Channel morphology and sedimentation in the Cardrona River

January 2010

Otago Regional Council
Private Bag 1954, 70 Stafford St, Dunedin 9054
Phone 03 474 0827 Fax 03 479 0015
Freephone 0800 474 082
www.orc.govt.nz

Published January 2010

ISBN: 1-877265-92-6

Foreword

Understanding the channel morphology and sedimentation characteristics of Otago's rivers enables their effective management. The Otago Regional Council (ORC) undertakes scheduled cross section surveys of selected rivers as part of its river monitoring programme. This information is used to understand the dynamic fluvial processes of each river and to establish the general state of the river's channel morphology and gravel resource. From this, the information can be used to support river management.

This report explores how the morphology and sedimentation of the Cardrona River has changed over the surveyed periods, as well as providing a synthesis of the study's results to guide river management into the future.

Executive Summary

Investigations into the channel morphology and sedimentation of the Cardrona River indicate that the river has experienced a net degradational trend over the surveyed periods, generally 1988 to 2007. This study has noted that sediment storage within the active channel has decreased considerably, with sediment replenishment of the river's main stem primarily a function of large and/or recurrent flood events, such as that which occurred in November 1999. Changes in the Cardrona River channel morphology are also apparent in aerial photography, as shown in imagery taken in 1966, which exhibited a naturally braided, sediment-rich active channel margin. Subsequent photography, taken during the late 1990s and in 2006, indicates that the braided complexity of the natural river form has been lost due to extensive modification of the active channel, including commercial gravel extraction, and a reduction in sediment replenishment rates.

Channel form and development within the Cardrona River is indicative of a very dynamic system that exhibits periodic reaches of braided to single-thread channel planforms. Analysis of cross sections, aerial photographs and anecdotal records, supported by detailed field inspection, indicate that the river is in a presiding degradational state, due to extensive contemporary modification of the channel form and reduced sediment replenishment rates within the active channel margin. This trend is represented in mean bed-level analyses, where 22 of 34 surveyed cross section locations, from the Cardrona Village to the Clutha River/Mata-Au confluence, experienced net degradation. Of these, 13 locations experienced degradation of greater than 0.5m over each respective survey period. Comparable surveyed cross sections extend 26.5km along the river, from the confluence with the Clutha River/Mata-Au to just downstream of the Cardrona village.

Observations of the longitudinal profile identify a 6.9km reach of bed degradation, extending from the State Highway 6 Bridge upstream to The Larches. The profile exhibits five reaches of notable degradation of the channel thalweg, compared to one notable reach of aggradation. These net degradational trends are reflected in the field by channel incision and significant reaches of bank erosion along the length of the river.

Observed change in the Cardrona River's channel morphology and sedimentation characteristics indicates that sediment storage within the active channel margin has decreased considerably over surveyed periods. Mean bed-level and river profile analyses indicate that, while the river experienced an extraordinary sedimentation event in November 1999, the net trend over all surveyed periods has been one of net degradation. Should sediment replenishment rates along the Cardrona River main stem remain infrequent, it is anticipated that the river system will degrade further. Further degradation may contribute to bank erosion and greater channel incision along the length of the river.

Table of Contents

Table of Figures

Tables

1 Introduction

The Cardrona River is a dynamic hydraulic and sediment system that is subject to change, both rapidly and over prolonged temporal scales. Change can be represented through variation in the supply, storage and removal of sediment, or reflected in changes of the river's morphology. Such changes can occur rapidly, such as sedimentation observed during November 1999, or they may occur gradually over years or decades as the river morphology responds to sediment variation. The latter may induce change downstream some time after sediment input or removal as the river form responds accordingly.

Cross section analyses and investigations provide an insight into how the river system is changing over time. Comparable survey periods provide a basis for this interpretation and can be used to determine the state of the gravel resource and morphological state of the river system. The ORC has undertaken cross section surveys on a regular basis for parts of the Cardrona River downstream of Cardrona Village since 1985.

This document describes morphological change and sedimentation in the Cardrona River. Aerial photography, cross section analyses and anecdotal information are collated and interpreted to provide a comprehensive review of change over surveyed periods (maximum period 1985 to 2007). This information is used to understand the dynamic fluvial processes of the river and to establish the general state of the river's channel morphology and gravel resource. From this, the information can be used to support river management.

2 Catchment description

The Cardrona River catchment (Figure 2.1) drains an area of 337km^2 and is bound by the Crown Range to the south and west, and the Criffel and Pisa Ranges to the east. The river flows in a north-easterly direction from its headwaters, at the crest of the Crown Range, to its confluence with the Clutha River/Mata-Au adjacent to AlbertTown, a distance of approximately 40km.

2.1 Geology

The Cardrona valley is largely defined by the active NW and SE Cardrona Faults, which are considered to create earthquakes in the order of 7.0-7.1 magnitude every 5000 to 10000 years (Opus, 2005). Both faults define the present margins of a synclinal sedimentary basin within the valley. The NW Cardrona Fault is currently the most active, with mapped active traces that extend discontinuously to the Nevis Valley. The SE Cardrona Fault passes southwards into, or is truncated by, the Gentle Annie Fault, which includes broad zones of crushed basement schist traceable to the Kawarau River (McDonnell & Craw, 2003).

The Cardrona valley upper catchment geology is comprised of Mesozoic schist of the Rakaia terrane. These deposits are predominately grey quartzo-feldspathic sandstone, siltstone, with argillite with subordinate conglomerate, chert, volcanic rocks and limestone. Upper catchment schist is strongly foliated, generally with a 30° - 80° easterly dip of the foliation (Turnbull, 2000).

In the lower catchment, the Manuherikia Group is overlain by a sequence of alluvial gravels (>300m thick), thought to have been deposited by a proto-Clutha River/Mata-Au draining south via the Cardrona valley during the late Miocene-Pliocene (McDonnell & Craw, 2003). These geological units are being actively eroded and form the origin of most contemporary alluvial floodplain and fan deposits in the lower Cardrona valley. Downstream of the valley confines, the river traverses and re-works terraces and morainic post-glacial deposits of fluvio-glacial origin.

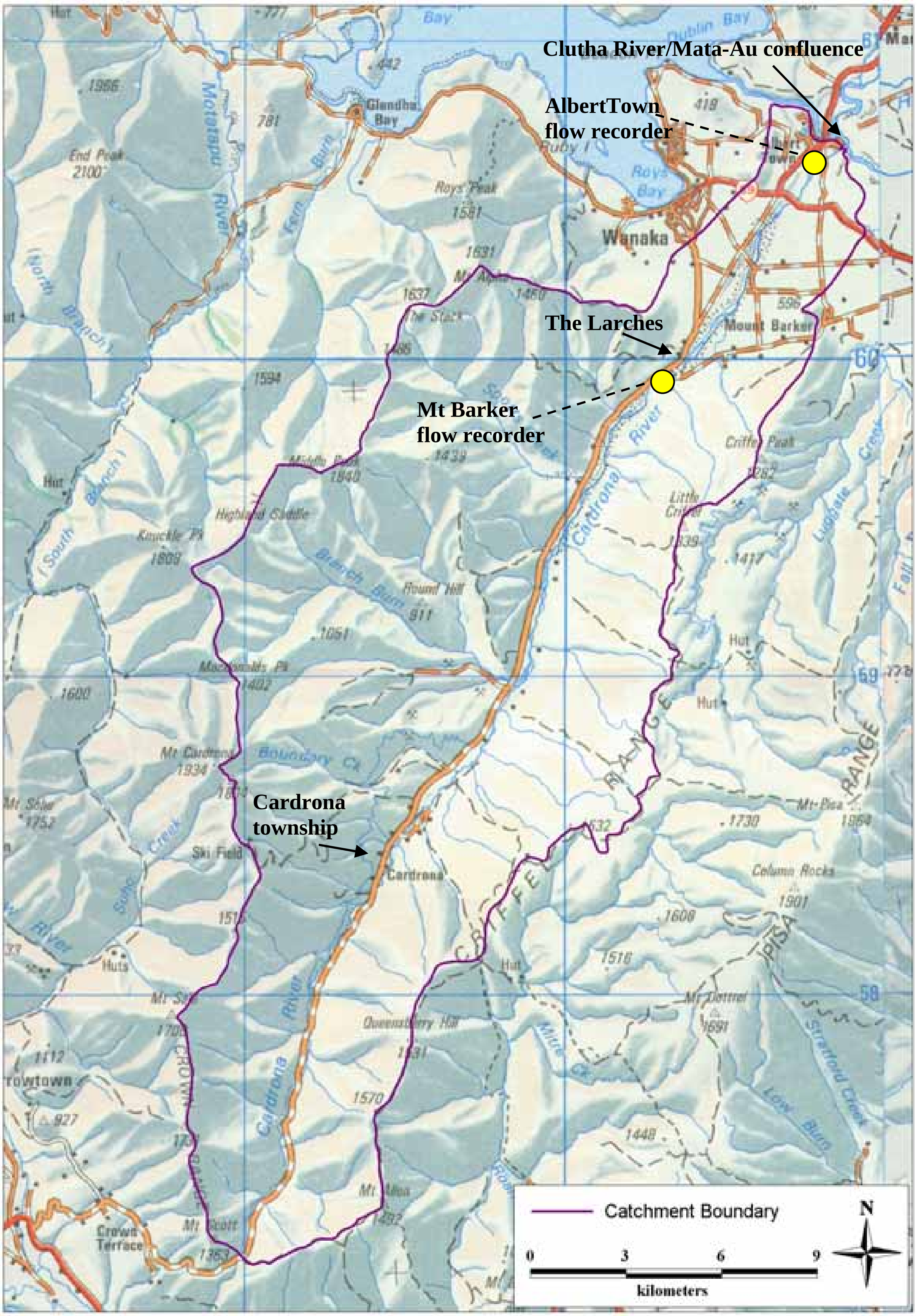

Figure 2.1 Cardrona River catchment locality map

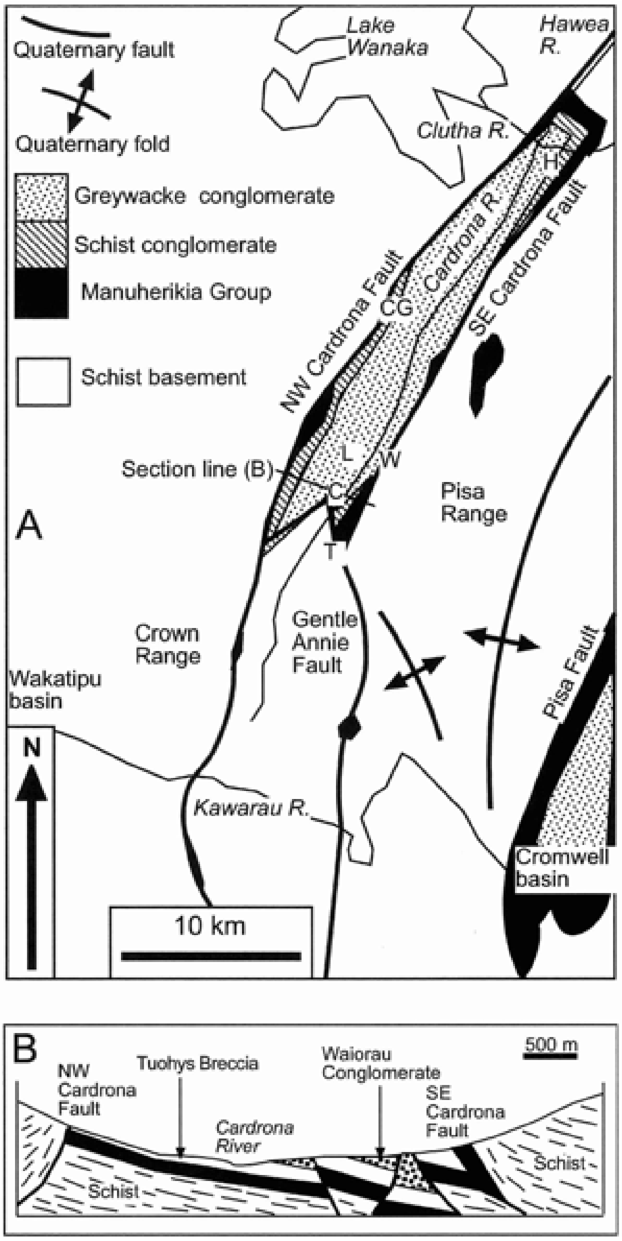

Figure 2.2 A geological map and cross section of the Cardrona valley. Reproduced from McDonnell & Craw (2003)

2.2 Hydrology

The Cardrona River flow record has been monitored at two long-term sites: Mt Barker and Albert Town. Despite being further upstream, with a smaller catchment area, the Mt Barker site has a greater average flow, specific yield and mean annual low flow than the Albert Town site, due to groundwater recharge and abstraction for irrigation (Otago Regional Council, 2007). Figure 2.3 shows the flow record for the Mt Barker site, which operated from 2 December 1976 to 21 October 1988, then closed for several years and was re-opened on 23 February 2001. Figure 2.4 shows the flow record for the Albert Town site, which operated from 28 September 1978 to 9 January 2002.

The movement of sediment along the length of the Cardrona River is largely dependent on hydrological flows, which have sufficient energy to erode, transport and deposit this material. Figure 2.3 shows that high flows have become less frequent over the last decade compared to those observed during the late 1970’s and 1980’s. The highest flow recorded at the Albert Town gauge was 124.2m^3/s on 17 November 1999 (Figure 2.4). Having had significant influence on current channel form and morphology this flood was the largest recorded event with no flows of similar or higher magnitude recorded over the last decade.

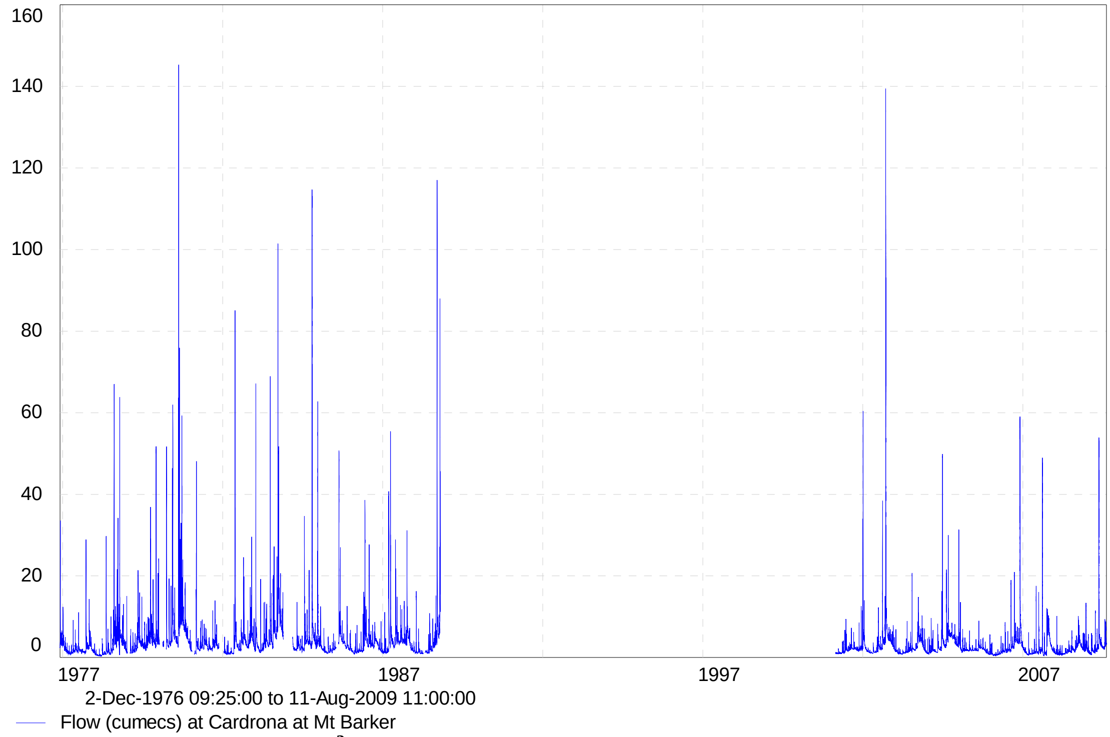

Figure 2.3 Flow record in m^3/sec for the Cardrona River at Mt Barker recorder, 2 December 1976 to 11 August 2009

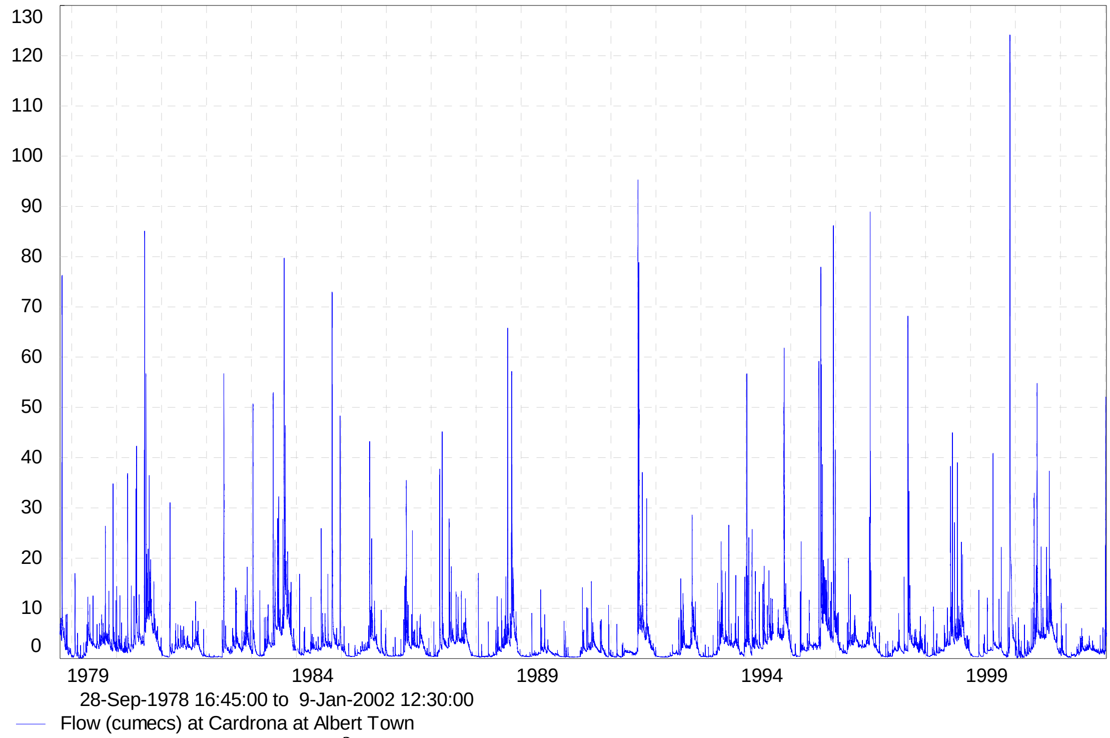

Figure 2.4 Flow record in m^3/sec for the Cardrona River at AlbertTown recorder, 28 September 1978 to 9 January 2002

3 Cross section and mean bed-level analysis

The Otago Regional Council undertakes scheduled cross section surveys for selected rivers, including the Cardrona River, on a periodic basis. The cross section programme enables changes in river morphology and sedimentation trends to be monitored.

Forty-two cross section locations have been intermittently surveyed along a 33.5km length of the Cardrona River (Figures 3.1 – 3.3). Fifteen surveys, from February 1985 to January 2007, exist, with comprehensive surveys being undertaken in February 1988 and January 2007. Survey periods generally span 19 years (1988-2007), with the exception of cross sections 1B, 2 and 3, which span 22 years (1985-2007), and five other cross sections, which have varying shorter survey periods. Cross sections located upstream of 25-1 are not included in analyses, as they were established during the most recent survey period and, as such, do not have a comparable survey year.

The mean bed-level of the active channel in each cross section was calculated using the X-Sect cross section database[1]. Table 8.1.1 shows each year surveyed and the respective mean bed-level calculation for each cross section. All survey extents, including historical, have been investigated and compared to aerial photography and are considered to be a fair representation of the active channel margin at the time of survey. While bed level results are expressed to two decimal places, these are mean values and may therefore have an error margin which exceeds this level of specificity. Table 8.1.2 shows the net change in mean bed-level over the different survey periods.

Table 8.1.3 shows the net change in channel thalweg level for each respective survey period. The thalweg is the lowest point of the cross section, which represents the deepest part of the channel surveyed.

Cross section, mean bed-level and thalweg results are discussed further in Section 5. Annotated plots of each cross section for all surveyed years are included in Section 8.3 – Individual cross sections. A commentary is provided for each cross section, which notes observed mean bed-level, morphological and geomorphic changes between survey periods.

[1] The database compiles a list of widths and their associated elevations (reduced level) for each cross section and survey period. X-Sect calculates all output information (minimum, maximum and mean bed-levels) from the respective widths and elevations.

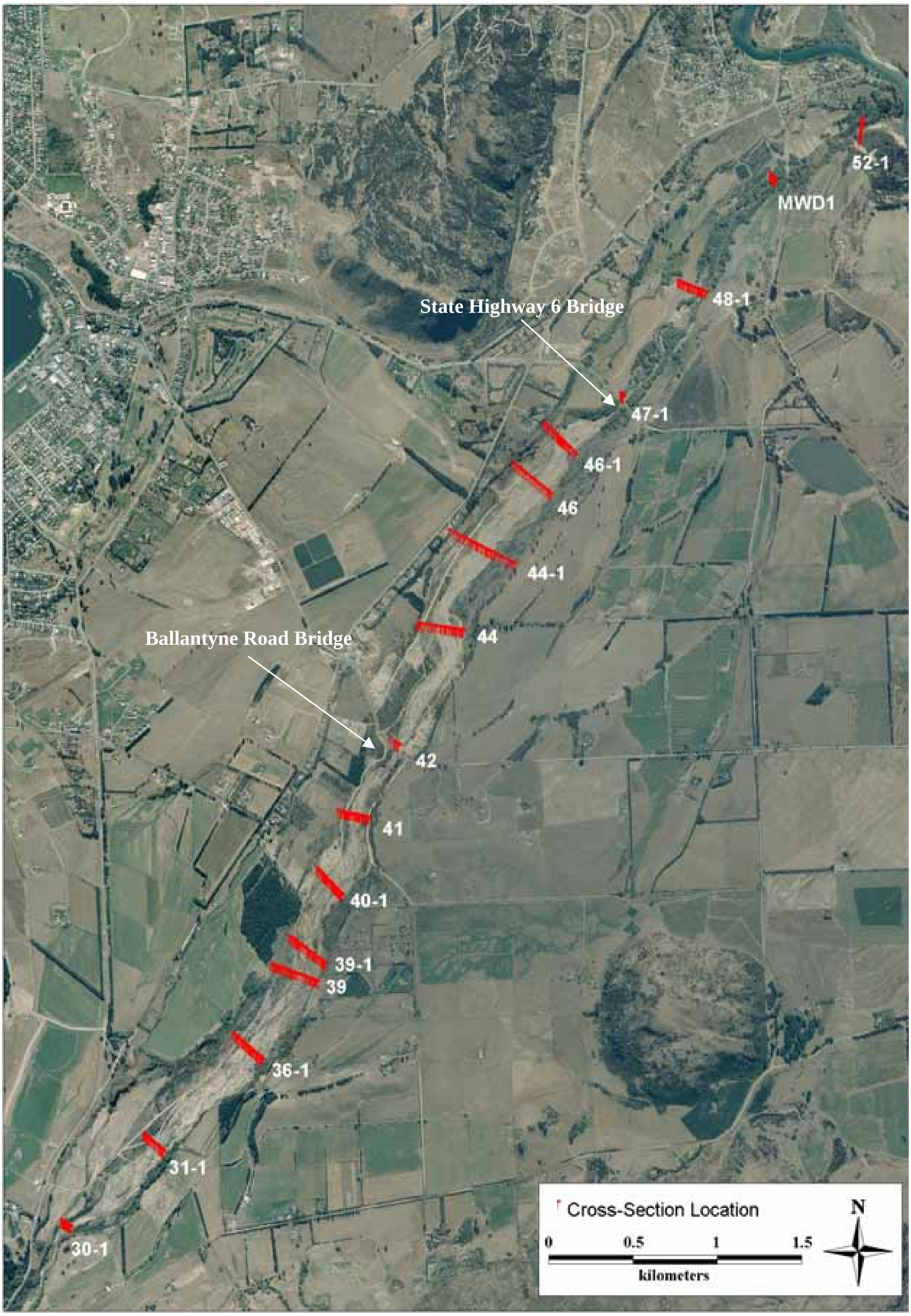

Figure 3.1 Location of surveyed cross sections for the Cardrona River lower catchment superposed onto 2006 aerial photography

