:

  (a) The geomorphology of the OWTO floodplain area; and

  (b) The potential influence of the geomorphology on future flood flows.

5. PRODUCT SPECIFICATIONS

5.1 Geomorphic Map

(i) Map Details

The geomorphic map will be compiled by the Consultant at a scale of 1:25,000.

The geomorphic map will include, where appropriate, the following type of information:

(1) Floodplain units including the present riverbed system (stream channels, bare riverbed, riverbed concealed by vegetation, riverbed converted to paddocks and riverbed reclaimed by stopbanks), other streams (streambeds and channels), historic floodways (principal floodways occupied prior to construction of any stopbanks and subordinate floodways), and major alluvial fans;

(2) Geomorphic units adjacent to the floodplain including river terraces and terrace risers, minor alluvial fans and coastal deposits;

(3) Any other significant landforms;

(4) Hydrological features including streams, rivers, wetlands and swamps, lagoon remnants, oxidation ponds and flooded workings;

(5) Any other significant and relevant features that may dam or divert flood flows such as stopbanks and groynes, prominent road and railway embankments, major roads, railway tracks and urban areas; and

(6) Potential *break-out* points from lateral bank erosion (based on changes in the active riverbed system over time) and avulsion zones, likely flood flow directions or depositional slope and any other relevant flood hazard information.

Any variation in boundary definition for map units or features will indicated by appropriate line symbols.

(ii) **Map Format**

The Consultant will supply the following map products to the Regional Council:

(1) An ESRI Arc/Info plot (one copy) at compilation scale with legend and only basic cartographic elements;

(2) The original base map compilation sheets (working drawings) with appropriate annotation and legend details; and

(3) An ESRI Arc/Info digital copy.

The ESRI Arc/Info coverage must have polygon, arc and if appropriate point topology. PAT files must contain appropriate items. Unique identification must be given to the study area boundary, the coastline and mapped units. Line symbols must be clearly defined, and appropriate items included in the AAT files. Draft plots of the Arc/Info coverages are to be produced by the Consultant and checked by the Consultant to confirm correct translation from the digital information.

The Consultant will discussed the format of the digital data with the Regional Council prior to the completion of the study to ensure the information can be readily transferred.

5.2 Report

(i) Report Content

The main purpose of the report is to provide an outline of the geomorphic mapping work completed and the potential significance of the geomorphology with respect to flooding.

The Consultants report will contain:

(1) A literature review including:

- (a) A description of the approach used to complete the review;
- (b) A list of relevant reports, papers, publications and any other documents reviewed including a full bibliographic reference for each;
- (c) A brief summary of the findings of each report, paper, publication or other document reviewed; and
- (d) A discussion on the implications of the review findings on map compilation;

(2) A description of the approach used to compile existing geomorphic information for the OWTO area, and for integrating existing information with observations made or concepts developed during the study; and

(3) The main results of the work including:

- (a) A description of the various geomorphic units mapped;
- (b) A discussion on the potential influence of the geomorphology of the OWTO floodplain on future flood flows. This will include information on potential breakout points, avulsion zones, and likely flood flow directions;
- (c) A summary A3 size map of the geomorphology of the study area;
- (d) Any limitations or uncertainties of the information compiled, or assumptions made; and
- (e) Recommendations for further work.

(ii) Report Copies

Four bound, one unbound, and a digital copy (Microsoft Word format) of the report will be supplied to the Regional Council by the Consultant.

A Regional Council report publication number will be supplied to the Consultant on completion of the draft report.

6. STUDY TEAM

The team available to complete the study will consist of Grant Hunter, Dr Les Basher (Project Leader), Ian Lynn, Trevor Webb and Terry Savage. Joseph Harris (University of Canterbury) will assist with air photo interpretation work.

7. STUDY PROGRAMME

The Consultant must complete the study by 31 July 1997. This places strict time constraints for completion of the work. The following deadlines must be met:

27 June 1997	Completed draft geomorphic map. Verbal presentation (at Regional Council office or in-field) on draft map to Regional Council staff. Completed draft geomorphic report. Regional Council to complete review of draft map and draft report by 11 July 1997.
31 July 1997	Final hard copies and digital copy of map, and hard copies and digital copy of report.

The Consultant may be required as part of the contract, to assist Regional Council staff with a presentation on the findings of the study to the Resource Planning Committee of the Regional Council.

8. PUBLICATIONS, REPORTS & AERIAL PHOTOGRAPHS

Published papers, reports and aerial photographs held by the Regional Council will be made available on request.

The Regional Council will, when requested, facilitate the Consultant obtaining any other necessary relevant information from third parties.

9. BASE MAP INFORMATION

The Consultant will purchase and pay for all base map products required to complete the mapping work.

10. BASIS OF PAYMENT

Monthly invoices are required and will be based on the percentage of work completed at the time of billing. **A short written report outlining the work undertaken during the preceding month and the progress made with the study will be required with each invoice.**

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