# Environment Canterbury

## Temuka River Report
## Status of Gravel Resources and Management Implications

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# 1. Introduction

As part of Environment Canterbury's wider "Regional Gravel Management Investigation" MWH have been commissioned to prepare reports on the Status of Gravel Resources and Management Implications for ten "Priority One" rivers within the Canterbury Region.

The Temuka River in South Canterbury is one of the ten "Priority One" rivers. Investigation of the Temuka River's gravel resources is important because:

- River gravels are used extensively throughout Canterbury (including from the Temuka River) as a construction material for roads, buildings and other infrastructure.
- Gravel aggradation in the Temuka River is a crucial aspect of flood management. Allowing gravel to accumulate in the channel has the effect of reducing the channel capacity and increases the likelihood of a flood escaping the main channel.
- Extracting too much gravel risks damage to infrastructure such as stopbank collapse and bridge pier undermining. These types of events are hazardous to life and property.

This report provides an initial overview of the Temuka River before reviewing its changing bed profile and gravel extraction records to assess the available gravel supply. On the basis of the assessed available gravel supply recommendations are made as to the river's future gravel resource management.

The definition of the Temuka River for the purposes of describing gravel extraction is the reach between the Waihi/Te Moana confluence and the Temuka/Opihi confluence. The term *overall Temuka River catchment* is used to refer to the Temuka River catchment above the Temuka/Opihi confluence including the Te Moana and Waihi Rivers.

# 2. Temuka River Description

The Temuka River runs for around 7.5km in a generally south-east direction around the western and southern periphery of Temuka. The Temuka River starts at the confluence of its two major tributaries the Waihi and the Te Moana Rivers. It ends where Temuka River joins the Opihi River around 4km upstream of where the Opihi reaches the sea. The Kakahu River is a major tributary of the Te Moana River.

The catchment area of the Temuka River is around 570km$^2$ and the top of the catchment is in the Four Peaks Range (elevation up to 1650m). The range is moderately steep with alpine vegetation, scree and bare rock in the higher areas. Moving down catchment the topography flattens into the Canterbury plains with more intensive land uses and pastoral groundcovers dominating.

The geology of the headwaters of the Te Moana, Kakahu and Waihi Rivers is characterised by "greywacke and argillite of medium induration". The lower reaches of the tributary rivers flow across till and outwash gravels of the Canterbury plains.

The Temuka River flows adjacent to Temuka township, which is the only major settlement in the catchment. The Timaru District Council website gives the population of Temuka as 3,981. State Highway 1 and the main trunk railway cross the Temuka River at Temuka township.

# 3. River Processes

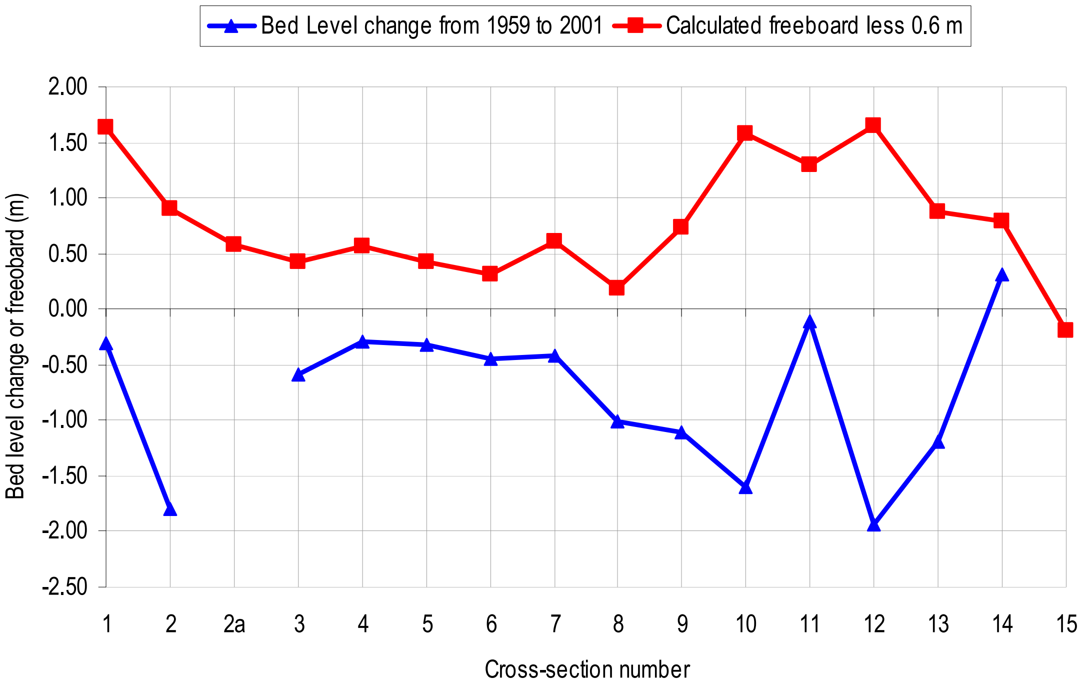
## 3.1 Flooding

The Temuka River has a river control scheme comprising of stopbanks on the true left bank. These are designed to take a flow of 722m$^3$/s with 600mm freeboard, this being the estimated 50-year design flow. However, subsequent hydrological analyses have reduced this return period to about ten years.