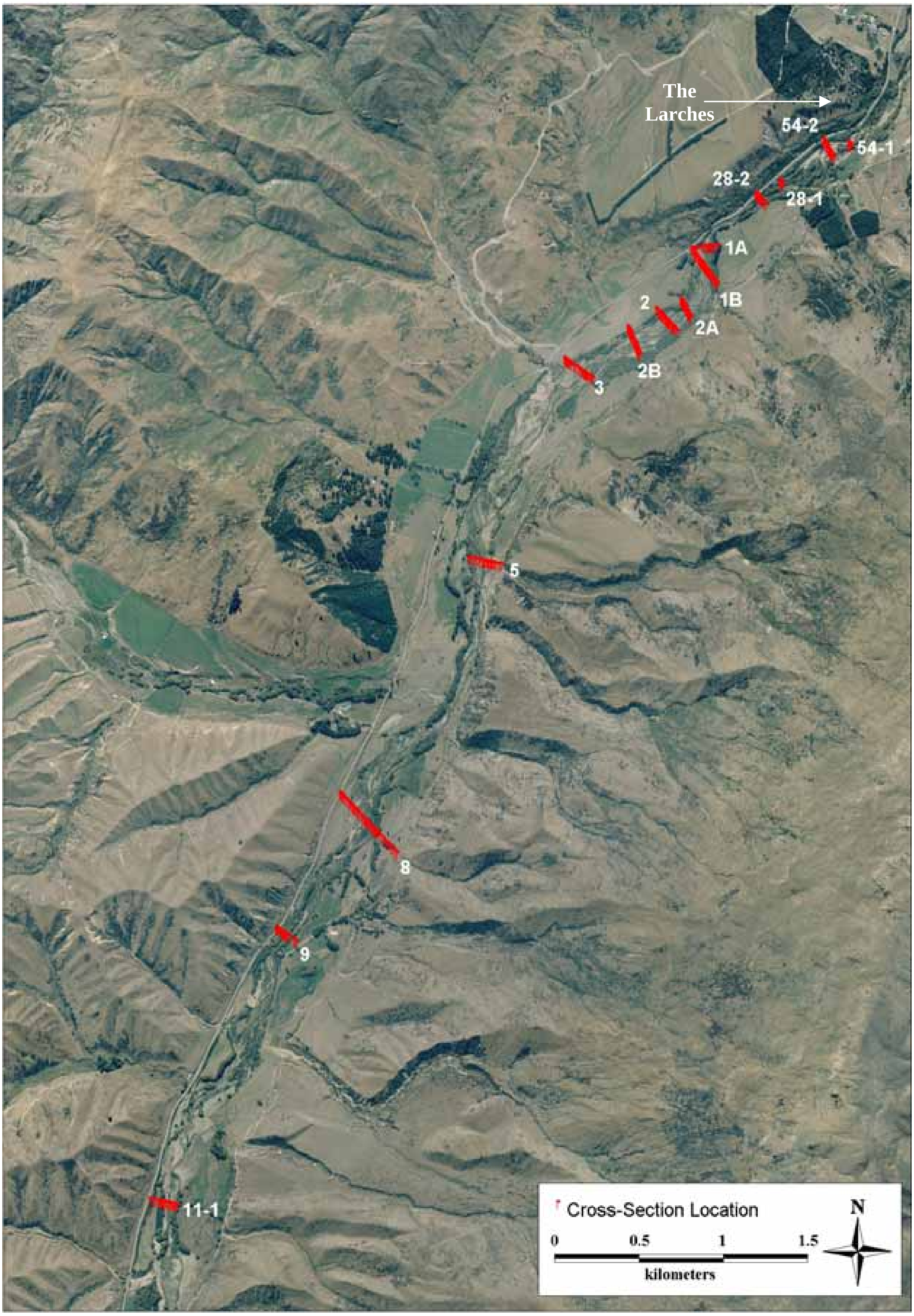

Figure 3.2 Location of surveyed cross sections for the Cardrona River mid-catchment superposed onto 2006 aerial photography

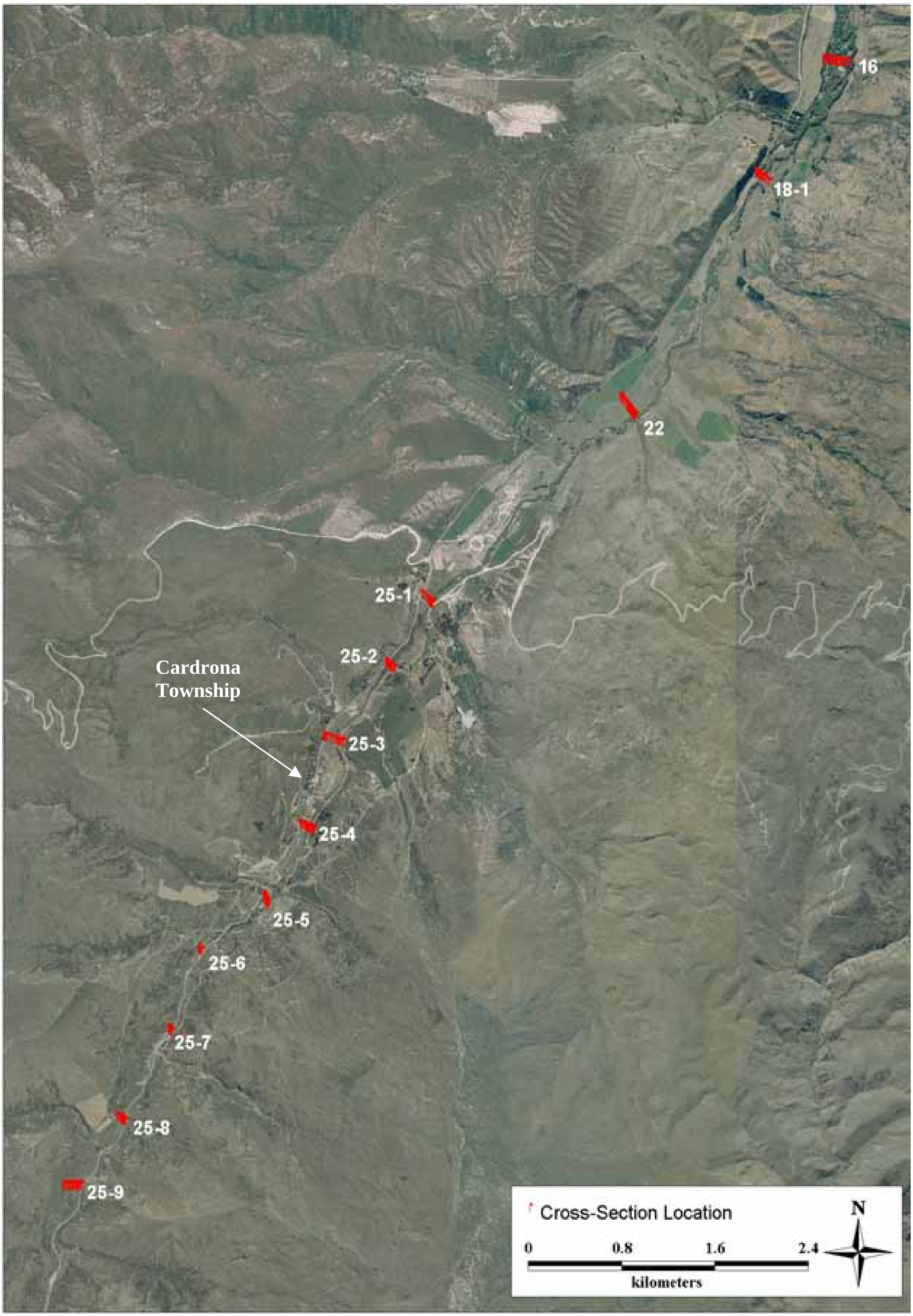

Figure 3.3 Location of surveyed cross sections for the Cardrona River upper catchment superposed onto 2006 aerial photography

4 Longitudinal profile analysis

Figures 4.1 and 4.2 show the longitudinal profile of the Cardrona River channel thalweg, the lowest point in the cross section, for 1988 and 2007. These two survey years were chosen as nearly all cross sections were surveyed in both years, and they cover a suitable temporal range of 19 years to enable long-term trends to be identified.

Figure 4.1 shows that the longitudinal profile just upstream of the Clutha River/Mata-Au confluence, from cross sections 52-1 to MWD1, has experienced degradation over the period 1988 to 2007. Upstream of cross section MWD1 to cross section 47-1, at the State Highway Bridge, thalweg levels have exhibited very little change between the two surveyed periods.

The most notable reach of thalweg degradation along the length of the Cardrona River is evident between cross sections 47-1 and 54-1 (Figure 4.1). Between 1988 and 2007, this 6.9km reach has degraded by greater than 0.7 m at every cross section location, including 1.51 m of thalweg degradation at cross section 44-1 (Table 8.1.3).

At The Larches, the longitudinal profile between cross sections 54-1 and 28-1 did not vary significantly during the period 1988 to 2007. Upstream of this location, further degradation of the channel thalweg is evident to cross section 2A, where little variation in the longitudinal profile becomes apparent. From cross section 2A to cross section 5, the profile has remained relatively unchanged over the period 1988 to 2007 (Figure 4.1).

The only notable reach of aggradation, along the length of the river, is located just upstream of Spotts Creek at cross section 8. The reach from cross section 8 to cross section 9 transitions back to exhibit further degradation. Upstream of cross section 9, the river profile did not exhibit significant change in thalweg levels during the period 1988 to 2007, apart from some degradation observed at cross section 16.

Figures 4.1 and 4.2 show that the Cardrona River longitudinal profile has been subject to presiding degradation of the channel thalweg over the period 1988 to 2007. Five reaches of notable degradation, compared to one reach of aggradation, were observed along the river's surveyed length. The presiding degradational trend indicates that the river profile has experienced significant change over this time. Of particular note is the 6.9km reach of degradation extending from the State Highway 6 Bridge to The Larches.

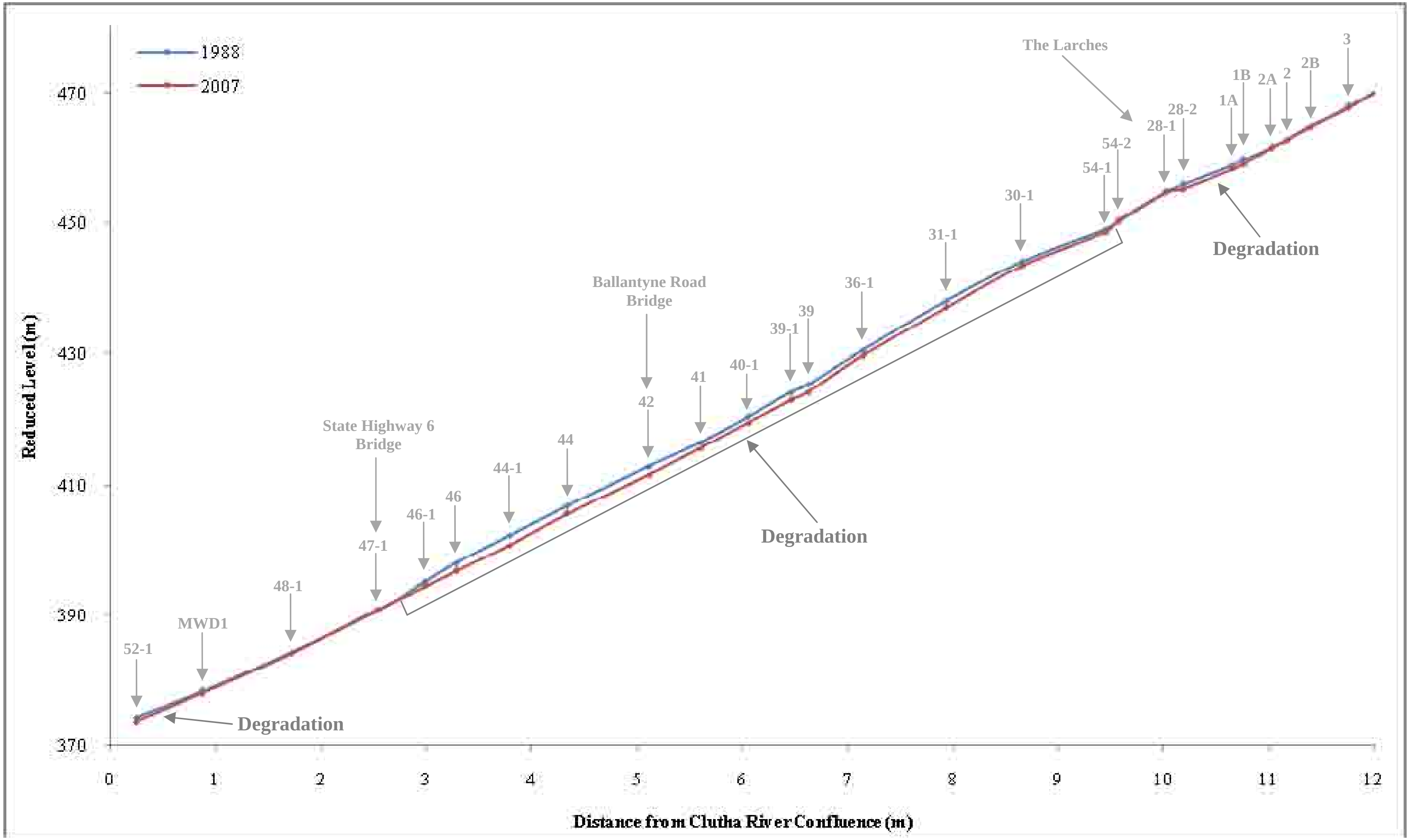

Figure 4.1 Longitudinal profile of the Cardrona River, lower to mid-reaches channel thalweg, for 1988 and 2007

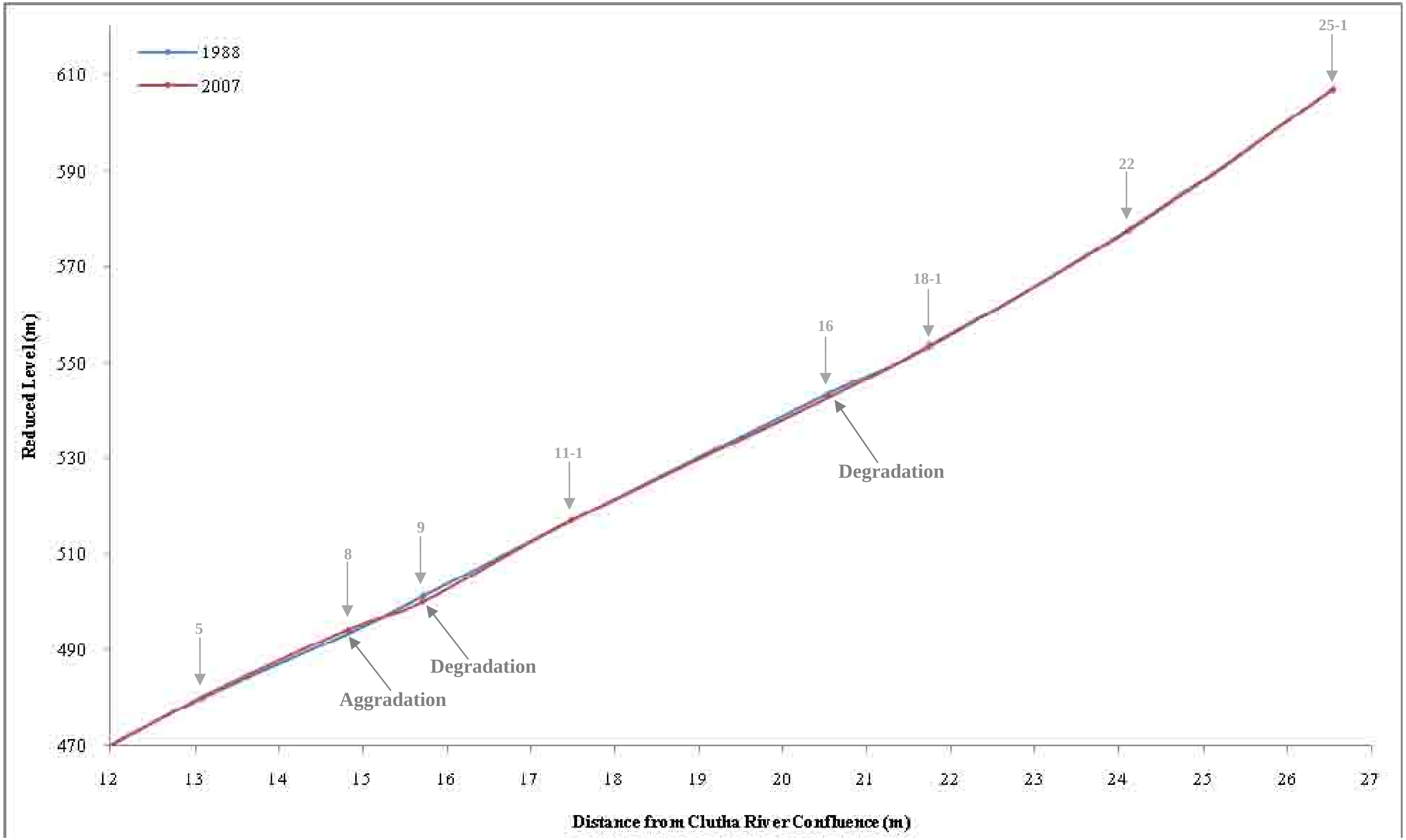

Figure 4.2 **Longitudinal profile of the Cardrona River mid-to upper reaches channel thalweg for 1988 and 2007**

5 Discussion

The Cardrona River is a very dynamic system that has experienced significant changes in sediment storage and bed levels. Historically, the river exhibited a dominant braided form in the surveyed reaches, where the channel laterally migrated between widespread point and lateral bar deposits (Figures 8.2.1 – 8.2.6).

5.1 River morphology

Contemporary channel form and development varies along the length of the river. A high degree of channel confinement in the upper reaches provides for channel-slope connectivity[2] and subsequent erosion of the basement schist. The dominant characteristic of the river's central reaches (Figures 8.2.4 – 8.2.6) is a relatively wide valley setting, associated with a reduction in profile gradient. Channel form within these reaches is influenced by sediment inputs derived from adjacent tributaries, such as the Branch Burn and Spotts Creek (Figure 2.1). In places, such as The Larches, geological and geomorphic controls dictate the river form by narrowing the valley floor considerably, in turn promoting a single-thread sinuous channel conducive to sediment transportation.

Downstream of The Larches to the State Highway, a prevailing depositional zone in the river form exists, as the river loses transport potential beyond the confines of The Larches. Naturally, these reaches are dominated by a wide, braided channel margin (Figure 5.1), which is subject to lateral migration. However, over recent decades, extensive modification of these areas, including commercial gravel extraction, has removed the braided complexity of the channel's form (Figures 8.2.2 and 8.2.3). Furthermore, this location experienced significant channel migration and aggradation during the November 1999 flood event, necessitating extensive works to re-establish the river's primary flowpath (Figure 5.2).

Figure 5.1 Braided form of the Cardrona River lower reaches in July 1952. The image was taken looking upstream (left) and downstream (right) in the reach between Ballantyne Road and the State Highway

[2] Channel-slope connectivity generally occurs where the valley is very confined. As the river channel meanders the valley floor, it often erodes into the adjacent valley slopes hence the 'connection' between channel and slope.

Figure 5.2 Ballantyne Road Bridge on 14 January 2000. Artificial embankments are evident along each side of the Cardrona River; part of the post-November 1999 remedial works

5.2 Cross section analyses

Cross section analyses and interpretations have also revealed significant change in channel form and thalweg levels, which infers a decline in the supply and storage of sediment within active channel margins. Figure 5.3 shows a graphical representation of the net change in mean bed-levels quantified for each cross section over each respective period of survey. An holistic interpretation of mean bed-level results indicates that the general trend in bed level change is one of net degradation, with some localised areas of aggradation.

Of the 34 comparable surveyed cross sections, the mean bed-level experienced net degradation at 22 locations, with 12 cross sections experiencing net aggradation. Two cross sections, 25-1 and 1A, experienced net aggradation in excess of 0.5m over surveyed periods. Comparatively, 13 cross sections experienced net degradation greater than 0.5m, of which 12 are located between The Larches and the State Highway 6 Bridge. Cross section 41 has experienced the greatest net change in mean bed-level, experiencing 1.41m of net degradation over the period 1988 to 2007. Notably, cross section 54-2 experienced net degradation of 1.38m over the nine-year survey period, 1998 to 2007 (Table 8.1.2).

Observations of the longitudinal profile (Figures 4.1 and 4.2) indicate that the Cardrona River form has, in general, been subject to a presiding degradational trend over the period 1988 to 2007. The morphometry of the 2007 profile indicates that active channel sediment storage, particularly in the 6.9km reach downstream of The Larches, has significantly decreased. Of the 34 surveyed locations, two cross sections, 54-2 and 8, had thalweg levels that increased by greater than 0.5m. In comparison, 16 cross section locations experienced lowering, or degradation, of the channel thalweg by 0.5m or greater over each survey period (Figure 5.3).

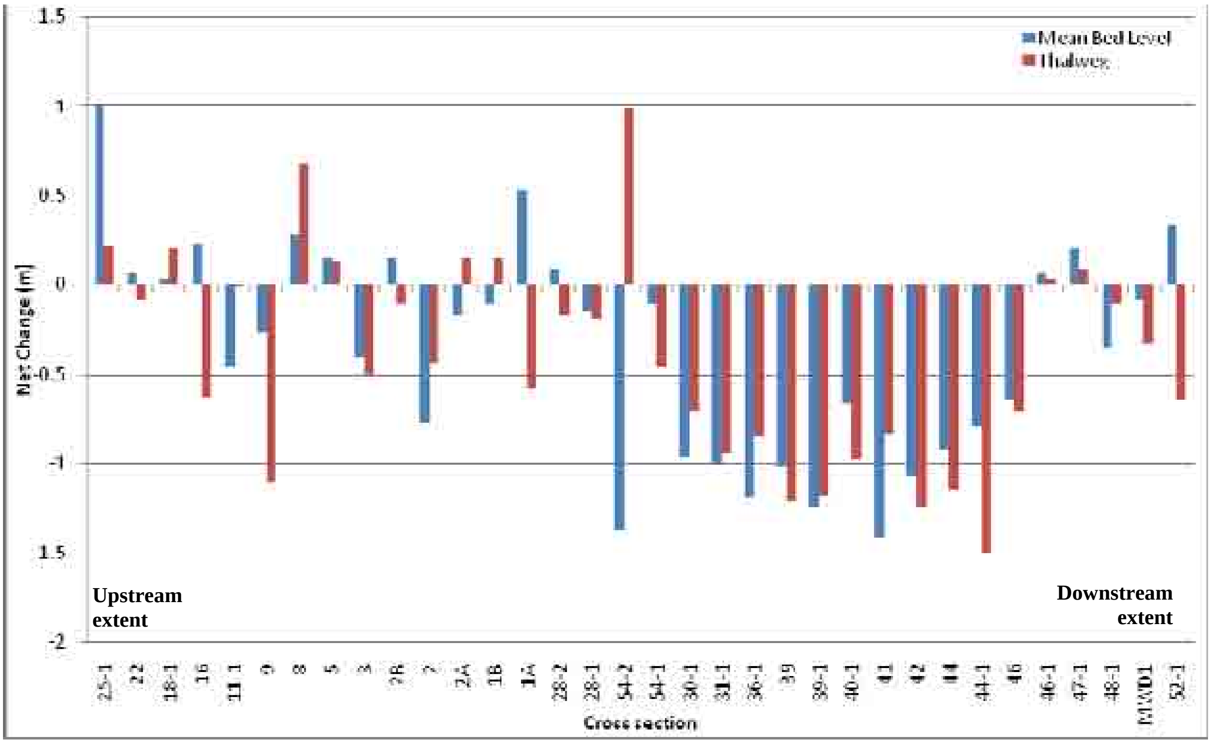

Figure 5.3 Graph showing net change in mean bed-level and thalweg level across all survey periods for each cross section

Figure 5.3 shows that, in general, thalweg levels reflect a similar trend to the respective mean bed-level change. However, some locations, such as cross section 54-2, experience net degradation of the mean bed-level and an increase in the channel thalweg. A few cross sections within the vicinity of The Larches experience these trends, which are primarily related to a significant change in channel form. This is best represented in Figure 8.3.18 where the channel form in 1988 exhibited a deep single-thread channel, which by 2007 had widened significantly, increasing the thalweg level, while lowering the mean bed-level of the cross section.

5.3 Gravel extraction

Figure 5.4 shows volumes of gravel extracted from the Cardrona River over the period 1984 to 2009, based on returns provided by gravel extractors. Historically, precise volumes of extracted gravel are not readily available, and therefore, the noted volumes are based on returns received for individual resource consents. Thus, these totals are an approximation, as they assume that returns have been filed diligently, and that they also accurately reflect the quantity extracted. Figure 5.4 represents the spatial extent of gravel extraction activities from the Clutha confluence to some 20km upstream. Over this period, in excess of 650,000m^3 of gravel has been extracted over this reach, with greater than 410,000m^3 extracted between State Highway 6 and The Larches. These equate to average annual volumes of 24,993m^3 and 15,841m^3, respectively.

Interestingly, it is this reach that has exhibited the greatest morphological change over surveyed periods and comparative aerial photograph flights. Notably, a reduction in the complexity of the braided system along these reaches is apparent and may be attributed in part to modification from gravel extraction and large flood events, such as that which occurred in November 1999.

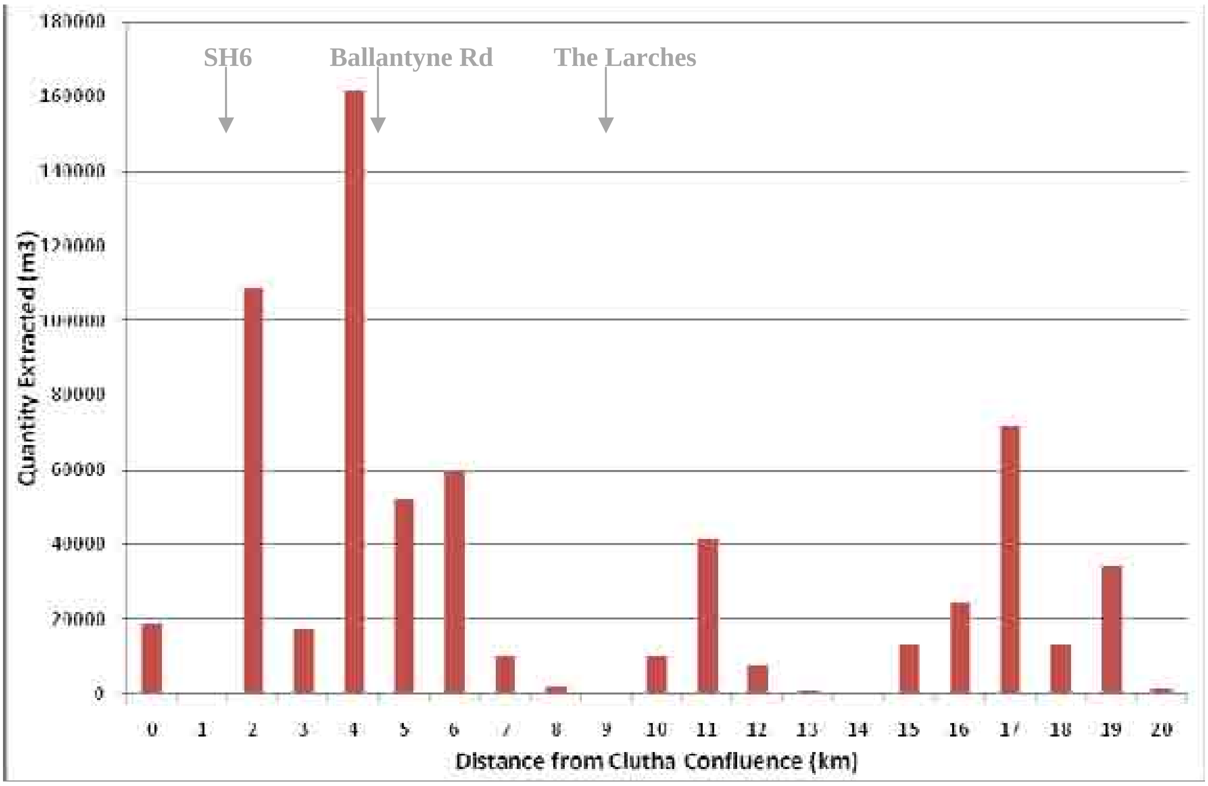

Figure 5.4 Returned gravel volumes for the period 1984 to 2009, showing indicative totals from the Clutha confluence for 20km upstream

5.4 Summary

Observed change in the Cardrona River's channel morphology and sedimentation characteristics indicates that sediment storage within the active channel margin has decreased considerably over surveyed periods. In addition, sediment replenishment within the river's main stem is primarily a function of large and/or recurrent flood events, which have sufficient energy to mobilise sediment deposits downstream. Mean bed-level and river profile analyses indicate that, while the river experienced an extraordinary sedimentation event in November 1999, the net trend over all surveyed periods has been one of net degradation. Should sediment replenishment rates along the Cardrona River main stem remain infrequent, it is anticipated that the river system will degrade further. Further degradation may contribute to bank erosion and greater channel incision along the length of the river.

6 Conclusion

Investigations into the channel morphology and sedimentation of the Cardrona River indicate that the river has experienced a significant net degradational trend over surveyed periods. Some cross section locations exhibited net aggradation of mean bed-levels and the channel thalweg, which, in general, has been attributed to localised effects of adjacent tributaries and changes in channel morphology. This study has noted that sediment storage within the active channel margin has decreased considerably over surveyed periods, with sediment replenishment of the river's main stem primarily being a function of large and/or recurrent flood events. Changes in the Cardrona River channel morphology are also apparent in aerial photography taken in 1966, which shows a naturally braided, sediment-rich active channel margin. Subsequent photography, during the late 1990s and in 2006, indicates that the braided complexity of the natural river form has been lost due to extensive modification of the active channel and a reduction in sediment replenishment rates.

7 References

McDonnell, M., Craw, D., (2003) *Stratigraphy and provenance of Pliocene greywacke-bearing conglomerate, Cardrona valley, Otago, New Zealand,* New Zealand Journal of Geology and Geophysics, 46 pp. 425-436.

Opus International Consultants (2005) *Seismic Risk in the Otago Region – Study Report,* Client Report SPT: 2004/23, Ref: 5C0656.00 for Otago Regional Council.

Otago Regional Council (2007) *The Water Resources of the Cardrona River*, Otago Regional Council publication.

Turnbull, I.M., (2000) *Geology of the Wakatipu Area*, Institute of Geological and Nuclear Sciences Limited, Lower Hutt, New Zealand.

8 Appendices

8.1 Cross section results

Table 8.1.1 Mean bed-level results[3] for surveyed cross sections of the Cardrona River. (A blank space indicates that the cross section was not surveyed that year)

X-section	Feb-85	Feb-88	Oct-89	Jan-96	Dec-96	Jan-98	Apr-99	Feb-00	Apr-00	Sep-02	Oct-02	Dec-02	Aug-03	Nov-03	Jan-07
52-1		375.53							376.44					376.05	375.86
MWD1		379.23							379.38					379.19	379.15
48-1		385.38							385.29					384.88	385.02
47-1		391.52					391.58		392.04			391.72			
46-1							395.66	396.27				395.87			395.73
46		398.51	398.39	398.25			397.54	397.85				397.87			
44-1		402.85	402.65	402.79			402.61	402.73				402.69			402.05
44		407.64	407.29	407.14			407.01					407.09			406.71
42		413.21	413.20	412.91			412.38					412.43			412.14
41		417.65	417.46	416.93			416.62					416.50			416.24
40-1		421.04	420.95	421.01			420.79							420.40	420.37
39-1		425.10		424.83			424.76					423.91	423.90		423.86
39		426.22		426.02			426.05					425.23	425.12		425.20
36-1		431.52		430.80			430.65					430.56	430.54		430.33
31-1		438.82					437.95					437.87	437.88		437.81
30-1		445.05						444.70				444.32			444.08
54-1		449.21				448.22						449.58			449.10
54-2						453.05								451.91	451.67
28-1		455.51	455.00			455.54						455.71			455.37
28-2						456.51								456.87	456.60
1A		459.13	459.28		459.77					459.60	459.79				459.66
1B	460.32	460.39												460.32	460.22
2A										462.44	462.35				462.27
2	464.27	463.82			464.28			464.32		463.89	463.72				463.50
2B										465.54	465.68				465.69
3	469.20	468.90			469.46			469.31						468.83	468.79
5		480.83			480.87			480.96						480.99	480.98
8		494.76												495.12	495.04
9		502.14						501.79						501.89	501.87
11-1		518.01												517.60	517.55
16		544.26						544.46						544.62	544.48
18-1		554.56												554.58	554.59
22		579.04												579.03	579.11

[3] Mean bed-levels are expressed in the Otago Datum, which lies 100m below the Dunedin Vertical Datum 1958.

<table>
<tr><td>25-1</td><td></td><td>606.96</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>607.38</td><td>607.97</td></tr>
</table>

Table 8.1.2 Net change in mean bed-level for each respective survey period

<table>
<tr><th>X-section</th><th>Feb-85 to Feb-88</th><th>Feb-88 to Oct-89</th><th>Oct-89 to Jan-96</th><th>Jan-96 to Dec-96</th><th>Dec-96 to Jan-98</th><th>Jan-98 to Apr-99</th><th>Apr-99 to Feb-00</th><th>Feb-00 to Apr-00</th><th>Apr-00 to Sep-02</th><th>Sep-02 to Oct-02</th><th>Oct-02 to Dec-02</th><th>Dec-02 to Aug-03</th><th>Aug-03 to Nov-03</th><th>Nov-03 to Jan-07</th><th>Net change</th></tr>
<tr><td>52-1</td><td></td><td colspan="7">+0.91</td><td colspan="5">-0.39</td><td>-0.19</td><td>+0.33</td></tr>
<tr><td>MWD1</td><td></td><td colspan="7">+0.15</td><td colspan="5">-0.19</td><td>-0.04</td><td>-0.08</td></tr>
<tr><td>48-1</td><td></td><td colspan="7">-0.09</td><td colspan="5">-0.41</td><td>+0.14</td><td>-0.36</td></tr>
<tr><td>47-1</td><td></td><td colspan="5">+0.06</td><td colspan="2">+0.46</td><td colspan="3">-0.32</td><td></td><td></td><td></td><td>+0.20</td></tr>
<tr><td>46-1</td><td></td><td></td><td></td><td></td><td></td><td></td><td>+0.61</td><td colspan="4">-0.40</td><td colspan="3">-0.14</td><td>+0.07</td></tr>
<tr><td>46</td><td></td><td>-0.12</td><td>-0.14</td><td colspan="3">-0.71</td><td>+0.31</td><td colspan="4">+0.02</td><td></td><td></td><td></td><td>-0.64</td></tr>
<tr><td>44-1</td><td></td><td>-0.20</td><td>+0.14</td><td colspan="3">-0.18</td><td>+0.12</td><td colspan="4">-0.04</td><td colspan="3">-0.64</td><td>-0.80</td></tr>
<tr><td>44</td><td></td><td>-0.35</td><td>-0.15</td><td colspan="3">-0.13</td><td colspan="5">+0.08</td><td colspan="3">-0.38</td><td>-0.93</td></tr>
<tr><td>42</td><td></td><td>-0.01</td><td>-0.29</td><td colspan="3">-0.53</td><td colspan="5">+0.05</td><td colspan="3">-0.29</td><td>-1.07</td></tr>
<tr><td>41</td><td></td><td>-0.19</td><td>-0.53</td><td colspan="3">-0.31</td><td colspan="5">-0.12</td><td colspan="3">-0.26</td><td>-1.41</td></tr>
<tr><td>40-1</td><td></td><td>-0.09</td><td>+0.06</td><td colspan="3">-0.22</td><td colspan="7">-0.39</td><td>-0.03</td><td>-0.67</td></tr>
<tr><td>39-1</td><td></td><td colspan="2">-0.27</td><td colspan="3">-0.07</td><td colspan="5">-0.85</td><td>-0.01</td><td colspan="2">-0.04</td><td>-1.24</td></tr>
<tr><td>39</td><td></td><td colspan="2">-0.20</td><td colspan="3">+0.03</td><td colspan="5">-0.82</td><td>-0.11</td><td colspan="2">+0.08</td><td>-1.02</td></tr>
<tr><td>36-1</td><td></td><td colspan="2">-0.72</td><td colspan="3">-0.15</td><td colspan="5">-0.09</td><td>-0.02</td><td colspan="2">-0.21</td><td>-1.19</td></tr>
<tr><td>31-1</td><td></td><td colspan="5">-0.87</td><td colspan="5">-0.08</td><td>+0.01</td><td colspan="2">-0.07</td><td>-1.01</td></tr>
<tr><td>30-1</td><td></td><td colspan="6">-0.35</td><td colspan="4">-0.38</td><td colspan="3">-0.24</td><td>-0.97</td></tr>
<tr><td>54-1</td><td></td><td colspan="4">-0.99</td><td colspan="6">+1.36</td><td colspan="3">-0.48</td><td>-0.11</td></tr>
<tr><td>54-2</td><td></td><td></td><td></td><td></td><td></td><td colspan="8">-1.14</td><td>-0.24</td><td>-1.38</td></tr>
<tr><td>28-1</td><td></td><td>-0.51</td><td colspan="3">+0.54</td><td colspan="6">+0.17</td><td colspan="3">-0.34</td><td>-0.14</td></tr>
<tr><td>28-2</td><td></td><td></td><td></td><td></td><td></td><td colspan="8">+0.36</td><td>-0.27</td><td>+0.09</td></tr>
<tr><td>1A</td><td></td><td>+0.15</td><td colspan="2">+0.49</td><td colspan="5">-0.17</td><td>+0.19</td><td colspan="4">-0.13</td><td>+0.53</td></tr>
<tr><td>1B</td><td>+0.07</td><td colspan="12">-0.07</td><td>-0.10</td><td>-0.10</td></tr>
<tr><td>2A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>-0.09</td><td colspan="4">-0.08</td><td>-0.17</td></tr>
<tr><td>2</td><td>-0.45</td><td colspan="3">+0.46</td><td colspan="3">+0.04</td><td colspan="2">-0.43</td><td>-0.17</td><td colspan="4">-0.22</td><td>-0.77</td></tr>
<tr><td>2B</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>+0.14</td><td colspan="4">+0.01</td><td>+0.15</td></tr>
<tr><td>3</td><td>-0.30</td><td colspan="3">+0.56</td><td colspan="3">-0.15</td><td colspan="6">-0.48</td><td>-0.04</td><td>-0.41</td></tr>
<tr><td>5</td><td></td><td colspan="3">+0.04</td><td colspan="3">+0.09</td><td colspan="6">+0.03</td><td>-0.01</td><td>+0.15</td></tr>
<tr><td>8</td><td></td><td colspan="12">+0.36</td><td>-0.08</td><td>+0.28</td></tr>
<tr><td>9</td><td></td><td colspan="6">-0.35</td><td colspan="6">+0.10</td><td>-0.02</td><td>-0.27</td></tr>
<tr><td>11-1</td><td></td><td colspan="12">-0.41</td><td>-0.05</td><td>-0.46</td></tr>
<tr><td>16</td><td></td><td colspan="6">+0.20</td><td colspan="6">+0.16</td><td>-0.14</td><td>+0.22</td></tr>
<tr><td>18-1</td><td></td><td colspan="12">+0.02</td><td>+0.01</td><td>+0.03</td></tr>
<tr><td>22</td><td></td><td colspan="12">-0.01</td><td>+0.08</td><td>+0.07</td></tr>
<tr><td>25-1</td><td></td><td colspan="12">+0.42</td><td>+0.59</td><td>+1.01</td></tr>
</table>

Table 8.1.3 Net change in channel thalweg[4] level for each respective survey period

<table>
<tr><th>X-section</th><th>Feb-85 to Feb-88</th><th>Feb-88 to Oct-89</th><th>Oct-89 to Jan-96</th><th>Jan-96 to Dec-96</th><th>Dec-96 to Jan-98</th><th>Jan-98 to Apr-99</th><th>Apr-99 to Feb-00</th><th>Feb-00 to Apr-00</th><th>Apr-00 to Sep-02</th><th>Sep-02 to Oct-02</th><th>Oct-02 to Dec-02</th><th>Dec-02 to Aug-03</th><th>Aug-03 to Nov-03</th><th>Nov-03 to Jan-07</th><th>Net change</th></tr>
<tr><td>52-1</td><td></td><td colspan="7">+0.84</td><td colspan="5">-1.14</td><td>-0.34</td><td>-0.64</td></tr>
<tr><td>MWD1</td><td></td><td colspan="7">+0.12</td><td colspan="5">-0.33</td><td>-0.12</td><td>-0.33</td></tr>
<tr><td>48-1</td><td></td><td colspan="7">+0.16</td><td colspan="5">-0.08</td><td>-0.19</td><td>-0.11</td></tr>
<tr><td>47-1</td><td></td><td colspan="5">+0.06</td><td colspan="2">+0.50</td><td colspan="3">-0.47</td><td></td><td></td><td></td><td>+0.09</td></tr>
<tr><td>46-1</td><td></td><td></td><td></td><td></td><td></td><td></td><td>+0.85</td><td colspan="4">-0.05</td><td colspan="3">-0.77</td><td>+0.03</td></tr>
<tr><td>46</td><td></td><td>-0.47</td><td>-0.16</td><td colspan="3">-1.10</td><td>+0.24</td><td colspan="4">+0.79</td><td></td><td></td><td></td><td>-0.70</td></tr>
<tr><td>44-1</td><td></td><td>-0.42</td><td>+0.26</td><td colspan="3">+0.01</td><td>-0.55</td><td colspan="4">+0.21</td><td colspan="3">-1.02</td><td>-1.51</td></tr>
<tr><td>44</td><td></td><td>-0.51</td><td>+0.03</td><td colspan="3">+0.03</td><td colspan="5">+0.16</td><td colspan="3">-0.86</td><td>-1.15</td></tr>
<tr><td>42</td><td></td><td>+0.12</td><td>-0.64</td><td colspan="3">-0.40</td><td colspan="5">+0.30</td><td colspan="3">-0.63</td><td>-1.25</td></tr>
<tr><td>41</td><td></td><td>-0.19</td><td>+0.03</td><td colspan="3">-0.65</td><td colspan="5">+0.47</td><td colspan="3">-0.49</td><td>-0.83</td></tr>
<tr><td>40-1</td><td></td><td>-0.37</td><td>-0.21</td><td colspan="3">+0.36</td><td colspan="7">-0.42</td><td>-0.34</td><td>-0.98</td></tr>
<tr><td>39-1</td><td></td><td colspan="2">+0.73</td><td colspan="3">-0.86</td><td colspan="5">-1.04</td><td>+0.20</td><td colspan="2">-0.21</td><td>-1.18</td></tr>
<tr><td>39</td><td></td><td colspan="2">0.00</td><td colspan="3">-0.18</td><td colspan="5">-1.04</td><td>+0.22</td><td colspan="2">-0.21</td><td>-1.21</td></tr>
<tr><td>36-1</td><td></td><td colspan="2">-0.67</td><td colspan="3">+0.29</td><td colspan="5">-0.38</td><td>+0.02</td><td colspan="2">-0.11</td><td>-0.85</td></tr>
<tr><td>31-1</td><td></td><td colspan="5">-0.94</td><td colspan="5">-0.20</td><td>+0.33</td><td colspan="2">-0.14</td><td>-0.95</td></tr>
<tr><td>30-1</td><td></td><td colspan="6">-0.46</td><td colspan="4">-0.29</td><td colspan="3">+0.04</td><td>-0.71</td></tr>
<tr><td>54-1</td><td></td><td colspan="4">-1.18</td><td colspan="6">+1.62</td><td colspan="3">-0.90</td><td>-0.46</td></tr>
<tr><td>54-2</td><td></td><td></td><td></td><td></td><td></td><td colspan="8">+1.61</td><td>-0.62</td><td>+0.99</td></tr>
<tr><td>28-1</td><td></td><td>-0.05</td><td colspan="3">-0.18</td><td colspan="6">+0.41</td><td colspan="3">-0.38</td><td>-0.20</td></tr>
<tr><td>28-2</td><td></td><td></td><td></td><td></td><td></td><td colspan="8">-0.02</td><td>-0.16</td><td>-0.18</td></tr>
<tr><td>1A</td><td></td><td>-0.21</td><td colspan="2">+0.05</td><td colspan="5">-0.27</td><td>+0.17</td><td colspan="4">-0.32</td><td>-0.58</td></tr>
<tr><td>1B</td><td>+0.92</td><td colspan="12">-0.11</td><td>-0.66</td><td>+0.15</td></tr>
<tr><td>2A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>+0.07</td><td colspan="4">+0.08</td><td>+0.15</td></tr>
<tr><td>2</td><td>-0.45</td><td colspan="3">+0.76</td><td colspan="3">-0.02</td><td colspan="2">-0.64</td><td>+0.21</td><td colspan="4">-0.30</td><td>-0.44</td></tr>
<tr><td>2B</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>+0.13</td><td colspan="4">-0.24</td><td>-0.11</td></tr>
<tr><td>3</td><td>-0.11</td><td colspan="3">-0.07</td><td colspan="3">+0.13</td><td colspan="6">+0.09</td><td>-0.54</td><td>-0.50</td></tr>
<tr><td>5</td><td></td><td colspan="3">-0.35</td><td colspan="3">+0.22</td><td colspan="6">+0.19</td><td>+0.07</td><td>+0.13</td></tr>
<tr><td>8</td><td></td><td colspan="12">+0.54</td><td>+0.14</td><td>+0.68</td></tr>
<tr><td>9</td><td></td><td colspan="6">-0.87</td><td colspan="6">+0.24</td><td>-0.47</td><td>-1.10</td></tr>
<tr><td>11-1</td><td></td><td colspan="12">-0.03</td><td>+0.02</td><td>-0.01</td></tr>
<tr><td>16</td><td></td><td colspan="6">-1.03</td><td colspan="6">-0.09</td><td>+0.49</td><td>-0.63</td></tr>
<tr><td>18-1</td><td></td><td colspan="12">-0.17</td><td>+0.37</td><td>+0.20</td></tr>
<tr><td>22</td><td></td><td colspan="12">-0.14</td><td>+0.06</td><td>-0.08</td></tr>
<tr><td>25-1</td><td></td><td colspan="12">-0.04</td><td>+0.25</td><td>+0.21</td></tr>
</table>

[4] The thalweg is the lowest point of the cross section (i.e. the deepest part of the channel)

8.2 Aerial photography

Figure 8.2.1 Aerial images of the Cardrona River in the vicinity of cross sections 52-1 to 47-1 for 1966, 1997 and 2006. These cross sections are located downstream of the State Highway 6 Bridge and between 0.25 and 2.5km upstream of the Clutha River/Mata-Au confluence

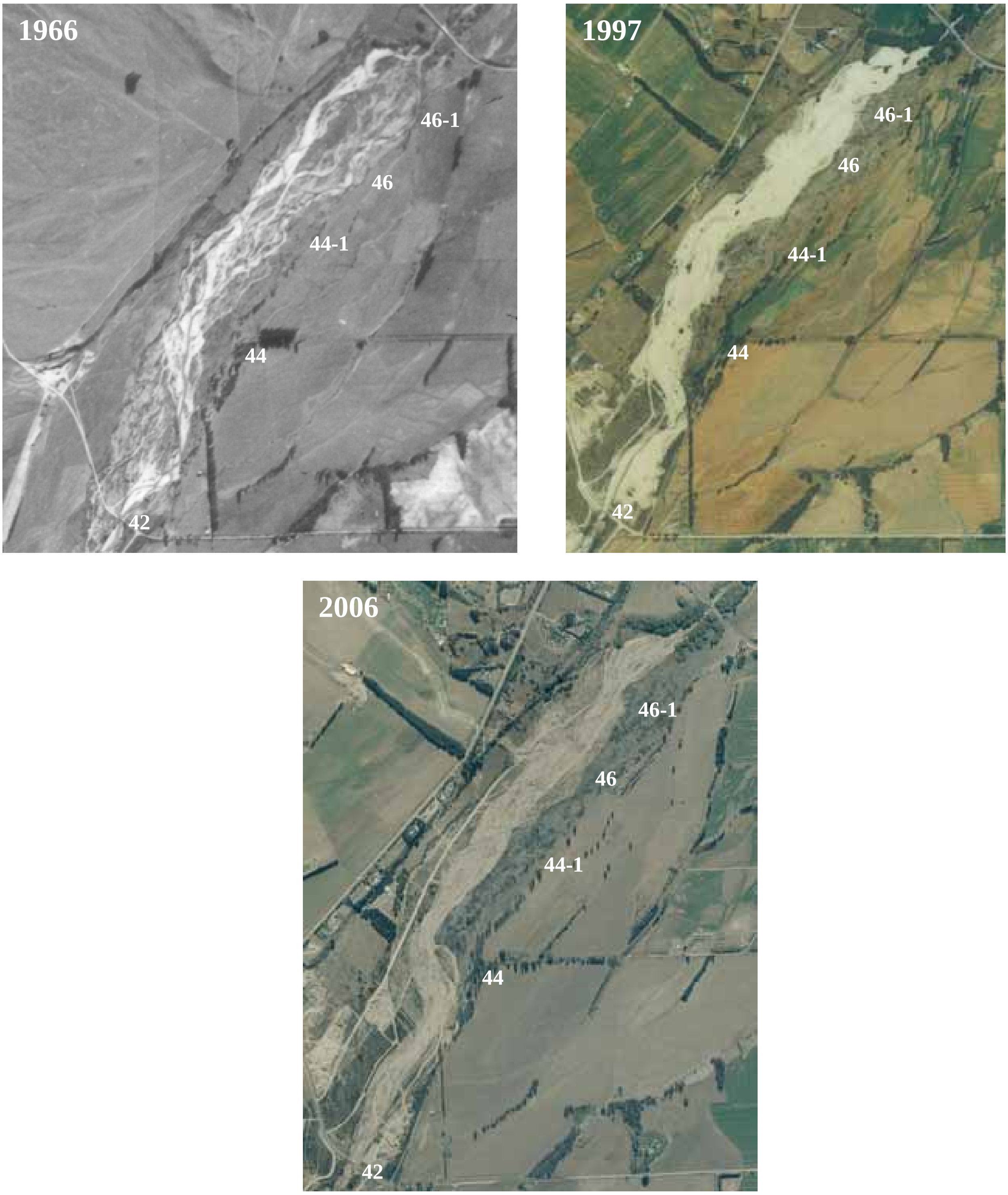

Figure 8.2.2 Aerial images of the Cardrona River in the vicinity of cross sections 46-1 to 42 for 1966, 1997 and 2006. These cross sections are located between the State Highway 6 and Ballantyne Road bridges and are between 3 and 5.1km upstream of the Clutha River/Mata-Au confluence

Figure 8.2.3 Aerial images of the Cardrona River in the vicinity of cross sections 41 to 30-1 for 1966, 1997 and 2006. These cross sections are located between the Ballantyne Road bridge and The Larches and are between 5.6 and 8.7km upstream of the Clutha River/Mata-Au confluence

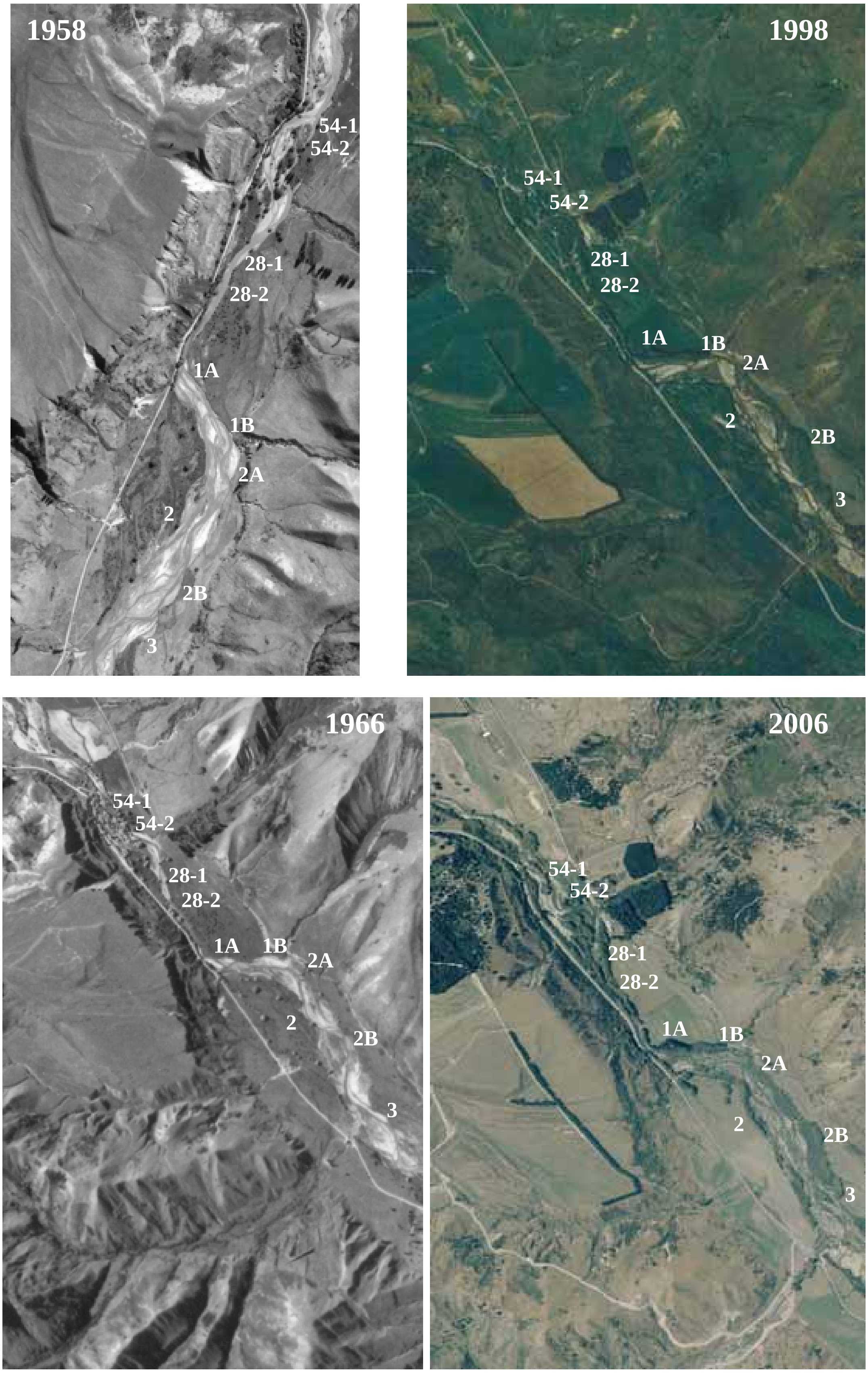

Figure 8.2.4 Aerial images of the Cardrona River in the vicinity of cross sections 54-1 to 3 for 1958, 1966, 1998 and 2006. These cross sections are located between The Larches and Timber Creek and are between 9.4 and 11.8km upstream of the Clutha River/Mata-Au confluence