The river scheme can take a greater peak flow than this, however, as it is not stopbanked on the true right bank. The existing scheme design has been improved in two places: Firstly, at the railway bridge, where the stopbank was realigned under the railway bridge so that flood waters entering the town could exit; the stopbank under the railway bridge having a capacity of 1,300m$^3$/s without freeboard. And secondly, at the downstream end where the design flow was upgraded to 1,055m$^3$/s with 300mm to 600mm freeboard, or at about the estimated 30 year flood event level.

The design review (Connell, 2005) indicates that the river channel can accommodate an exceedance of the design flows except at the confluence with the Waihi and Hae Hae Te Moana Rivers where the bed needs to be lowered by 300mm at cross-sections 14 and 15. The calculated freeboard less 600mm is given in Figure 3.1 below.

**Figure 3.1: Temuka River - Bed level changes verses freeboards**




This shows that there is considerable freeboard at the downstream end of the river and also at the upstream end of the river. The reason for this is two-fold:

- The first reason is that the riverbed levels have decreased in these areas. This is can be seen in the chart above as the freeboard reflects the bed level change in the river fairway for this period (between the river bed when the stopbanks were designed in 1960 and the latest survey in 2001). This shows a very good fit in most places. The drop in bed level at cross-section 11 is the largest discrepancy, but this can be explained by the backwater effect from lowering the bed level downstream.

The reason that the bed levels dropped by so much at these cross-sections was that the design fairway was shifted (to make a better fairway alignment) to an area that had a high bed level. For instance, if the lowest portion of cross-section 2 is taken (over the fairway width of 63.06m used to compare the bed level changes) the bed level is 13.15m compared to 14.28m. This is a little higher than the 1983 bed level for this section.

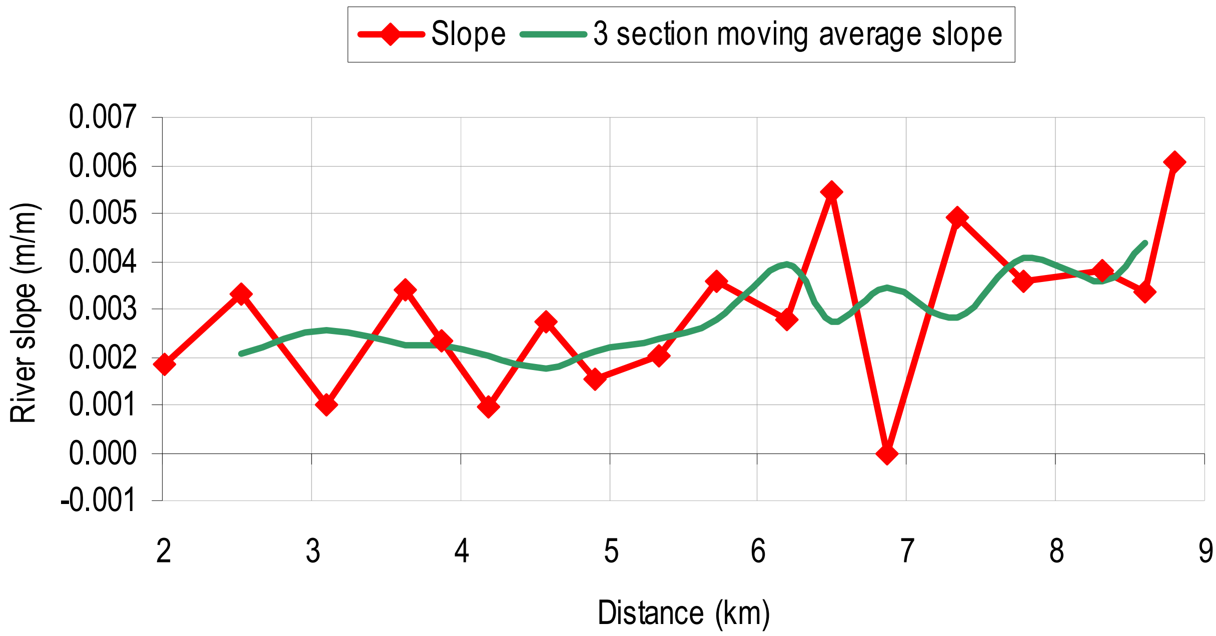
- The second reason is that in the upstream sections (cross-sections 10 to 12) the stopbanks were built almost 1m higher than the proposed design level.