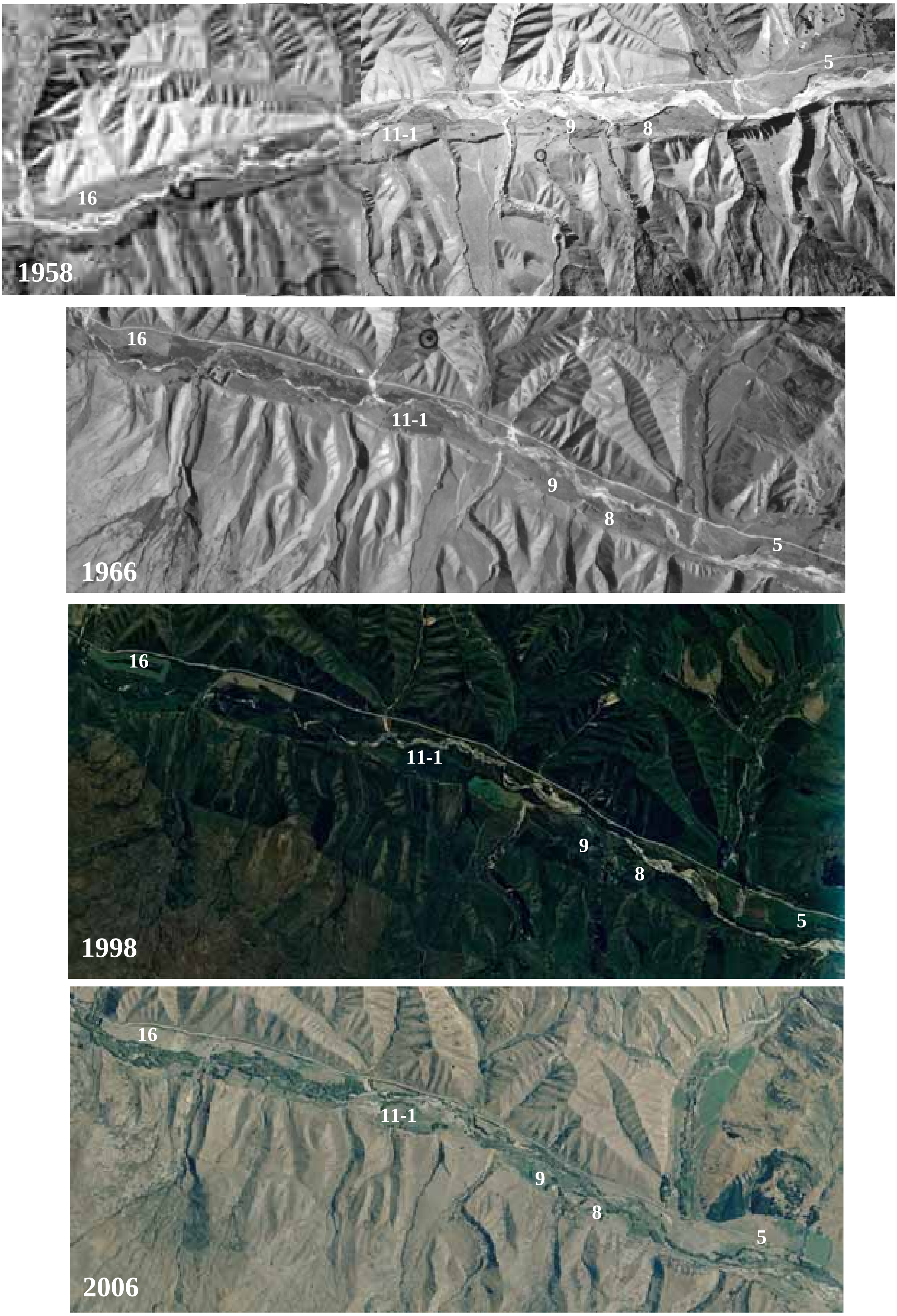

Figure 8.2.5 Aerial images of the Cardrona River in the vicinity of cross sections 5 to 16 for 1958, 1966, 1998 and 2006. These cross sections are located between Timber Creek and the Branch Burn and are between 13.1 and 20.5km upstream of the Clutha River/Mata-Au confluence.

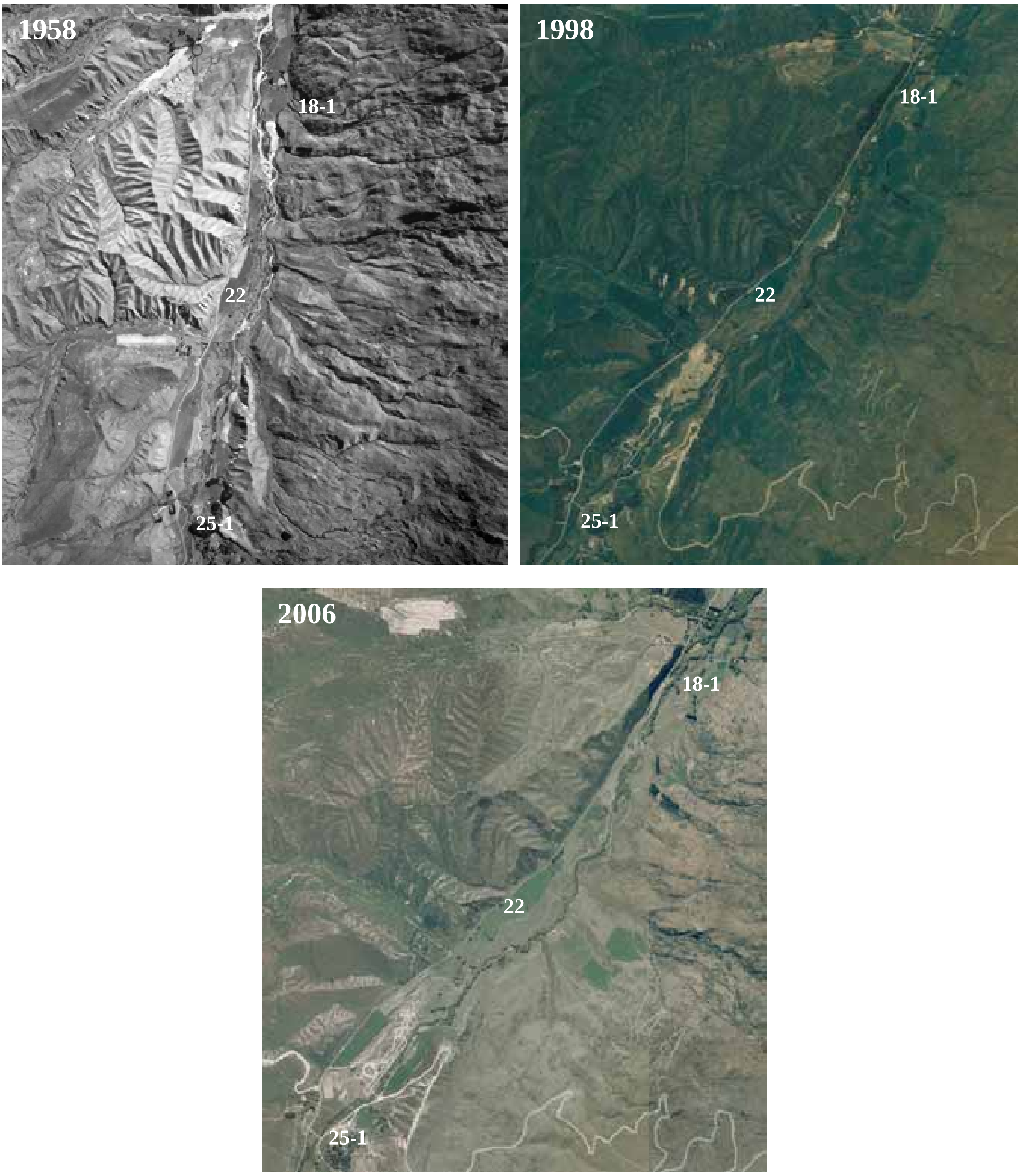

Figure 8.2.6 Aerial images of the Cardrona River in the vicinity of cross sections 18-1 to 25-1 for 1958, 1998 and 2006. These cross sections are located between the Branch Burn and Cardrona township and are between 21.7 and 26.5km upstream of the Clutha River/Mata-Au confluence

8.3 Individual cross sections

8.3.1 Cross section 52-1

Cross section 52-1 extends across the upper margins of the Cardrona River delta, approximately 250m upstream of the Clutha River/Mata-Au confluence (Figure 2.1). Figure 8.3.1 shows a plot of cross section 52-1 for the February 1988, April 2000, November 2003 and January 2007 surveys.

Recent surveys, 2000 to 2007, indicate that the primary active channel margin has been located on the true left of the delta since channel re-establishment after the November 1999 flood. Mean bed-level analysis shows net aggradation of 0.33m during the period 1988 and 2007 (Table 8.1.2). Most aggradation occurred during the period February 1988 and April 2000, which could be indicative of sedimentation resulting from large flood events during the mid-1990s and in November 1999. However, since the April 2000 survey, a presiding trend of net degradation has become prevalent, with the most recent survey period, 2003 to 2007, experiencing net degradation of 0.19m. This degradational trend is further represented by a lowering of the channel thalweg by 0.64m over the period 1988 to 2007.

The gravel embankment shown on the April 2000 cross section is inferred to be a result of channel re-establishment after the November 1999 flood event.

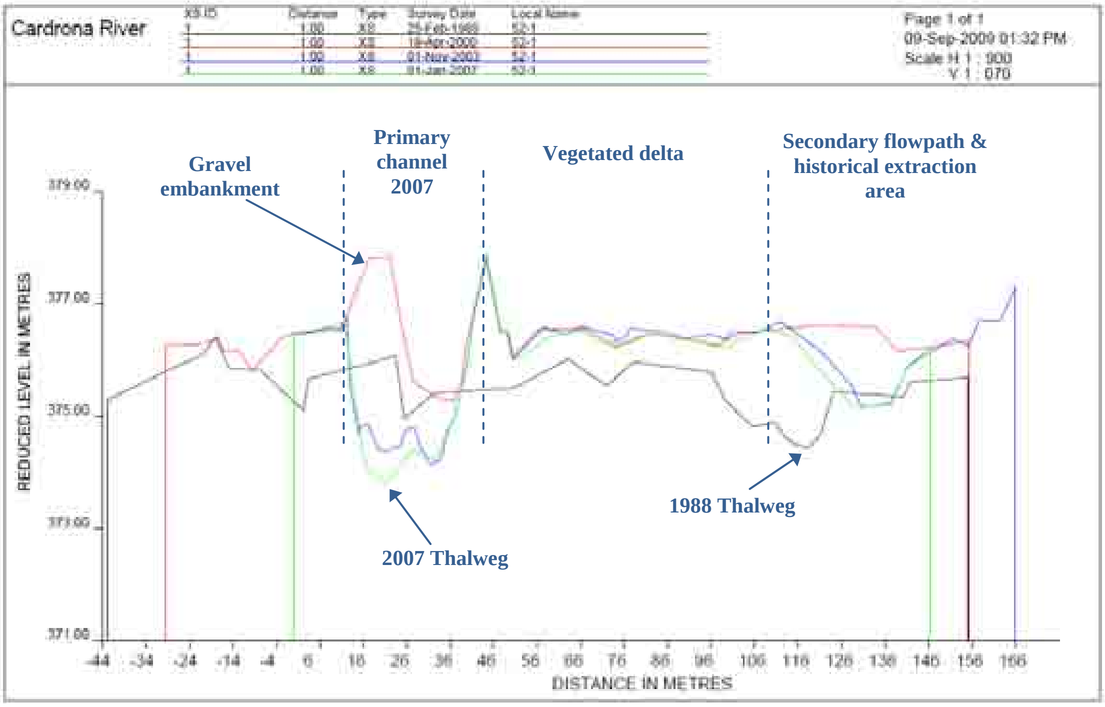

Figure 8.3.1 Cross section 52-1, looking downstream

8.3.2 Cross section MWD1

Cross section MWD1 is located approximately 0.9km upstream of the Clutha River/Mata-Au confluence and adjacent to the lateral margins of the Albert Town community. Figure 8.3.2 shows a plot of cross section MWD1 for the February 1988, April 2000, November 2003 and January 2007 surveys.

The active channel covers a surveyed width of 24.5m at this location. Mean bed-level analysis shows net degradation of 0.08m over the active channel width during the period 1988 and 2007 (Table 8.1.2). Similar to cross section 52-1, this location experienced net aggradation between 1988 and 2000, with subsequent survey periods showing a degradational trend. This trend is also reflected by a lowering of the channel thalweg by 0.33m during the period 1988 to 2007 (Table 8.1.3).

The geomorphology of this location is indicative of the lower reaches of the river downstream of the State Highway 6 Bridge. Since 1958, willow growth, has led to a general decrease in the width of the active channel zone and contributed to a relatively stable active margin. This has likely increased sediment transport rates through this reach, by confining lower magnitude flows within a reduced width to depth ratio channel. The observed lowering of the channel thalweg and degradational trend in mean bed-levels may reflect the increased sediment transport rates at this location.

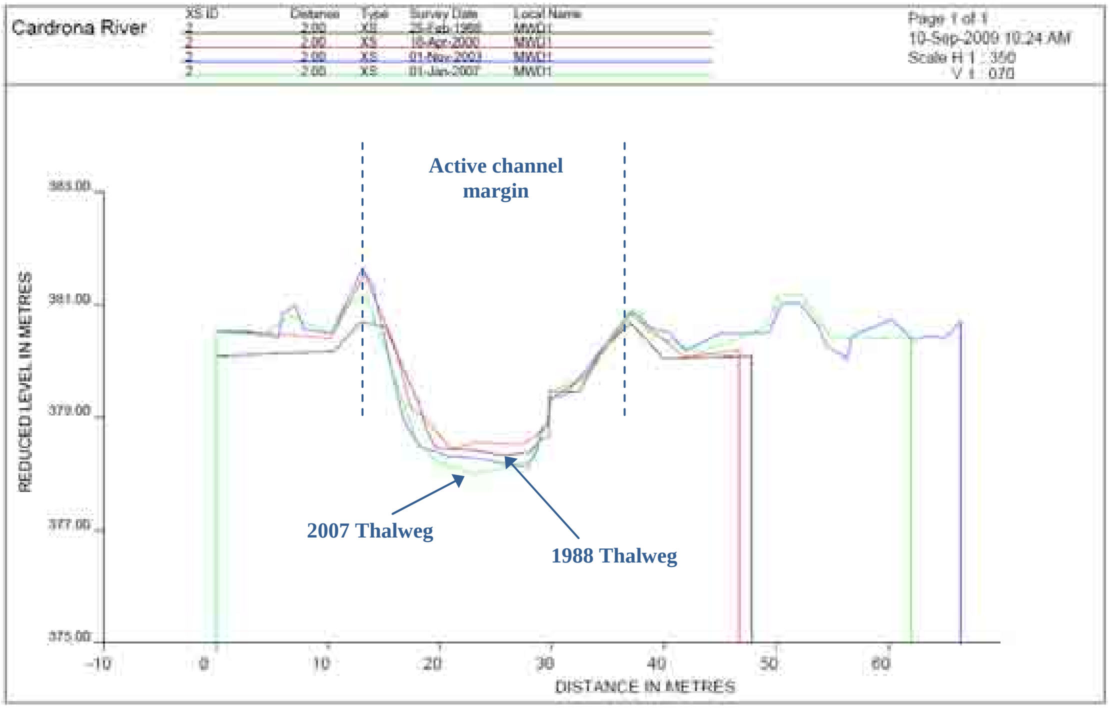

Figure 8.3.2 Cross section MWD1, looking downstream

8.3.3 Cross section 48-1

Cross section 48-1 is located approximately 1.7km upstream of the Clutha River/Mata-Au confluence and 0.78km downstream of the State Highway 6 Bridge. Figure 8.3.3 shows a plot of cross section 48-1 for the February 1988, April 2000, November 2003 and January 2007 surveys.

The 1988 active channel margin covered a distance of 26.50m, which had increased to 53.61m by November 2003. Mean bed-level analysis shows net degradation of 0.36m over the active channel width during the period 1988 and 2007 (Table 8.1.2). The largest proportion of net degradation, 0.41m, occurred during the period 2000 to 2003, coinciding with some 27.1m of right bank erosion (Figure 8.3.3). At this location, bed levels have slightly recovered in the most recent survey period, 2003 to 2007, with net aggradation of 0.14m. During the period 1988 to 2007, the thalweg has lowered by 0.11m at this cross section.

The morphology of the channel at this cross section is similar to the single thread, confined nature observed downstream of the State Highway. The extent of right bank erosion at this cross section is difficult to attribute to any particular event. It is unclear whether the bank position represented in the April 2000 cross section is the true right bank or an embankment from channel re-alignment following November 1999.

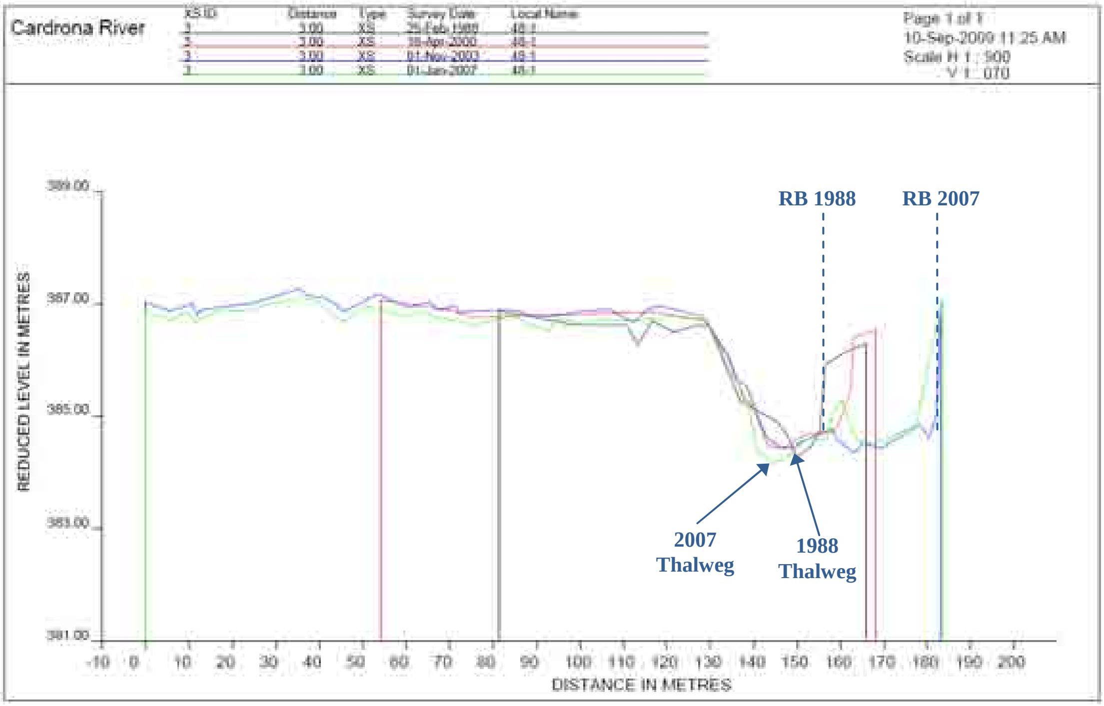

Figure 8.3.3 **Cross section 48-1, looking downstream**

8.3.4 Cross section 47-1

Cross section 47-1 is located at the State Highway 6 Bridge, approximately 2.5km upstream of the Clutha River/Mata-Au confluence. Figure 8.3.4 shows a plot of cross section 47-1 for the February 1988, April 1999, April 2000 and December 2002 surveys.

The active channel covers a surveyed width of 36.1m and is confined by the State Highway bridge abutments at this location. Mean bed-level analysis shows net aggradation of 0.20m over the active channel width during the period 1988 to 2002. This cross section was not re-surveyed in January 2007; although net degradation of 0.32m was observed over the last survey period, April 2000 to December 2002. The level of the channel thalweg also reflects similar variation to bed levels, in that during the period 1988 to 2000, it had aggraded by 0.56m, but by 2002, it had lowered 0.47m.

The morphology of the channel at this cross section is largely dictated by the constraints of the bridge.

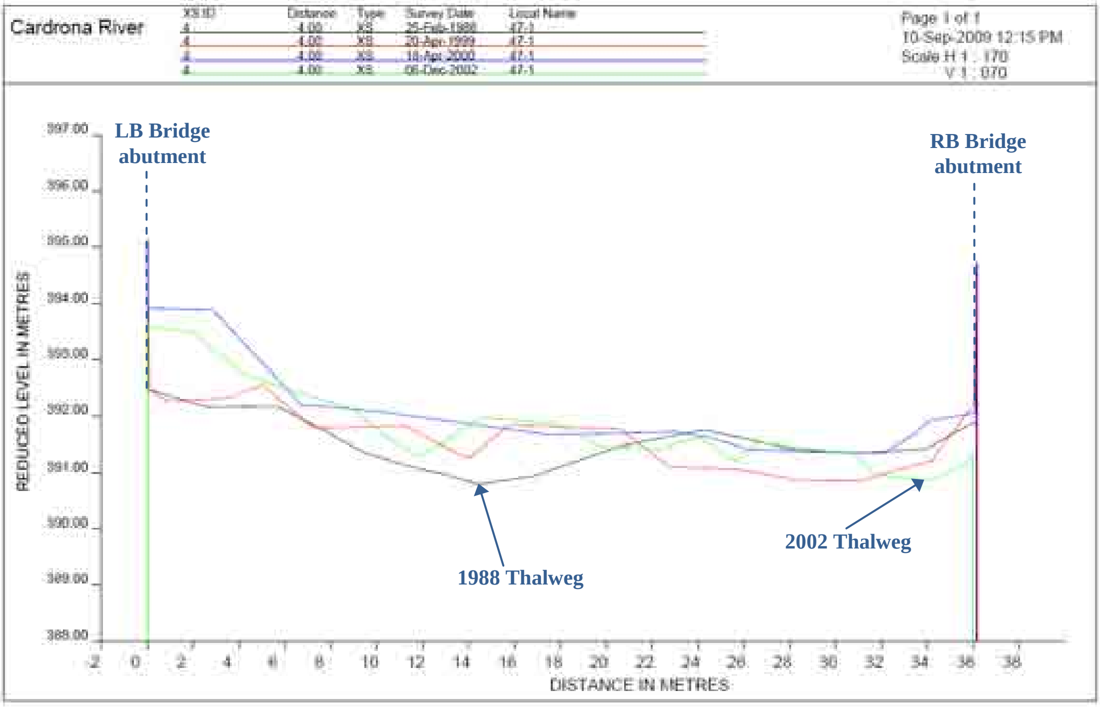

Figure 8.3.4 Cross section 47-1, looking downstream

8.3.5 Cross section 46-1

Cross section 46-1 is located approximately 3km upstream of the Clutha River/Mata-Au confluence and 0.5km upstream of cross section 47-1. Figure 8.3.5 shows a plot of cross section 46-1 for the April 1999, February 2000, December 2002 and January 2007 surveys.

The 2007 active channel covers a surveyed width of 142.8m at this location. Mean bed-level analysis shows net aggradation of 0.07m over the active channel width during the period 1999 to 2007. The largest proportion of aggradation, 0.61m, occurred during the period April 1999 to February 2000 and is largely attributable to the November 1999 flood event. The trend in net aggradation is also reflected, with minor aggradation of the channel thalweg by 0.03m for the period 1999 to 2007. Similar to cross sections downstream, a presiding trend of net degradation has prevailed since the February 2000 survey.

Upstream of the State Highway Bridge, the active channel margin widens considerably (Figure 8.3.5). This reach has been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone. This is largely represented by a more defined thalweg (Figure 8.3.5), with secondary flowpaths becoming less prevalent.

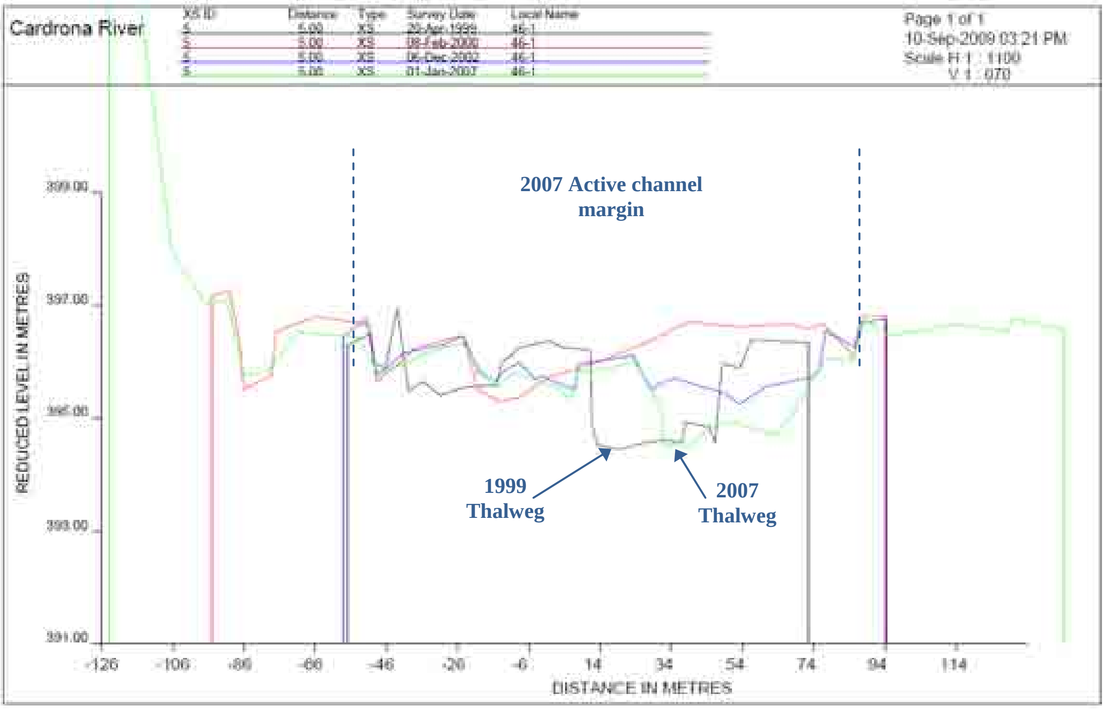

Figure 8.3.5 Cross section 46-1, looking downstream

8.3.6 Cross section 46

Cross section 46 is located approximately 3.4km upstream of the Clutha River/Mata-Au confluence and 0.4km upstream of cross section 46-1. Figure 8.6 shows a plot of cross section 46 for the February 1988, January 1996, February 2000, and December 2002 surveys. This cross section was also surveyed in October 1989 and April 1999, but was not resurveyed in January 2007.

The 1988 active channel margin covered a surveyed width of 143.2m compared to 171.4m in the 2002 survey. Mean bed-level analysis shows net degradation of 0.64m over the active channel width between 1988 and 2002. The largest proportion of net degradation, 0.71m, occurred during the period January 1996 to April 1999, while the period April 1999 to February 2000 experienced net aggradation of 0.31m. This period of aggradation is inferred to be a result of sedimentation from the November 1999 flood. The trend in net degradation is also reflected by a lowering of the channel thalweg by 0.70m over the period 1988 to 2002.

At this cross section location, the Cardrona River has a very mobile bed, which is reflected in Figure 8.3.6 by lateral movement of the active channel to the true right. Similar to cross section 46-1, this reach has been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone.

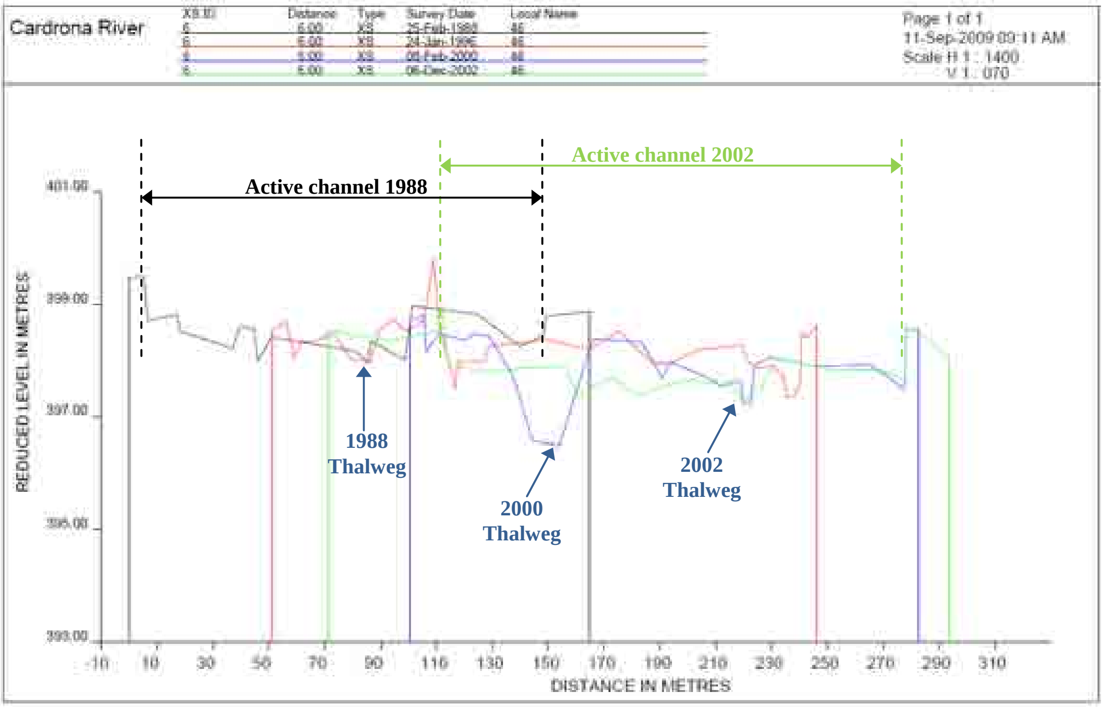

Figure 8.3.6 Cross section 46, looking downstream

8.3.7 Cross section 44-1

Cross section 44-1 is located approximately 3.8km upstream of the Clutha River/Mata-Au confluence and 0.4km upstream of cross section 46. Figure 8.3.7 shows a plot of cross section 44-1 for the February 1988, April 1999, February 2000, December 2002 and January 2007 surveys. This cross section was also surveyed in October 1989 and January 1996.

The 1988 active channel margin covered a surveyed width of 158.7m, compared to 270.4m in the 2007 survey. Mean bed-level analysis shows net degradation of 0.80m over the active channel width during the period 1988 to 2007 (Table 8.1.2). Most surveyed periods experienced net degradation, apart from 1989 to 1996 and April 1999 to February 2000, which aggraded in response to flood-induced sedimentation. The greatest proportion of degradation, 0.64m, occurred in the most recent survey period, August 2003 to January 2007. The degradational trend at this location is further reflected by a lowering of the thalweg by 1.51m over the surveyed periods.

Similar to the cross sections immediately downstream, this reach of the river has been subjected to a high degree of the historical gravel extraction. In addition, erosion of the true right bank, 25.1m (1988 to 2000) and 51.5m (2000 to 2002), has contributed to widening of the active channel margin.

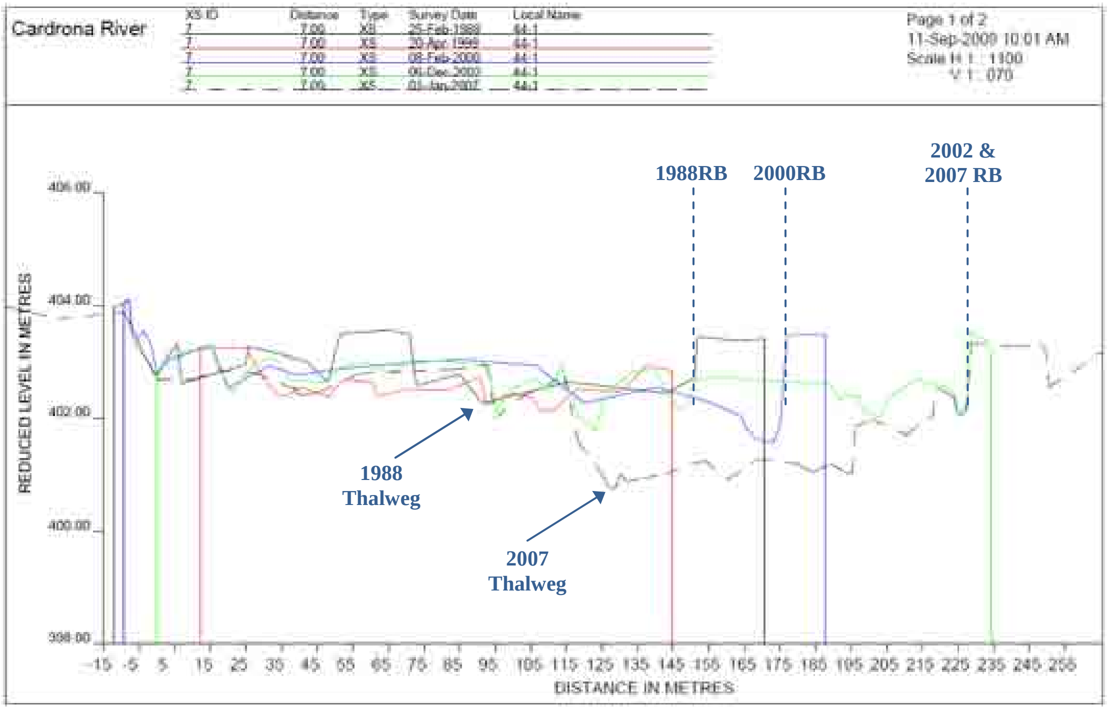

Figure 8.3.7 Cross section 44-1, looking downstream

8.3.8 Cross section 44

Cross section 44 is located approximately 4.3km upstream of the Clutha River/Mata-Au confluence and 0.5km upstream of cross section 44-1. Figure 8.3.8 shows a plot of cross section 44 for the February 1988, January 1996, December 2002 and January 2007 surveys. This cross section was also surveyed in October 1989 and April 1999.

The 1988 active channel margin covered a surveyed width of 143.6m, compared to 282.3m in the 2002 survey. Mean bed-level analysis shows net degradation of 0.93m over the active channel width during the period 1988 to 2007 (Table 8.1.2). The period February 1988 to April 1999 exhibited net degradation of 0.63m. Like cross section 44-1, the period April 1999 to December 2002 experienced net aggradation of 0.08m, which most probably can be attributed to sedimentation from the November 1999 flood event. The most recent period of survey, 2002 to 2007, has experienced further net degradation of 0.29m. This degradational trend is reflected in lowering of the channel thalweg by some 1.15m over the period 1988 to 2007.

Changes in channel morphology at cross section 44 are very similar to those observed downstream at cross section 44-1. Erosion of the true right bank is observed over surveyed periods with 30.2m (1988 to 1996) and 105.5m (1996 to 2002). This has widened the active channel margin significantly at this location.

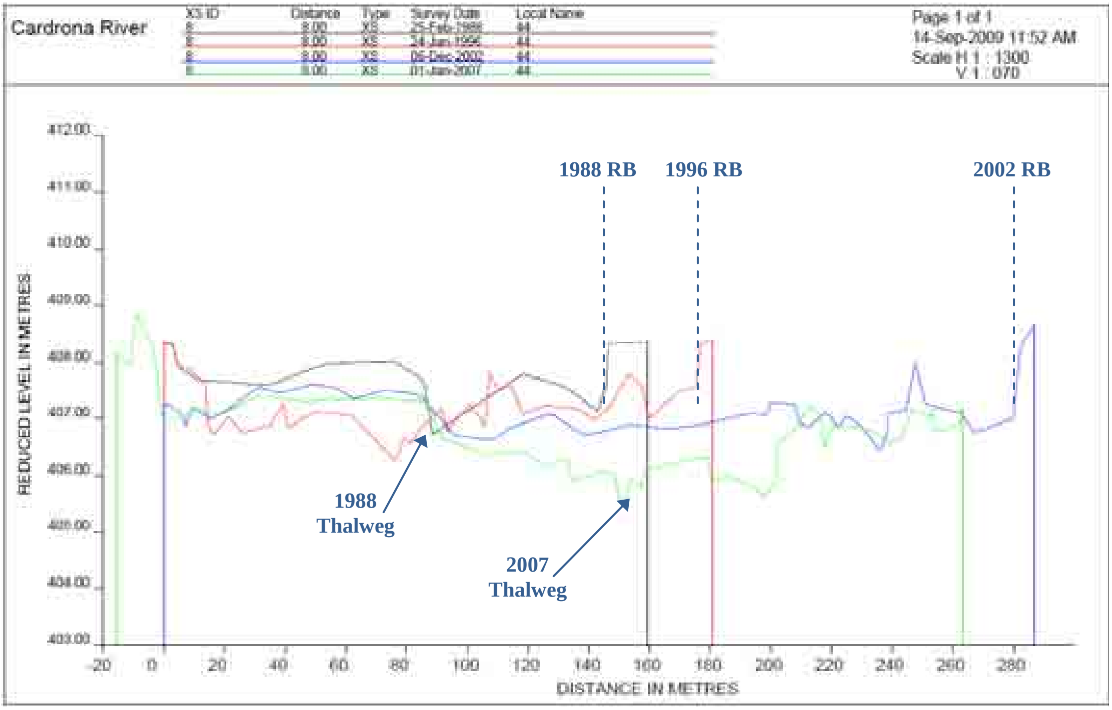

Figure 8.3.8 **Cross section 44, looking downstream**

8.3.9 Cross section 42

Cross section 42 is located at the Ballantyne Road Bridge, approximately 5.1km upstream of the Clutha River/Mata-Au confluence. Figure 8.3.9 shows a plot of cross section 42 for the February 1988, October 1989, January 1996, April 1999, December 2002 and January 2007 surveys.

The active channel covers a surveyed width of 32m and is confined by the bridge abutments at this location. Mean bed-level analysis shows net degradation of 1.07m over the active channel width during the period 1988 to 2007. Like cross section 44, the only survey period that experienced aggradation, 0.05m, was April 1999 to December 2002 where all other survey periods experienced net degradation. The latest survey period, 2002 to 2007, experienced net degradation of 0.29m at this location. This trend is also reflected by a lowering of the channel thalweg by 1.25m between the period 1988 to 2007 (Table 8.1.3).

The morphology of the channel at this cross section location is largely dictated by the constraints of the bridge. Where the bridge acts as an impediment to flow, flood flows are forced between this small cross sectional area.

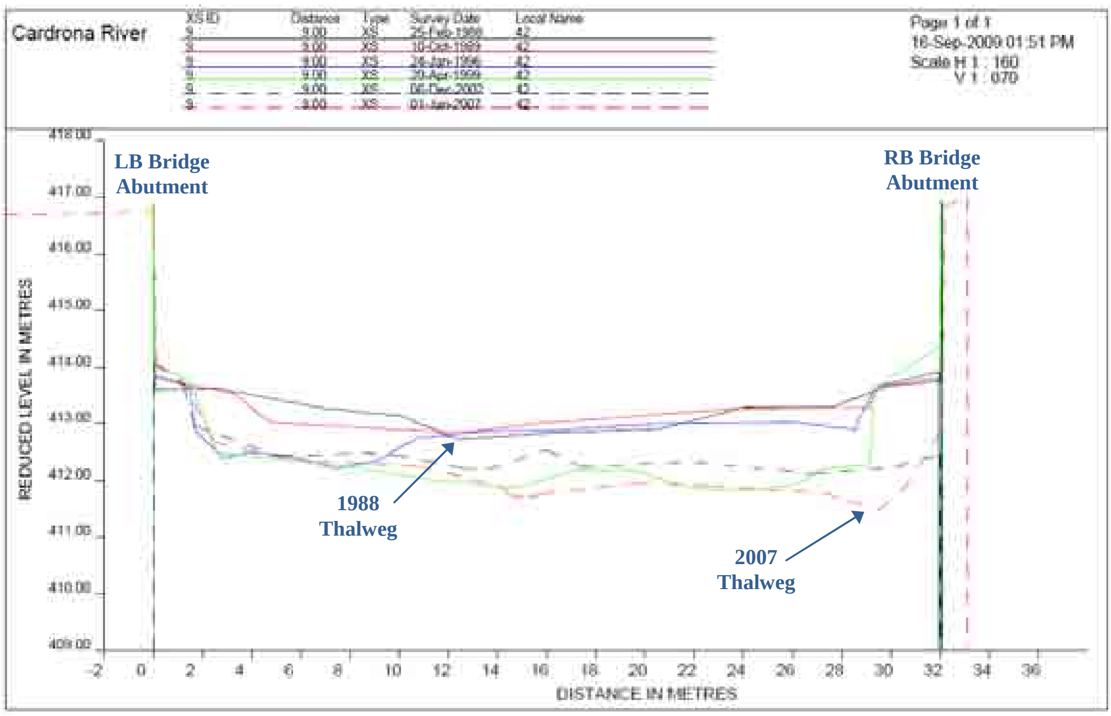

Figure 8.3.9 Cross section 42, looking downstream

8.3.10 Cross section 41

Cross section 41 is located approximately 5.6km upstream of the Clutha River/Mata-Au confluence and 0.5km upstream of cross section 42. Figure 8.3.10 shows a plot of cross section 41 for the February 1988, October 1989, January 1996, April 1999, December 2002 and January 2007 surveys.

The 1988 active channel margin covered a surveyed width of 64m, compared to 109.7m in the 2007 survey. Mean bed-level analysis shows net degradation of 1.41m over the active channel width during the period 1988 to 2007 (Table 8.1.2). All surveyed periods exhibited net degradation at this location, with the most recent survey period experiencing net degradation of 0.26m. This degradational trend is further reflected by a lowering of the channel thalweg by 0.83m during the period 1988 to 2007.

At this cross section location, the Cardrona River has a very mobile bed, which is reflected in Figure 8.3.10 by lateral movement and widening of the active channel margin. This reach has been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone.

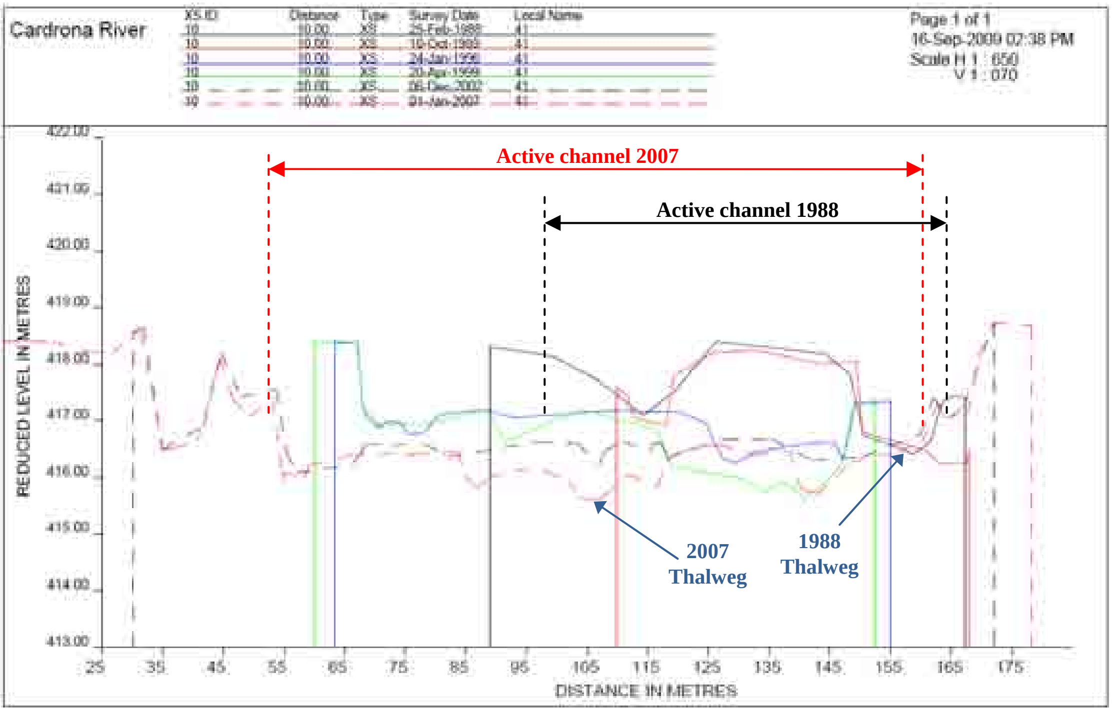

Figure 8.3.10 Cross section 41, looking downstream

8.3.11 Cross section 40-1

Cross section 40-1 is located approximately 6km upstream of the Clutha River/Mata-Au confluence and 0.4km upstream of cross section 41. Figure 8.3.11 shows a plot of cross section 40-1 for the February 1988, October 1989, January 1996, April 1999, November 2003 and January 2007 surveys.

The 1988 active channel margin covered a surveyed width of 55m, compared to 171m in the 2007 survey. Mean bed-level analysis shows net degradation of 0.67m over the active channel width during the period 1988 to 2007 (Table 8.1.2). Most surveyed periods experienced net degradation, apart from 1989 to 1996, which experienced net aggradation of 0.06m. The greatest proportion of degradation, 0.41m, occurred during the last two survey periods, April 1999 to 2007. The degradational trend at this location is further reflected by a lowering of the thalweg by 0.98m over the surveyed periods.

At this cross section location, the Cardrona River has a very mobile bed, which is reflected in Figure 8.3.11 by lateral movement and widening of the active channel margin. This reach has been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone.

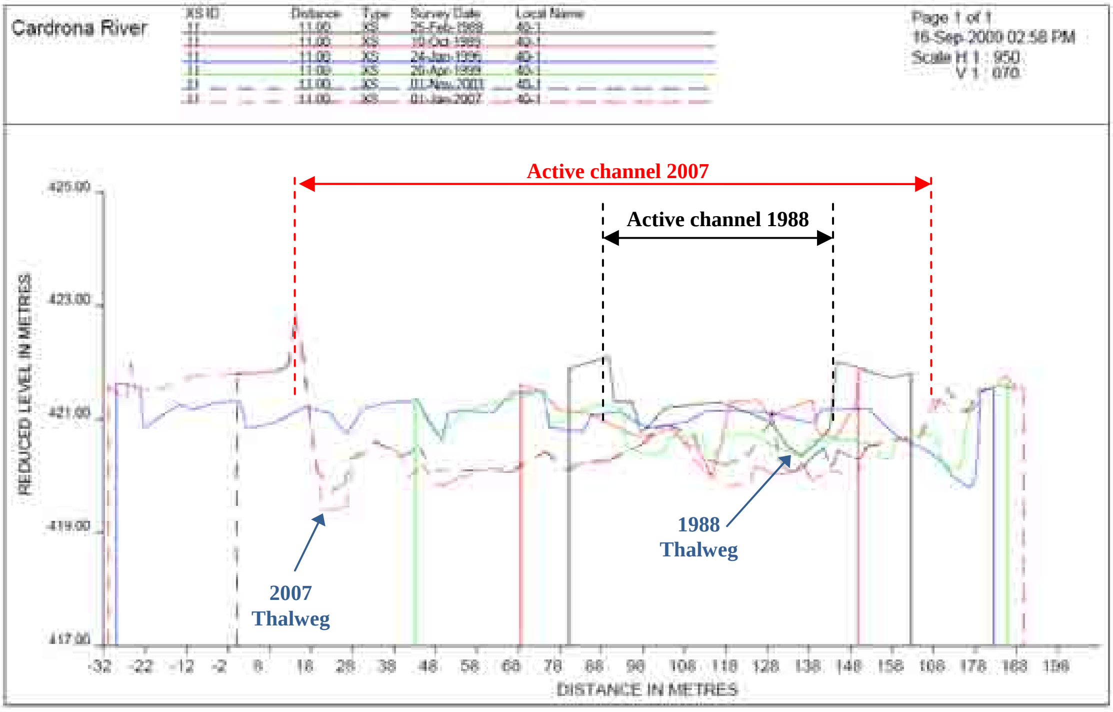

Figure 8.3.11 Cross section 40-1, looking downstream

8.3.12 Cross section 39-1

Cross section 39-1 is located approximately 6.5km upstream of the Clutha River/Mata-Au confluence and 0.5km upstream of cross section 40-1. Figure 8.3.12 shows a plot of cross section 39-1 for the February 1988, January 1996, April 1999, December 2002, August 2003 and January 2007 surveys.

The 1988 active channel margin covered a surveyed width of 101m, compared to 203m in the 2007 survey. Mean bed-level analysis shows net degradation of 1.24m over the active channel width during the period 1988 to 2007 (Table 8.1.2). All surveyed periods experienced net degradation with the greatest proportion, 0.85m, occurring during the period April 1999 to December 2002. The degradational trend at this location is further reflected by a lowering of the thalweg by 1.18m over the surveyed periods.

At this cross section location, the Cardrona River has a very mobile bed, which is reflected in Figure 8.3.12 by lateral movement and widening of the active channel margin. This reach has also been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone.

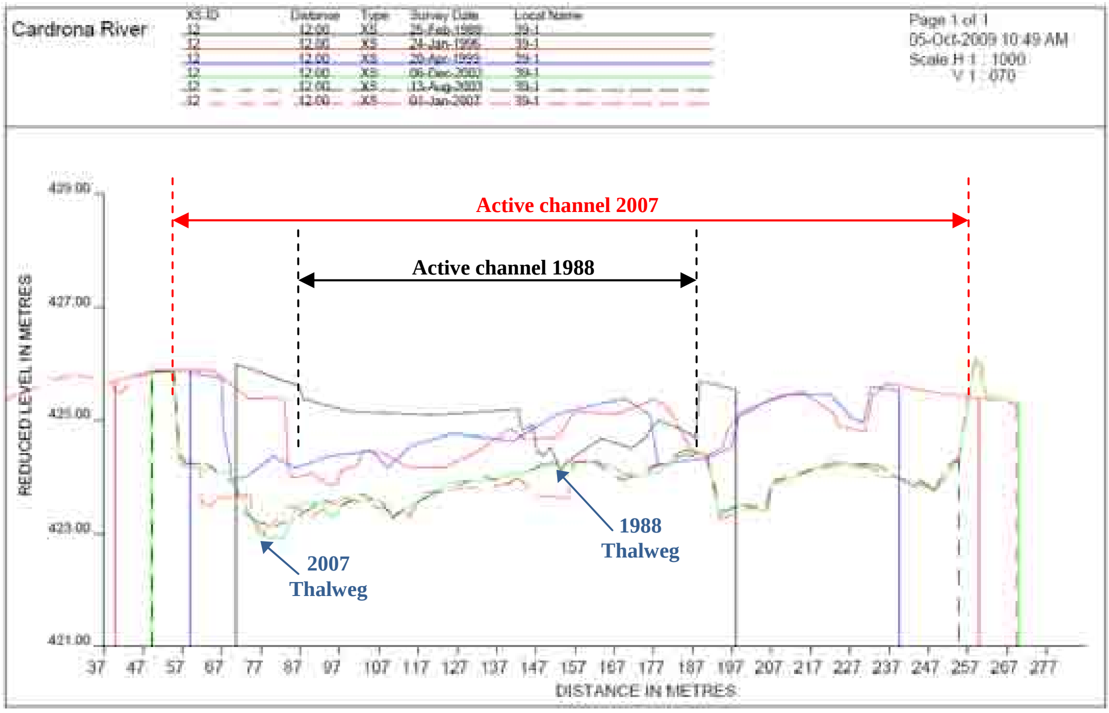

Figure 8.3.12 Cross section 39-1, looking downstream

8.3.13 Cross section 39

Cross section 39 is located approximately 6.6km upstream of the Clutha River/Mata-Au confluence and 0.15km upstream of cross section 39-1. Figure 8.3.13 shows a plot of cross section 39 for the February 1988, January 1996, April 1999, December 2002, August 2003 and January 2007 surveys.

The 1988 active channel margin covered a surveyed width of 114m, compared to 155m in the 2007 survey. Mean bed-level analysis shows net degradation of 1.02m over the active channel width during the period 1988 to 2007 (Table 8.1.2). The largest proportion of net degradation, 0.82m, occurred during the period April 1999 to December 2002. Periods of both net aggradation and degradation have occurred over surveyed periods, with the most recent survey period, August 2003 to January 2007, experiencing net aggradation of 0.08m. The net degradational trend at this location is further reflected by a lowering of the thalweg by 1.21m over the surveyed periods.

At this cross section location, the Cardrona River has a very mobile bed, which is reflected in Figure 8.3.13 by lateral movement and widening of the active channel margin. Lateral erosion of both banks has occurred over many surveyed periods, including 22m of true right bank erosion during the period April 1999 to December 2002 (Figure 8.3.13). This reach has also been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone.

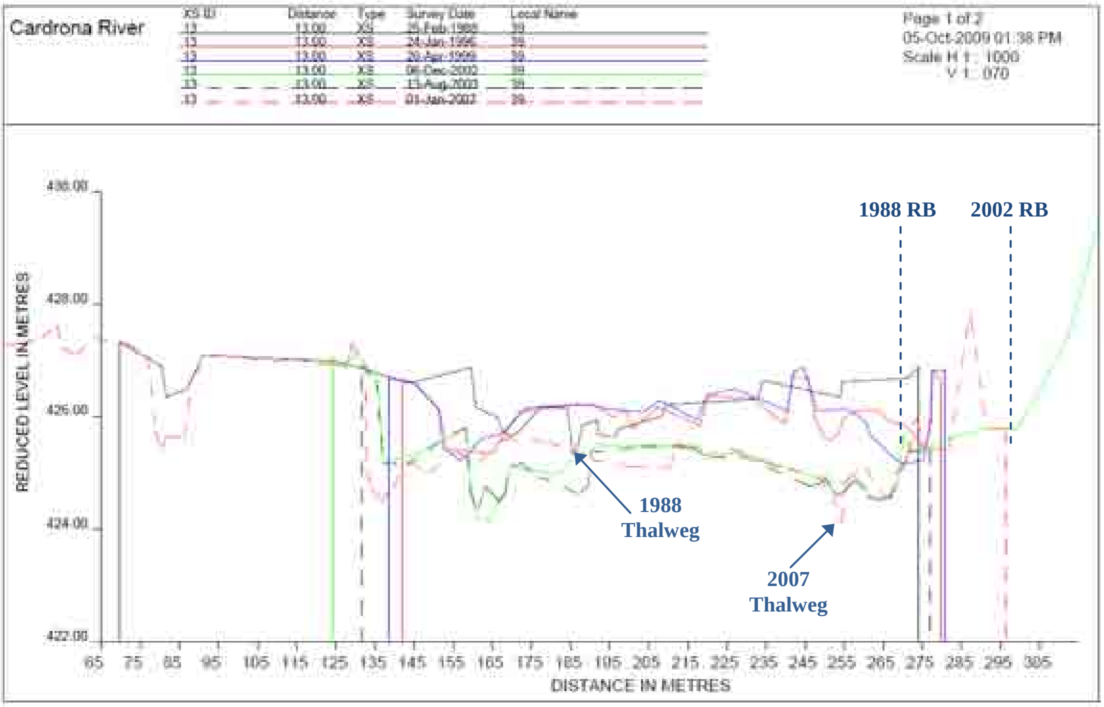

Figure 8.3.13 Cross section 39, looking downstream

8.3.14 Cross section 36-1

Cross section 36-1 is located approximately 7.1km upstream of the Clutha River/Mata-Au confluence and 0.5km upstream of cross section 39. Figure 8.3.14 shows a plot of cross section 36-1 for the February 1988, April 1999, December 2002, and January 2007 surveys. This cross section was also surveyed in January 1996 and August 2003.

The 1988 active channel margin covered a surveyed width of 88m compared to 136m in the 2007 survey. Mean bed-level analysis shows net degradation of 1.19m over the active channel width during the period 1988 to 2007 (Table 8.1.2). All surveyed periods experienced net degradation, with the greatest proportion, 0.72m, occurring during the period February 1988 to January 1996. The net degradational trend at this location is further reflected by a lowering of the thalweg by 0.85m over the surveyed periods.

At this cross section location, the Cardrona River has a very mobile bed, which is reflected in Figure 8.3.14 by lateral movement and widening of the active channel margin. Erosion of the true left bank has been observed at this cross section over many surveyed periods: 41.8m between 1988 and 2002 and 43.1m between 2002 and 2007. This reach has also been subject to a high degree of historical gravel extraction, which has reduced the complexity within the active channel zone.

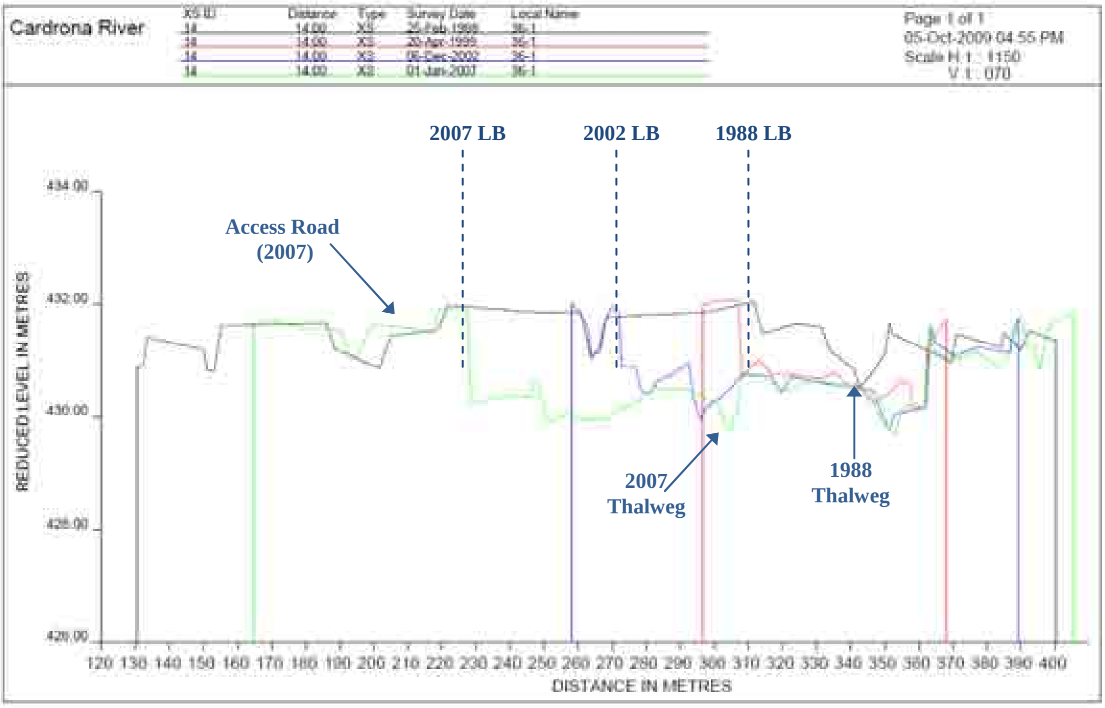

Figure 8.3.14 Cross section 36-1, looking downstream

8.3.15 Cross section 31-1

Cross section 31-1 is located approximately 7.9km upstream of the Clutha River/Mata-Au confluence and 0.8km upstream of cross section 36-1. Figure 8.3.15 shows a plot of cross section 36-1 for the February 1988, April 1999, December 2002, August 2003 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 1.01m over the active channel width during the period 1988 to 2007 (Table 8.1.2). The largest proportion of net degradation, 0.87m, occurred during the period February 1988 to April 1999. All surveyed periods exhibited net degradation, apart from minor aggradation of 0.01m in the period December 2002 to August 2003. The net degradational trend at this location is further reflected by a lowering of the thalweg by 0.95m over the surveyed periods.

Channel morphology at this location has lowered and widened significantly between April 1999 and December 2002 (Figure 8.3.15). Subsequent survey periods note the active channel margin has not significantly deviated since December 2002; rather, bed level variation on the true right of the channel has experienced variation.

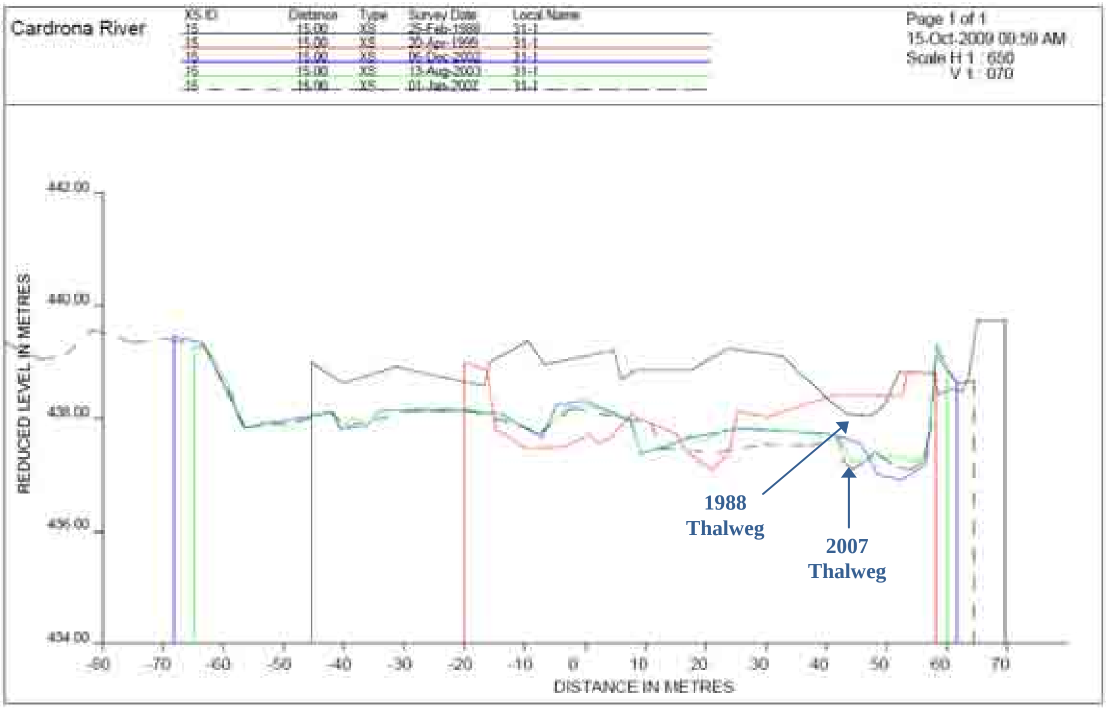

Figure 8.3.15 Cross section 31-1, looking downstream

8.3.16 Cross section 30-1

Cross section 30-1 is located approximately 8.7km upstream of the Clutha River/Mata-Au confluence and 0.8km upstream of cross section 31-1. Figure 8.3.16 shows a plot of cross section 30-1 for the February 1988, February 2000, December 2002 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.97m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). All surveyed periods experienced net degradation with the greatest proportion, 0.38m, occurring during the period February 2000 to December 2002. Net degradational trends are further reflected in a lowering of the channel thalweg by 0.71m over the surveyed periods.

Historical aerial photography and cross section extents indicate that the channel width at this location has become very confined, due to the establishment of willows on the true right bank. Stabilisation of the channel margins within the vicinity of The Larches is characteristic of cross sections within this reach.

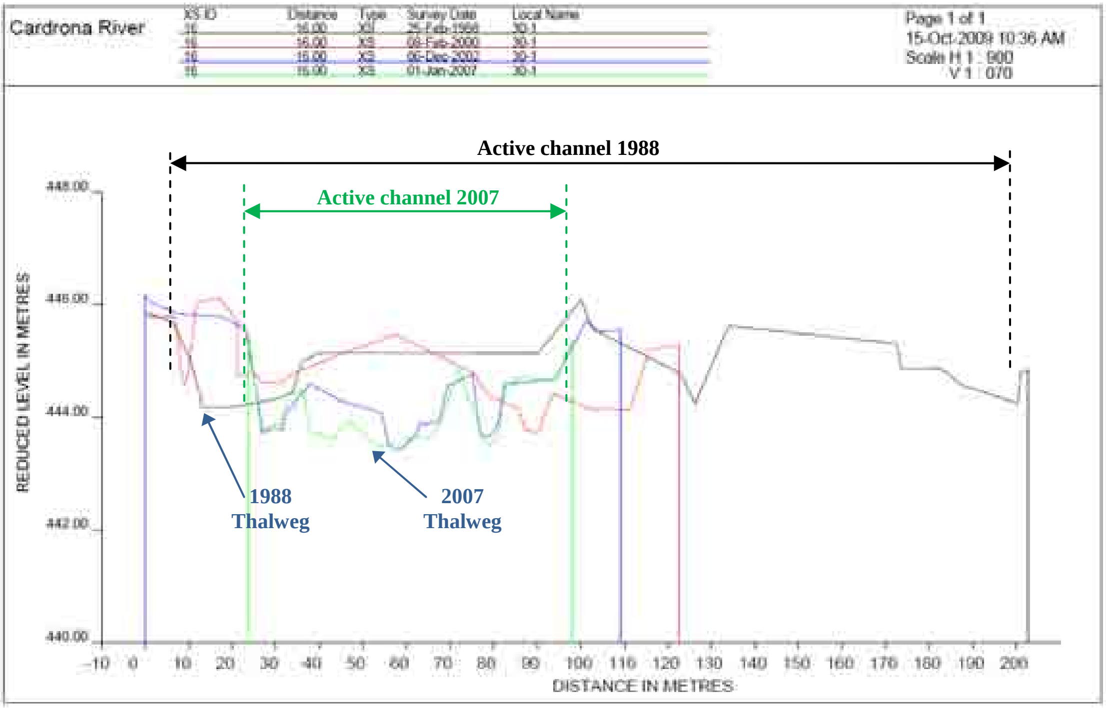

Figure 8.3.16 Cross section 30-1, looking downstream

8.3.17 Cross section 54-1

Cross section 54-1 is located approximately 9.4km upstream of the Clutha River/Mata-Au confluence and 0.7km upstream of cross section 30-1. Figure 8.3.17 shows a plot of cross section 54-1 for the February 1988, January 1998, December 2002 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.11m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Significant variation in mean bed-levels were experienced between surveyed periods, with 0.99m degradation occurring during the period 1988 to 1998 followed by aggradation of 1.36m during the period 1998 to December 2002. Variation at this location may be attributable to relatively small active channel margin, approximately 10m. The net degradational trend is further reflected by a lowering of the thalweg by 0.46m over surveyed periods.

Historical aerial photography and cross section extents indicate that the channel width at this location is confined, due to the establishment of willow plantings and vehicle tracks within the active channel margin. Under normal flow conditions, the channel remains within the confined 10m width; however, flood capacity is limited and the channel leaves the primary channel during flood flows.

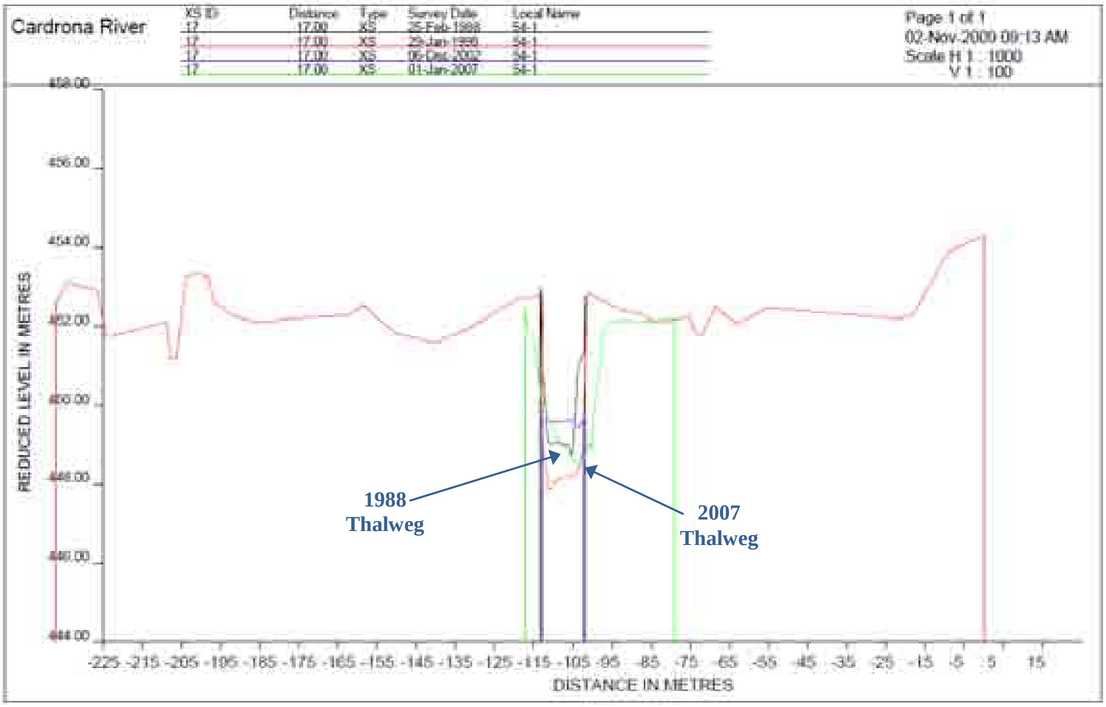

Figure 8.3.17 Cross section 54-1, looking downstream

8.3.18 Cross section 54-2

Cross section 54-2 is located approximately 9.6km upstream of the Clutha River/Mata-Au confluence and 0.2km upstream of cross section 54-1. Figure 8.3.18 shows a plot of cross section 54-2 for the January 1998, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 1.38m over the active channel margin during the period 1998 to 2007 (Table 8.1.2). Net degradation has occurred over all surveyed periods, with 1.14m of degradation between 1998 and 2003, followed by a further 0.24m degradation in the most recent survey period, 2003 to 2007. Contrary to this degradational trend, the thalweg level has increased by 0.99m over the period 1998 to 2007. This is largely attributable to significant widening of the active channel margins at this location, where the channel occupied a relatively confined area similar to the existing 54-1 in 1998, it now occupies a much wider reach encompassing the true left margin.

The channel morphology has changed significantly over the surveyed periods. In the 1998 survey, the active channel was confined to an area on the true right of the current channel margins. The 2003 and 2007 surveys indicate that the channel margins have widened significantly at this location, presumably as a result of the 1999 flood event.

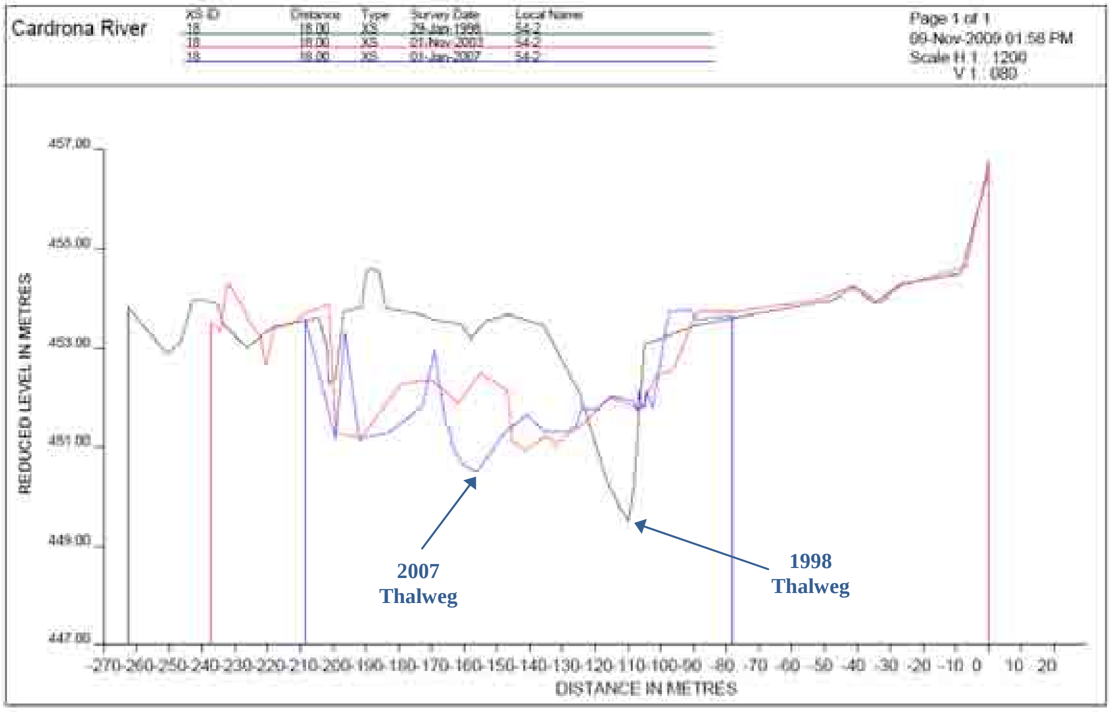

Figure 8.3.18 Cross section 54-2, looking downstream

8.3.19 Cross section 28-1

Cross section 28-1 is located approximately 10km upstream of the Clutha River/Mata-Au confluence and 0.4km upstream of cross section 28-1. Figure 8.3.19 shows a plot of cross section 28-1 for the February 1988, October 1989, January 1998, December 2002 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.14m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Significant variation in mean bed-levels were experienced between surveyed periods, with 0.51m degradation occurring during the period 1988 to 1989, followed by aggradation of 0.54m during the period 1989 to January 1998. The most recent survey period, 2002 to 2007, has experienced net degradation of 0.34m. The small variation in mean bed-level is also reflected in degradation of 0.2m in the channel thalweg during the period 1988 to 2007.

The channel morphology at cross section 28-1 has remained relatively consistent over surveyed periods. While the channel has experienced periods of both aggradation and degradation, the channel margins have remained relatively stable between surveyed periods. This reach is very confined by willow growth, which may be the primary reason for channel confinement and stable nature.

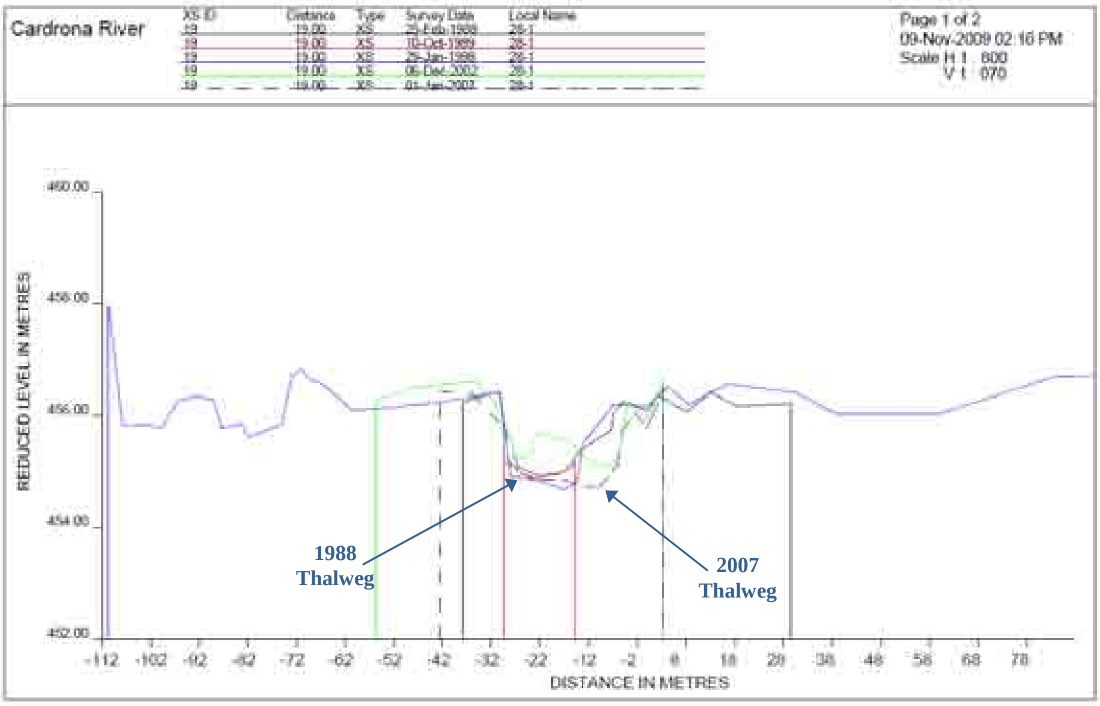

Figure 8.3.19 Cross section 28-1, looking downstream

8.3.20 Cross section 28-2

Cross section 28-2 is located approximately 10.2km upstream of the Clutha River/Mata-Au confluence and 0.2km upstream of cross section 28-1. Figure 8.3.20 shows a plot of cross section 28-2 for the January 1998, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.09m over the active channel margin during the period 1998 to 2007 (Table 8.1.2). Mean bed-levels at this location experienced net aggradation of 0.36m during the period 1998 to 2003; while the most recent survey period, 2003 to 2007, experienced net degradation of 0.27m. The thalweg at this location has experienced lowering of 0.18m over the surveyed periods.

The channel morphology at this location is indicative of this reach and has remained relatively constant over the surveyed periods. This reach is very confined by willow growth, which may be the primary reason for channel confinement and stable nature.

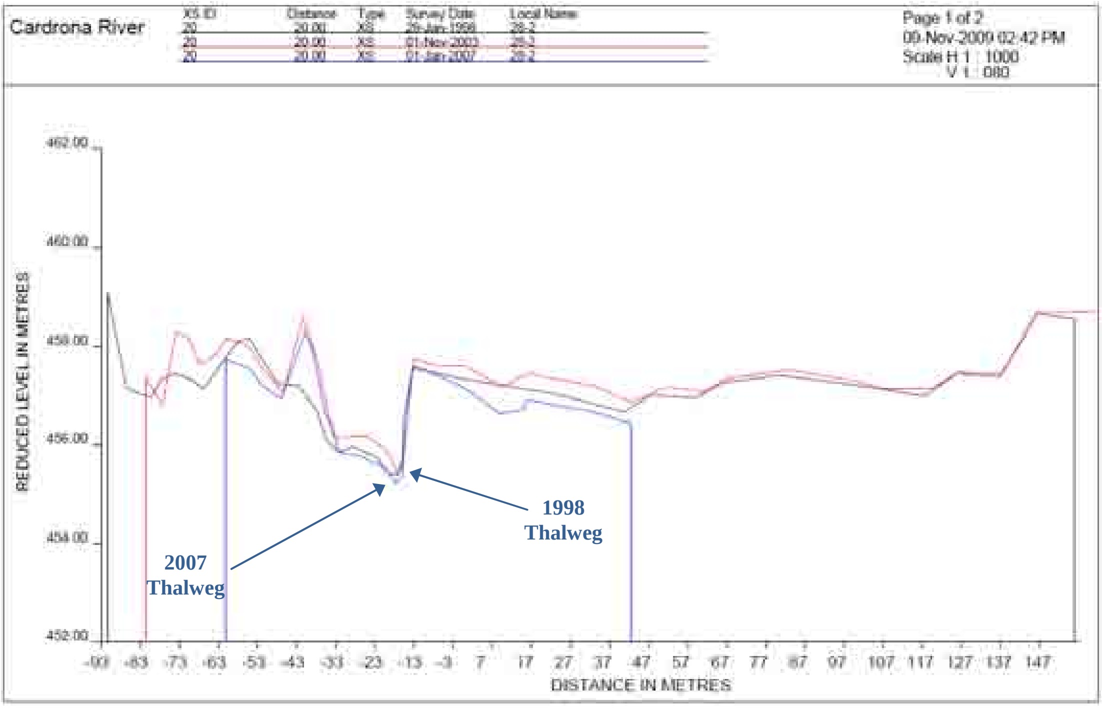

Figure 8.3.20 Cross section 28-2, looking downstream

8.3.21 Cross section 1A

Cross section 1A is located approximately 10.65km upstream of the Clutha River/Mata-Au confluence and 0.45km upstream of cross section 28-2. Figure 8.3.21 shows a plot of cross section 1A for the February 1988, October 1989, December 1996, September 2002, October 2002 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.53m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Mean bed-levels have varied between periods of both aggradation and degradation over the surveyed periods with the greatest proportion of aggradation occurring during the period 1989 to 1996. Comparatively, the thalweg at this location has experienced lowering of 0.58m over the surveyed periods.

The active channel margin widens at this cross section location to exhibit a more braided form than the cross sections immediately downstream. Bed-level variability is more pronounced at this location, which is reflected in the mean bed-level variation over surveyed periods.

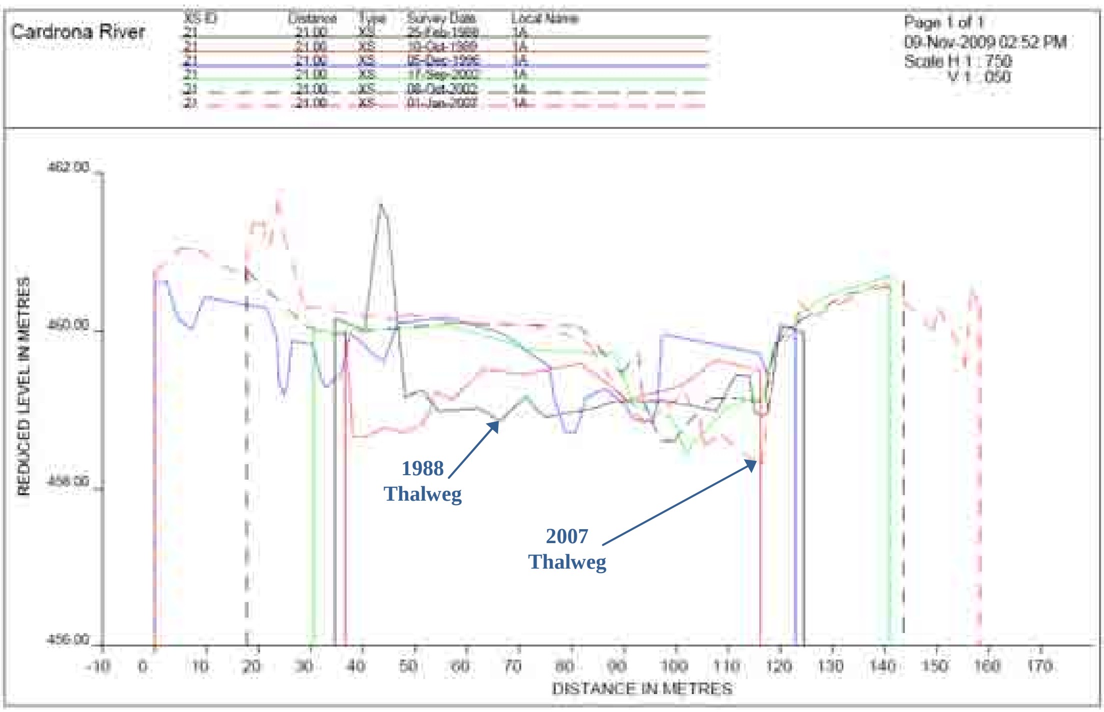

Figure 8.3.21 Cross section 1A, looking downstream

8.3.22 Cross section 1B

Cross section 1B is located approximately 10.8km upstream of the Clutha River/Mata-Au confluence and 0.15km upstream of cross section 1A. Figure 8.3.22 shows a plot of cross section 1B for the February 1985, February 1988, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.10m over the active channel margin during the period 1985 to 2007 (Table 8.1.2). Mean bed-levels have varied between periods of both minor aggradation and degradation over surveyed periods. Comparatively, the thalweg at this location has experienced aggradation of 0.15m over the surveyed period 1985 to 2007.

Similar to cross section 1A, the active channel margin widens at this location to exhibit a more braided form. Channel form within this reach is related to the sediment input from Timber Creek just upstream. Bed-level variability is more pronounced at this location, which is reflected in the mean bed-level variation over surveyed periods.

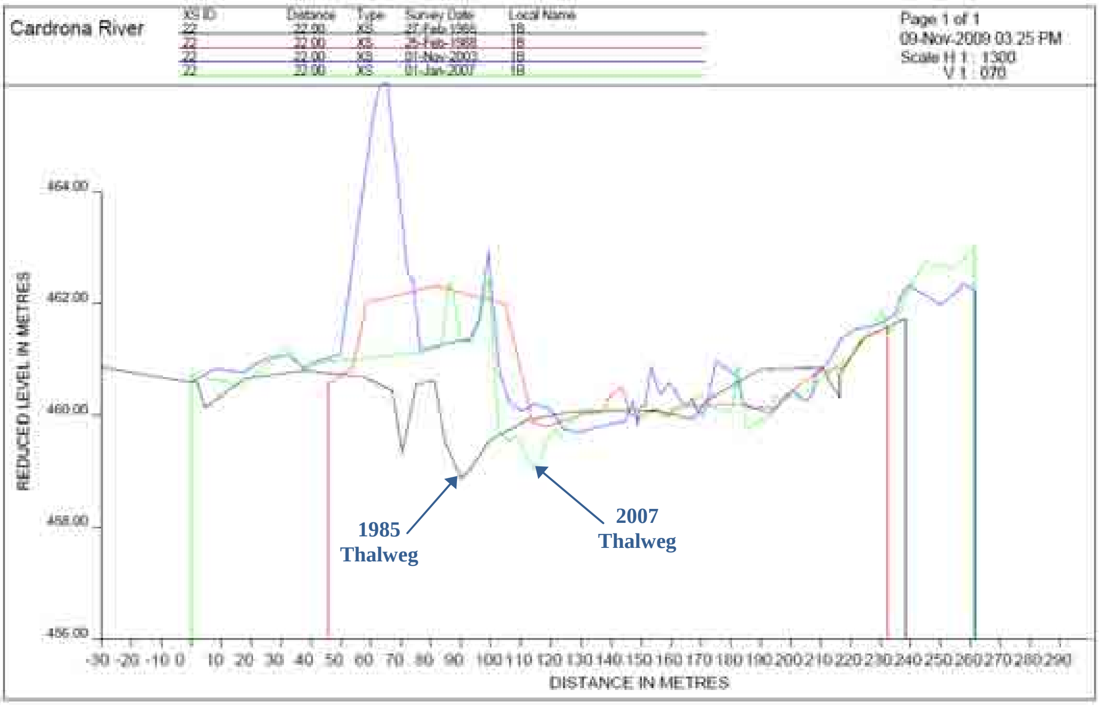

Figure 8.3.22 Cross section 1B, looking downstream

8.3.23 Cross section 2A

Cross section 2A is located approximately 11km upstream of the Clutha River/Mata-Au confluence and 0.2km upstream of cross section 1B. Figure 8.3.23 shows a plot of cross section 2A for the September 2002, October 2002 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.17m over the active channel margin during the period 2002 to 2007 (Table 8.1.2). Both surveyed periods exhibited periods of net degradation. Comparatively, the thalweg at this location has experienced aggradation of 0.15m over the surveyed period 2002 to 2007.

Similar to cross section 1B, the active channel margin widens at this location to exhibit a more braided form. Channel form within this reach is related to the sediment input from Timber Creek just upstream. Bed-level variability is more pronounced at this location, which is reflected in the mean bed-level variation over surveyed periods.

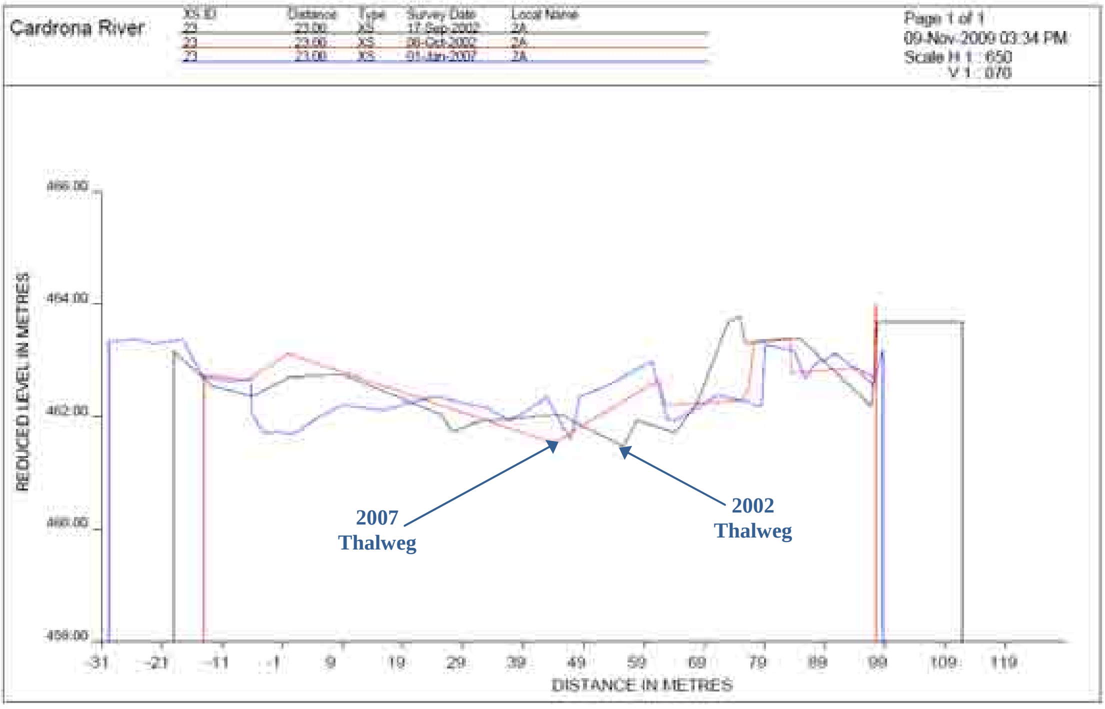

Figure 8.3.23 Cross section 2A, looking downstream

8.3.24 Cross section 2

Cross section 2 is located approximately 11.2km upstream of the Clutha River/Mata-Au confluence and 0.2km upstream of cross section 2A. Figure 8.3.24 shows a plot of cross section 2 for the February 1985, February 1988, December 1996, February 2000, September 2002, October 2002 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.77m over the active channel margin during the period 1985 to 2007 (Table 8.1.2). Mean bed-levels have varied between phases of both aggradation and degradation over the surveyed periods, with net degradation of 0.82m occurring between 2000 and 2007. This net degradational trend is further reflected in lowering of the channel thalweg by 0.44m over the period 1985 to 2007.

Similar to cross section 2A, the active channel margin widens at this location to exhibit a more braided form. The active channel margin has significantly increased over surveyed periods, where the channel occupied the true left in the 1985 and 1988 surveys, by February 2000 it had widened significantly. Channel form within this reach is related to the sediment input from Timber Creek just upstream. Bed-level variability is more pronounced at this location, which is reflected in the mean bed-level variation over surveyed periods.

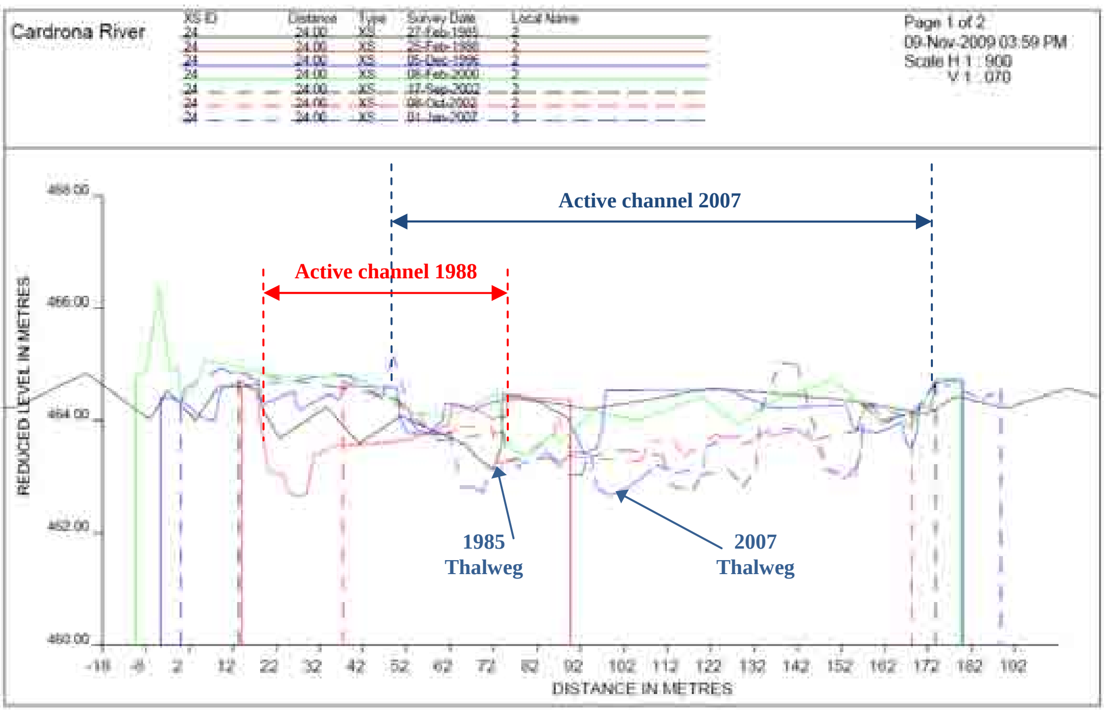

Figure 8.3.24 Cross section 2, looking downstream

8.3.25 Cross section 2B

Cross section 2B is located approximately 11.4km upstream of the Clutha River/Mata-Au confluence and 0.2km upstream of cross section 2. Figure 8.3.25 shows a plot of cross section 2B for the September 2002, October 2002 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.15m over the active channel margin during the period 2002 to 2007 (Table 8.1.2). Both surveyed periods exhibited periods of net aggradation. Comparatively, the thalweg at this location has experienced degradation of 0.11m over the surveyed period, 2002 to 2007.

Similar to cross section 2 located just downstream, the active channel margin widens at this location to exhibit a more braided form. Channel form within this reach is related to the sediment input from Timber Creek just upstream. Bed-level variability is more pronounced at this location, which is reflected in the mean bed-level variation over surveyed periods.

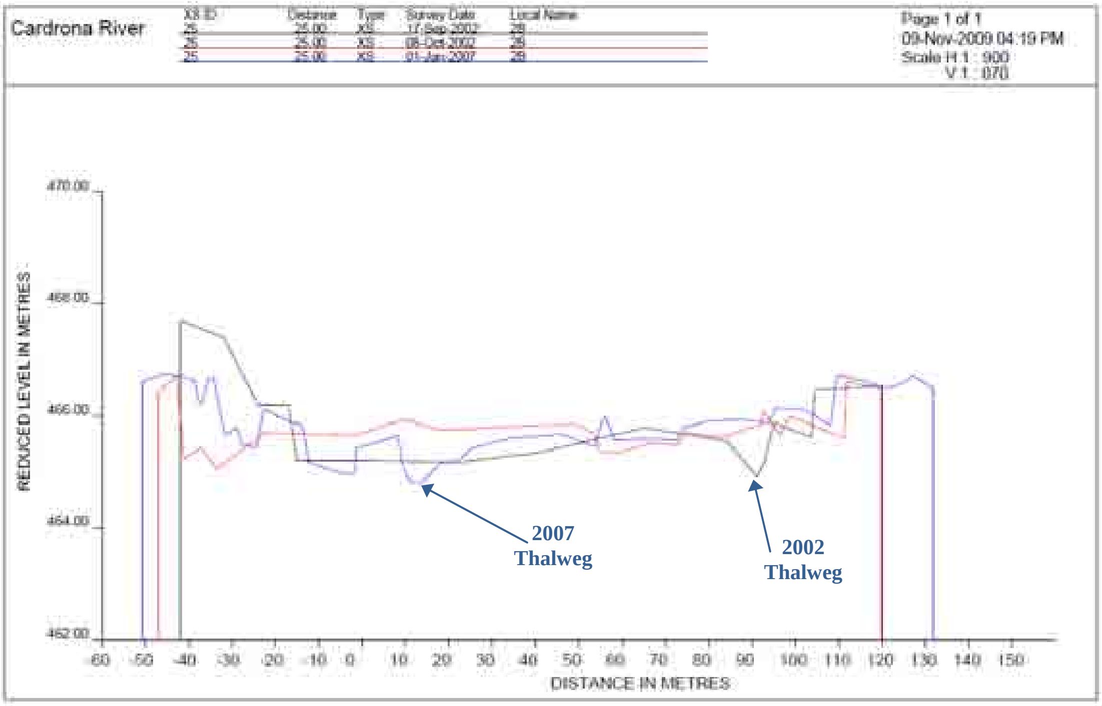

Figure 8.3.25 Cross section 2B, looking downstream

8.3.26 Cross section 3

Cross section 3 is located approximately 11.8km upstream of the Clutha River/Mata-Au confluence and 0.6km upstream of cross section 2B. Figure 8.3.26 shows a plot of cross section 3 for the February 1985, February 1988, December 1996, February 2000, September 2002, October 2002 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.41m over the active channel margin during the period 1985 to 2007 (Table 8.1.2). Surveyed periods all experienced net degradation, apart from 1988 to 1996, which experienced aggradation of 0.56m. This trend in net degradation is further reflected by lowering of the channel thalweg by 0.5m over the period 1985 to 2007.

Channel morphology and bed levels are highly influenced by sediment fluxes by Timber Creek. During periods of high flow, toe-cutting of the Timber Creek alluvial fan surface, true left of the cross section, by the axial Cardrona River channel may occur. Comparatively, the active channel margins of the Cardrona River main stem may be affected by encroachment of the alluvial fan, with depositional phases of the Timber Creek catchment contributing to intermittent sediment fluxes across the Cardrona River floodplain.

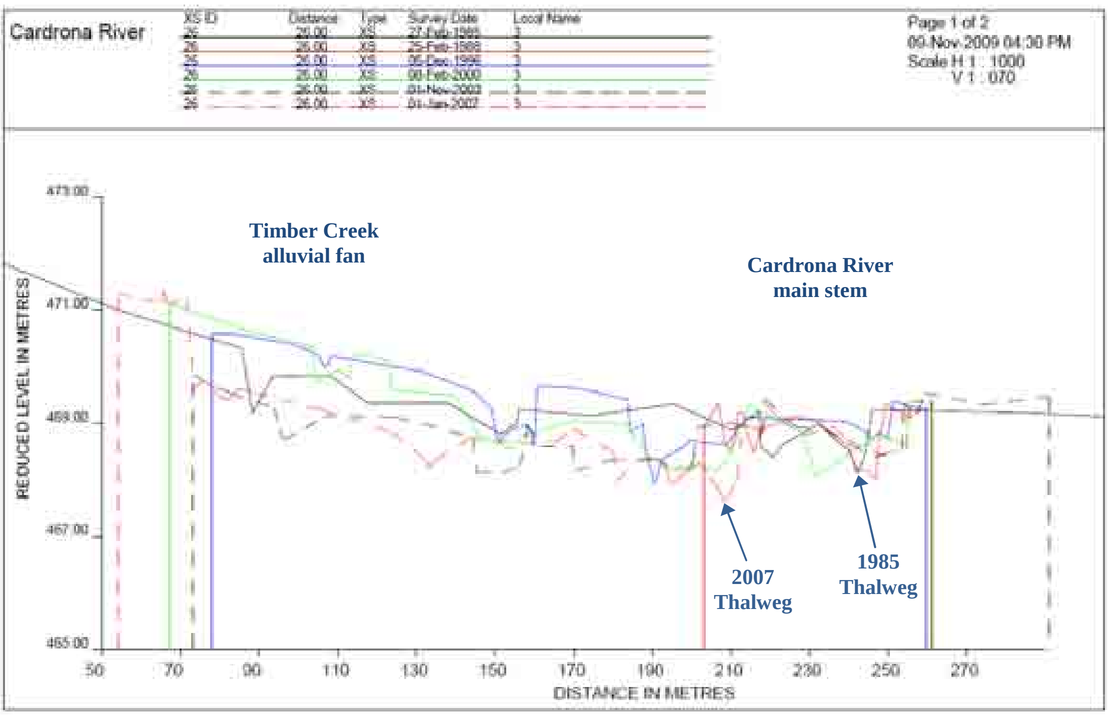

Figure 8.3.26 Cross section 3, looking downstream

8.3.27 Cross section 5

Cross section 5 is located approximately 13.1km upstream of the Clutha River/Mata-Au confluence and 1.3km upstream of cross section 3. Figure 8.3.27 shows a plot of cross section 5 for the February 1988, December 1996, February 2000, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.15m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Mean bed-levels have remained relatively consistent at this cross section location over surveyed periods. All periods exhibited net aggradation, apart from the most recent, 2003 to 2007, which exhibited minor degradation. The thalweg reflects the net aggradational trend, by rising 0.13m during the period 1988 to 2007.

The channel morphology and bed level at this cross section location is inferred to be influenced by sedimentation from the adjacent tributaries both up and downstream on the true right of the valley. These tributaries extend to the top of the Criffel Range and pass through ancient, highly erodible terrace deposits, which may contribute to sedimentation at this location. The topography at this cross section is very generic, which means that the river may easily migrate laterally across the wider floodplain during relatively frequent periods of high flow.

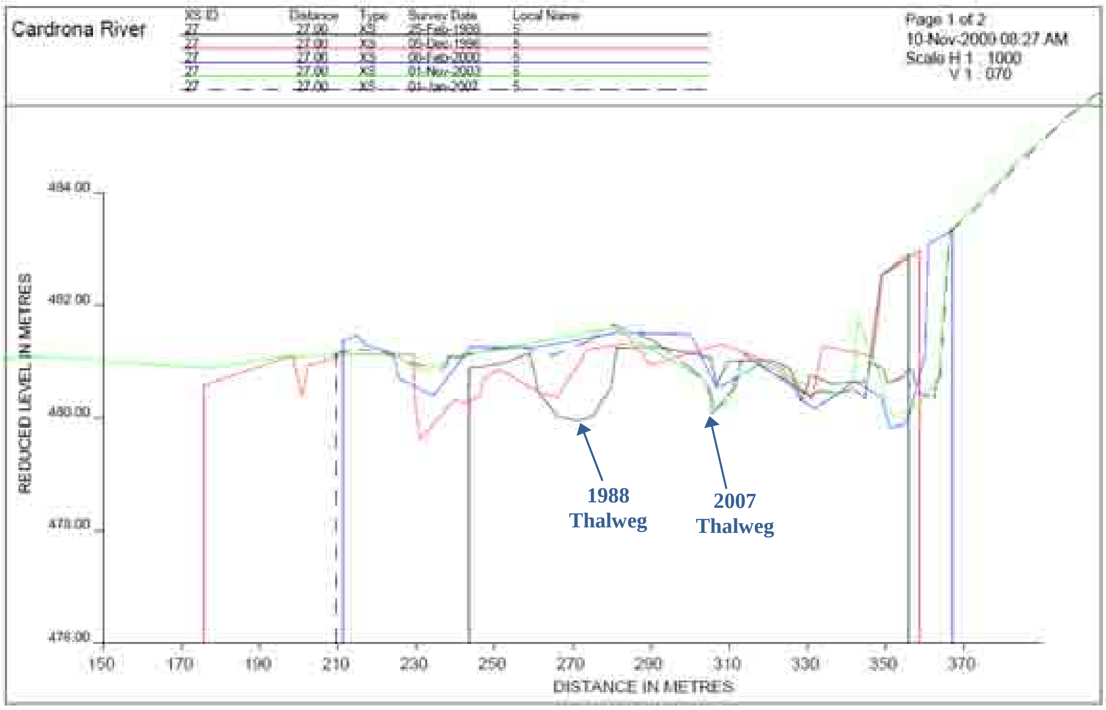

Figure 8.3.27 Cross section 5, looking downstream

8.3.28 Cross section 8

Cross section 8 is located approximately 14.8km upstream of the Clutha River/Mata-Au confluence and 1.7km upstream of cross section 5. Figure 8.3.28 shows a plot of cross section 8 for the February 1988, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.28m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Mean bed-levels exhibited a period of net aggradation of 0.36m between 1988 and 2003, with the most recent survey period exhibiting net degradation. The net aggradational is also reflected in the thalweg rising by 0.68m at this location.

The active channel margins at this location are primarily within the central part of the wider floodplain. Similar to the cross sections located downstream of this site, the topography is quite generic and relatively frequent flood events may leave the active channel margin.

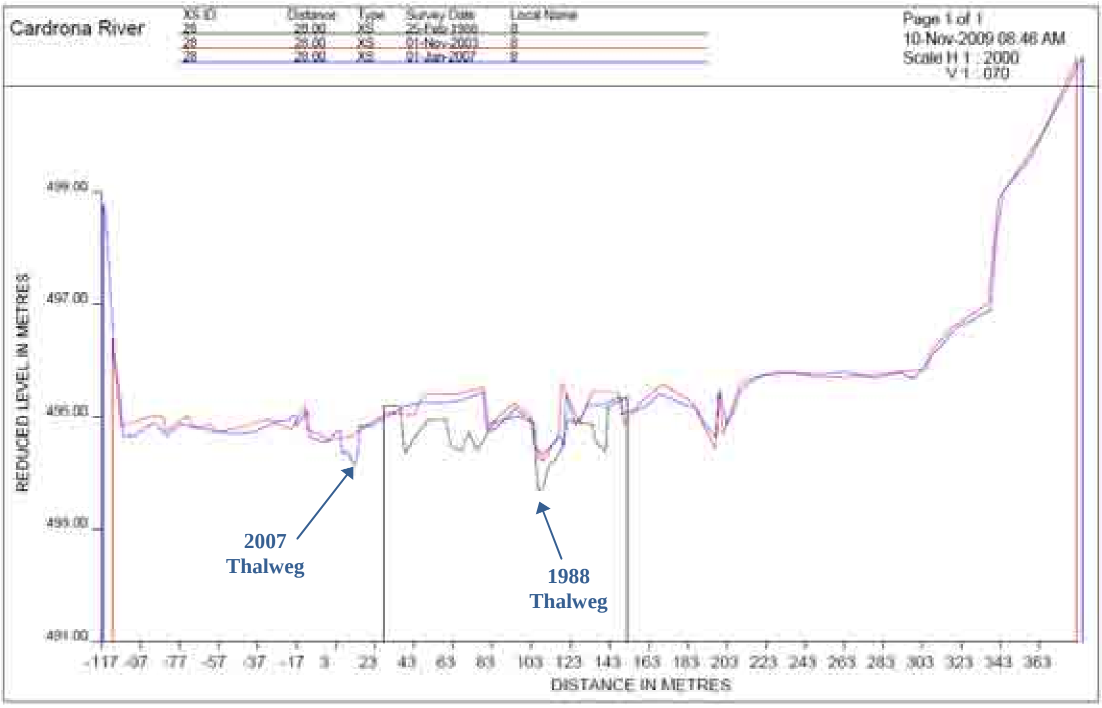

Figure 8.3.28 Cross section 8, looking downstream

8.3.29 Cross section 9

Cross section 9 is located approximately 15.7km upstream of the Clutha River/Mata-Au confluence and 0.9km upstream of cross section 8. Figure 8.3.29 shows a plot of cross section 9 for the February 1988, February 2000, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.27m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Surveyed periods have generally exhibited net degradation at this location, apart from the period 2000 to 2003, which exhibited minor aggradation. The net degradational trend is further reflected by a lowering of the channel thalweg by 1.1m.

The active channel margins at this location are primarily within the central part of the wider floodplain. Similar to the cross sections located downstream of this site, the topography is quite generic and relatively frequent flood events may leave the active channel margin.

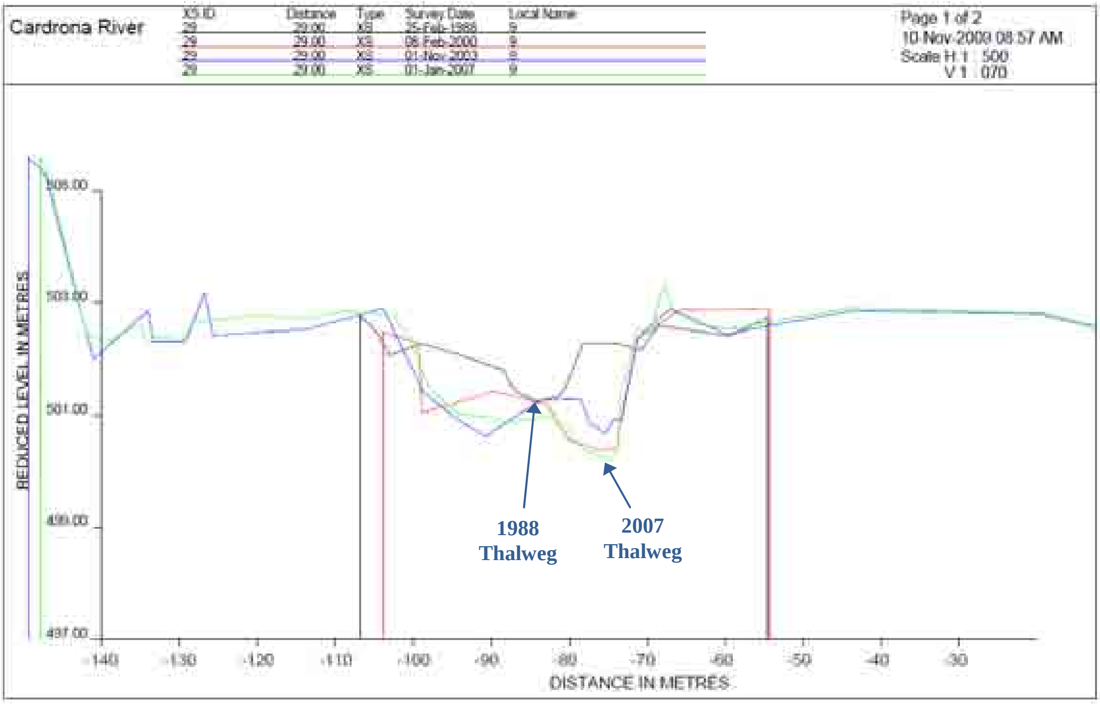

Figure 8.3.29 Cross section 9, looking downstream

8.3.30 Cross section 11-1

Cross section 11-1 is located approximately 17.5km upstream of the Clutha River/Mata-Au confluence and 1.8km upstream of cross section 9. Figure 8.3.30 shows a plot of cross section 11-1 for the February 1988, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net degradation of 0.46m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). All surveyed periods exhibited net degradation, with the largest proportion, 0.41m, occurring during the period 1988 to 2003. Net degradation at this location has occurred across the extents of the active channel margin, which is reflected by minor movement, 0.01m degradation, of the channel thalweg at this location.

The channel morphology at this location is largely constrained by the slopes on either side of the valley and is subject to intensive willow growth. This differs from the braided form exhibited by cross sections immediately downstream.

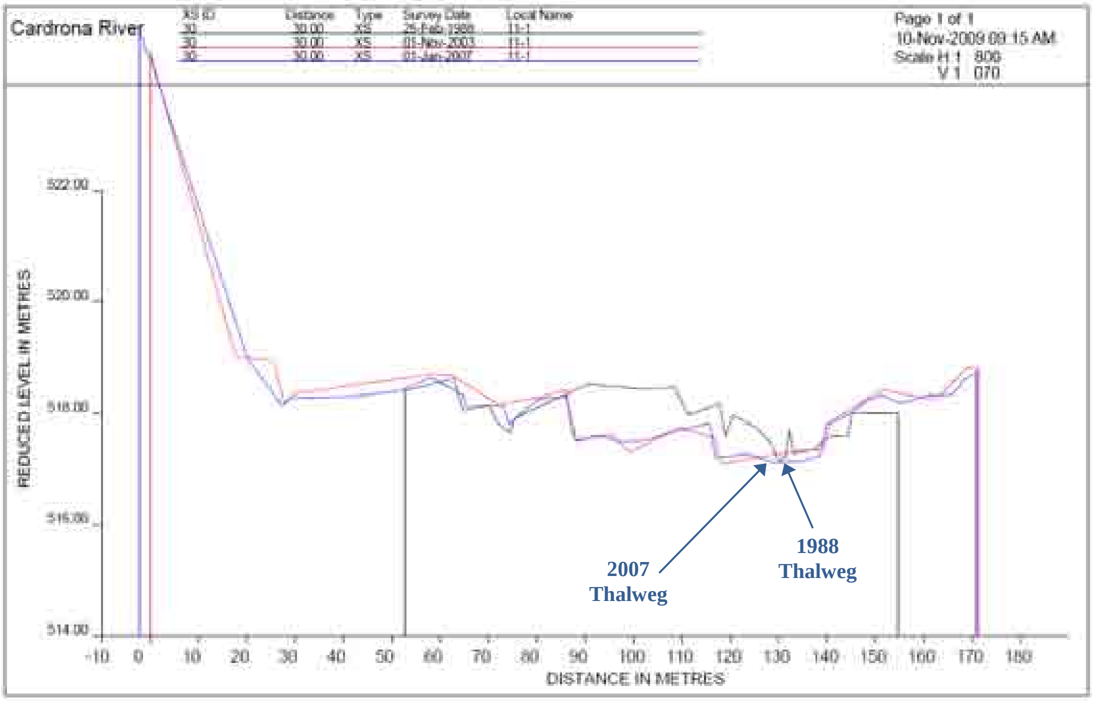

Figure 8.3.30 Cross section 11-1, looking downstream

8.3.31 Cross section 16

Cross section 16 is located approximately 20.5km upstream of the Clutha River/Mata-Au confluence and 3km upstream of cross section 11-1. Figure 8.3.31 shows a plot of cross section 16 for the February 1988, February 2000, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.22m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Both surveyed periods between 1988 and 2003 exhibited net aggradation at this location; while the most recent survey period to 2007 exhibited net degradation of 0.14m. Comparatively, the channel thalweg experienced lowering of 0.63m over all surveyed periods.

The active channel margin is located mid-cross section and appears to have been modified. Peaks towards the true right in both the 2003 and 2007 cross sections are inferred to be embankments or banks created by extensive willow growth. The general topography is very generic at this cross section, with willow growth on either side of the channel, maintaining the confinement of active channel margins.

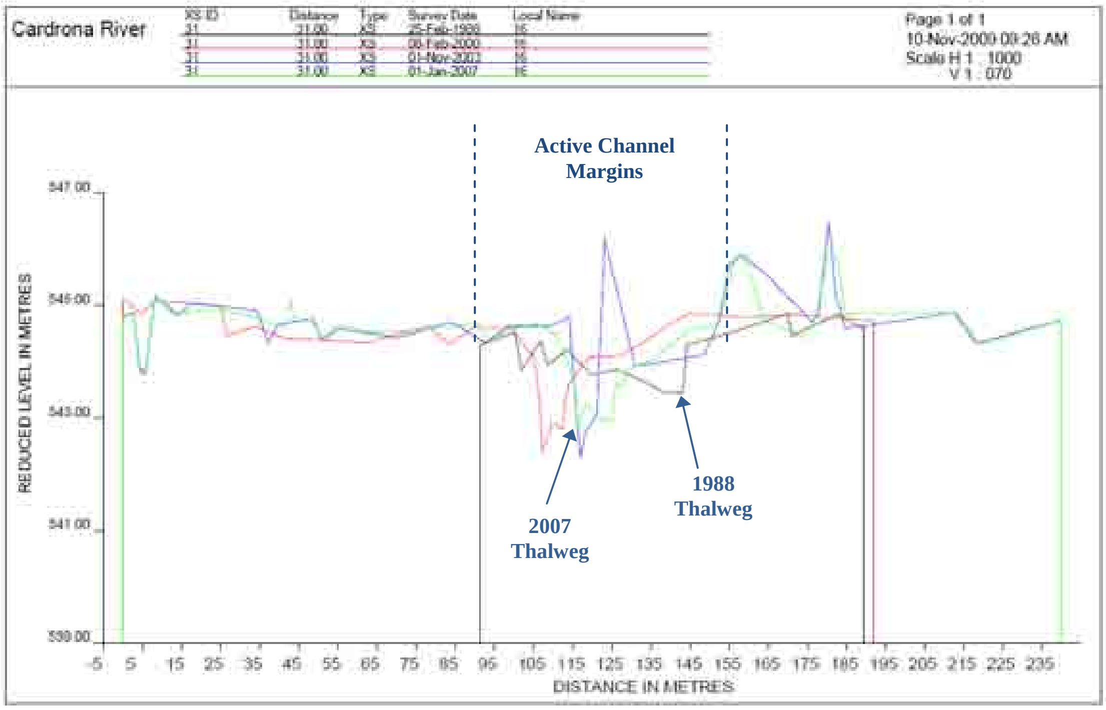

Figure 8.3.31 Cross section 16, looking downstream

8.3.32 Cross section 18-1

Cross section 18-1 is located approximately 21.7km upstream of the Clutha River/Mata-Au confluence and 1.2km upstream of cross section 16. Figure 8.3.32 shows a plot of cross section 18-1 for the February 1988, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.03m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Both surveyed periods between 1988 and 2007 exhibited minor net aggradation. The channel thalweg also exhibits net aggradation, 0.2m, at this location over the surveyed periods.

The channel morphology at this location is largely dictated by a private bridge located immediately downstream. Both banks are confined by the bridge abutments at this location. The floodplain topography is very generic at this location, and the river will leave its active margins and spread laterally during frequent flood events.

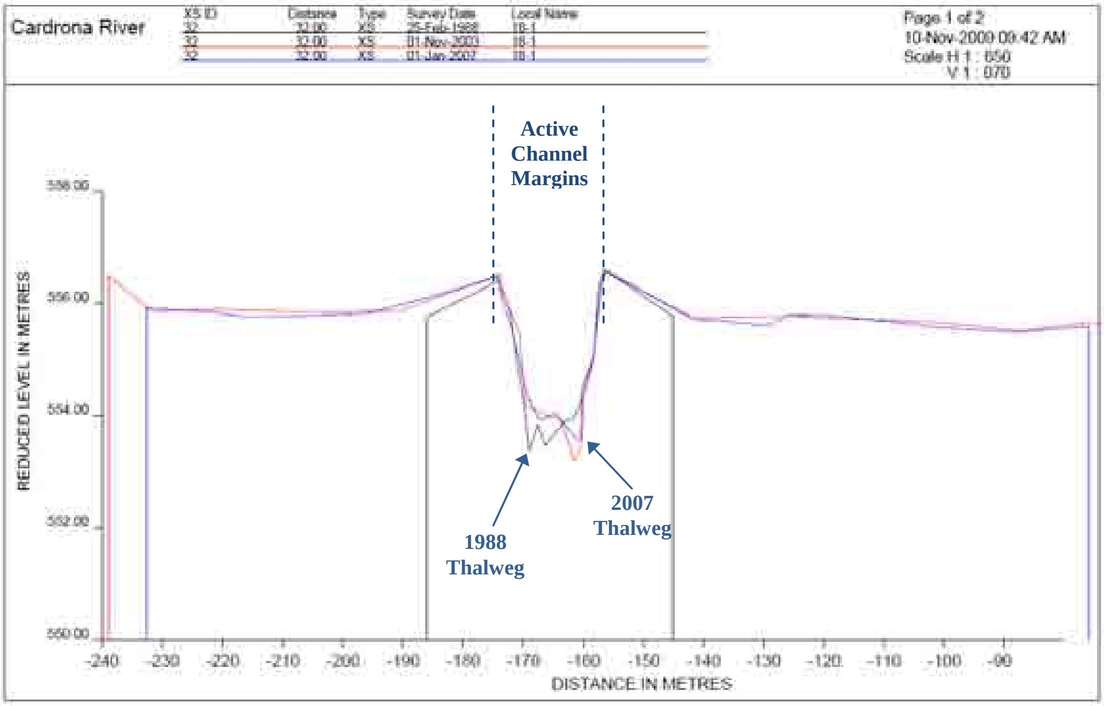

Figure 8.3.32 Cross section 18-1, looking downstream

8.3.33 Cross section 22

Cross section 22 is located approximately 24.1km upstream of the Clutha River/Mata-Au confluence and 2.4km upstream of cross section 18-1. Figure 8.3.33 shows a plot of cross section 22 for the February 1988, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 0.07m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). The minor change in bed levels between survey periods is attributable to this reach primarily being a transport zone of the river, rather than depositional. The channel thalweg experienced 0.08m of degradation at this location over the period 1988 to 2007.

The channel morphology at this location is indicative of this reach of the Cardrona River, where a willow-lined, single-thread channel dominates in generic topography. This area is still within the primary transportation zone of the river.

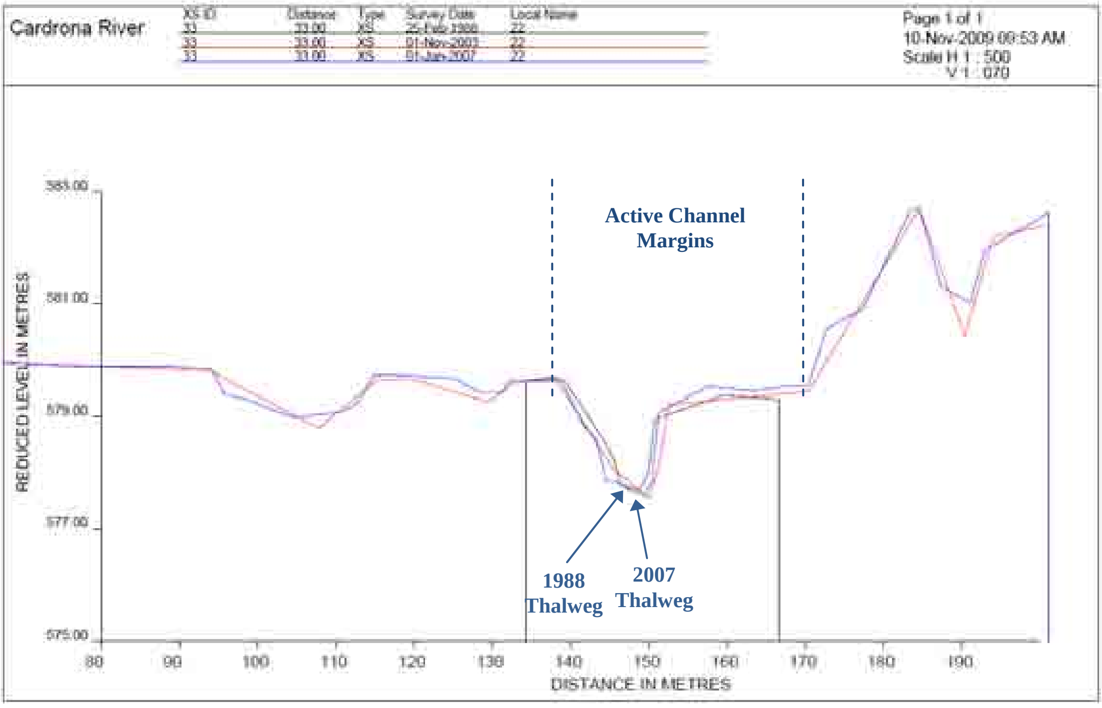

Figure 8.3.33 Cross section 22, looking downstream

8.3.34 Cross section 25-1

Cross section 25-1 is located approximately 26.5km upstream of the Clutha River/Mata-Au confluence and 2.4km upstream of cross section 22. Figure 8.3.34 shows a plot of cross section 25-1 for the February 1988, November 2003 and January 2007 surveys.

Mean bed-level analysis shows net aggradation of 1.01m over the active channel margin during the period 1988 to 2007 (Table 8.1.2). Both surveyed periods experienced net aggradation, with the most recent survey period, 2003 to 2007, experiencing 0.59m of aggradation. This net aggradational trend is also evident in a 0.21m increase in the channel thalweg level over surveyed periods.

The channel morphology at this location is similar to the cross sections immediately downstream. These areas are within a transportation zone of the Cardrona River and are largely confined within a single-thread, willow-bound channel.

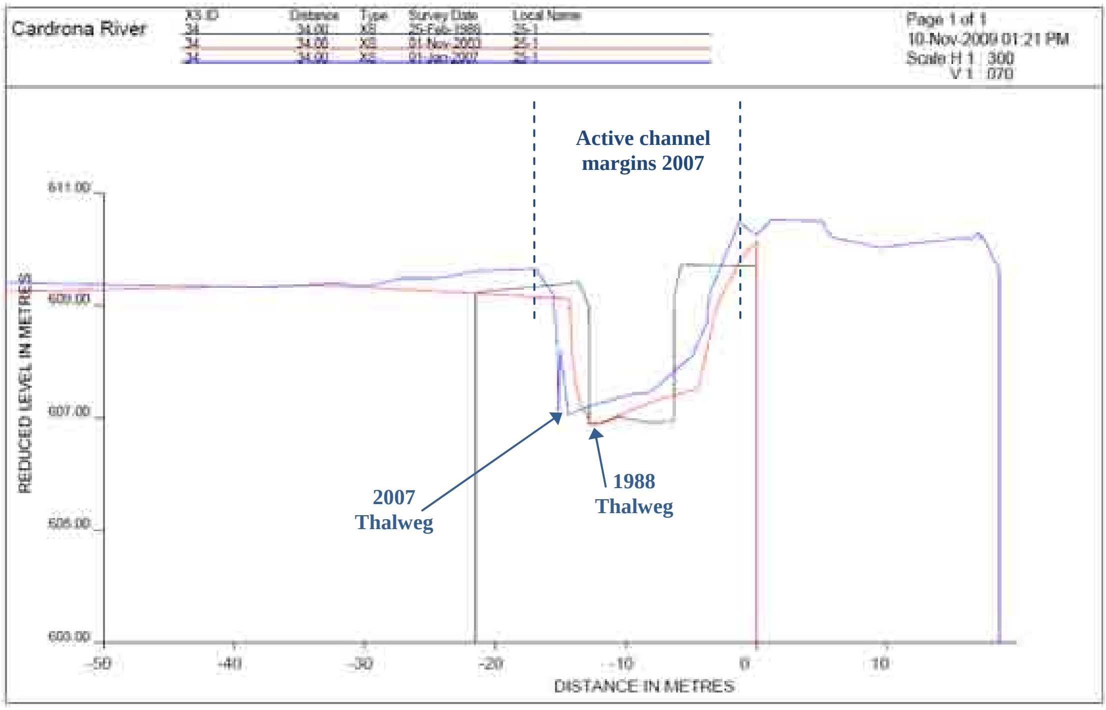

Figure 8.3.34 Cross section 25-1, looking downstream

9 Glossary

Aggradation: To raise the grade or level of the river bed primarily by depositing sediment accumulations

Argillite: Any compact sedimentary rock compose mainly of clay minerals; clay stone

Channel planform: The shape or outline of the river generally defined by morphometric characteristics

Channel-slope connectivity: Generally occurs where the valley is very confined. As the river channel meanders the valley floor, it often erodes into the adjacent valley slopes, hence the 'connection' between channel and slope

Chert: A compact rock generally consisting essentially of microcrystalline quartz

Conglomerate: A coarse-grained sedimentary rock, consisting of rounded fragments of rock embedded in a finer matrix

Degradation: To lower the grade or level of the river bed primarily through the removal of sediment

Lateral Bar: A depositional feature composed of sediment at the edge of a stream channel, formed as the channel shifts laterally. Lateral bar deposits are common in braided rivers

Longitudinal profile: The shape of the river profile along its length, determined by the channel thalweg

Mean annual low flow: The average of the lowest, in general, seven-day moving average for all years of record

Mean bed-level: The mean level of the river bed as calculated over the defined active channel margin

Morphology: The form or structure of the river

Point Bar: A depositional feature composed of sediment on the inside of a channel meander, formed by the process of lateral accumulation

Profile gradient: The gradient of the river reach, as determined by the longitudinal profile

Proto-Clutha river: This term refers to the large river system that drained southwards through the Cardrona valley during the late Miocene-Pliocene. During past glaciations, large sediment-laden rivers flowed from glaciers extending from the Southern Alps. This term refers to the river that would have flowed from where the contemporary Clutha River/Mata-Au exists today

Quartzo-feldspathic: Rocks rich in both quartz and feldspar minerals

Sinuous: Characterized by many curves and turns

Specific yield: Constitutes litres per second per square kilometer at mean annual low flow

Synclinal sedimentary basin: A sedimentary basin exhibiting a syncline like form. A syncline constitutes a downward fold of stratified rocks in which the strata slope towards vertical axis

Thalweg: The lowest point of the cross section (i.e. deepest part of the channel at the point, marking the point for the longitudinal profile)

X-Sect Cross section Database: The database compiles a list of widths and their associated elevations (reduced level) for each cross section and survey period. X-Sect calculates all output information (minimum, maximum and mean bed-levels) from the respective widths and elevations.