The report recommends retaining the present bed levels as design levels. However the report also recommends waiting for the minimum bed level requirements requested from the bridge authorities for the railway bridge, State Highway One bridge, Manse Road Bridge and possibly the Te Awa Road bridge, which is a short distance upstream on the Waihi River.

## 3.2 River bed Slope Analysis

Over its short 5km length, the slope of this river (derived from the 2001 mean bed levels) drops from about 0.004m/m at the upstream end to about 0.002m/m at the Opihi River confluence as shown in Figure 3.2 below. This means that there is potential for gravel to be deposited with the drop off in energy and the bed load transport capability of the river.

**Figure 3.2: Temuka River Bed Slopes (m/m)**




An approximate analysis (Connell 1992) using Yalin's formula (Henderson (1966) p444) and calibrated using the aggradation on the North Branch Ashburton River, indicates that a maximum of between 10,000$m^3$ and 14,000$m^3$ could be deposited in this reach per year as a result of the drop in slope. The model assumes that the sediment is moved by a 50% of mean annual flood discharge flowing for 0.5% of the year over about 50% of the fairway width. However, as the river catchment is in reasonably good condition, the river is probably not transporting its full potential bed load and therefore the actual figure could be less than this. Further work would be required to ascertain the extent of the difference between theoretical and actual loadings.

# 4. Gravel Extraction

Environment Canterbury monitor gravel extraction from the Temuka River and its tributaries by requiring extractors to submit returns indicating how much, when and where gravel is taken. The Temuka River gravel returns for the period from 1990 to June 2003 have been made available to us.

Our analysis of the returns data has been to determine the patterns of where and when gravel has been extracted from the Temuka River over the 13.5 years of record. Table 4.1 extends the record to14 years (by extending the 2003 returns out to a full year) and breaks the extractions down by year and part of the system where the extractions occurred.

**Table 4.1: Gravel Returns by Year for Each Part of the Temuka River System**

| Year | River / Tributary | | | | Volume by Year |
|---|---|---|---|---|---|
| | Temuka | Te Moana | Waihi | Kakahu | |
| 1990 | 2,450 | 10,660 | 5,260 | | **18,370** |
| 1991 | 1,100 | 590 | 1,280 | | **2,970** |
| 1992 | 1,650 | 3,990 | 3,560 | | **9,200** |
| 1993 | 1,370 | 4,620 | 5,870 | | **11,860** |
| 1994 | 8,600 | 770 | 4,960 | | **14,330** |
| 1995 | 1,040 | 9,840 | 8,200 | | **19,080** |
| 1996 | 2,840 | 20,530 | 6,530 | 770 | **30,670** |
| 1997 | 8,000 | 8,810 | 7,320 | | **24,130** |
| 1998 | 2,820 | 3,350 | 20,090 | | **26,260** |
| 1999 | 1,460 | 4,770 | 16,880 | | **23,110** |
| 2000 | 2,320 | 25,490 | 12,620 | | **40,430** |
| 2001 | 3,810 | 10,670 | 25,430 | | **39,910** |
| 2002 | 6,890 | 14,050 | 19,490 | | **40,430** |
| 2003[1] | 6740 | 13980 | 23,860 | | **44,580** |
| **Total by River/Tributary** | **51,090** | **132,120** | **151,250** | **770** | **335,230** |

[1.] Returns for year 2003 to June have been doubled to estimate full year extractions

For the Temuka River the total volume of gravel extracted over the period of record was 51,100m$^3$, at a rate of 3,650m$^3$/yr. For the overall Temuka River catchment the total volume extracted was 335,200m$^3$, at a rate of 24,670m$^3$/yr.

The temporal distribution of the extractions has not been even over the 14 years of return records. The following charts show an increasing volume trend through the period of record. These recorded extraction rates may follow economic activity, which was suppressed in the early to mid-nineties and has since grown strongly.

The two charts show the relatively minor role of the Temuka River in the overall catchment's gravel supply. The Temuka River only provided 15% of the gravel extracted in the period from 1990 to 2003.

The gravel extraction from the Waihi River is discussed by Hudson *("Waihi River: Status of gravel resources and management implications Report U05/32)*. Hudson's assessment was that the Waihi River is being unsustainably used for gravel extraction.

**Figure 4.1: Temuka River Gravel Extraction by Year**

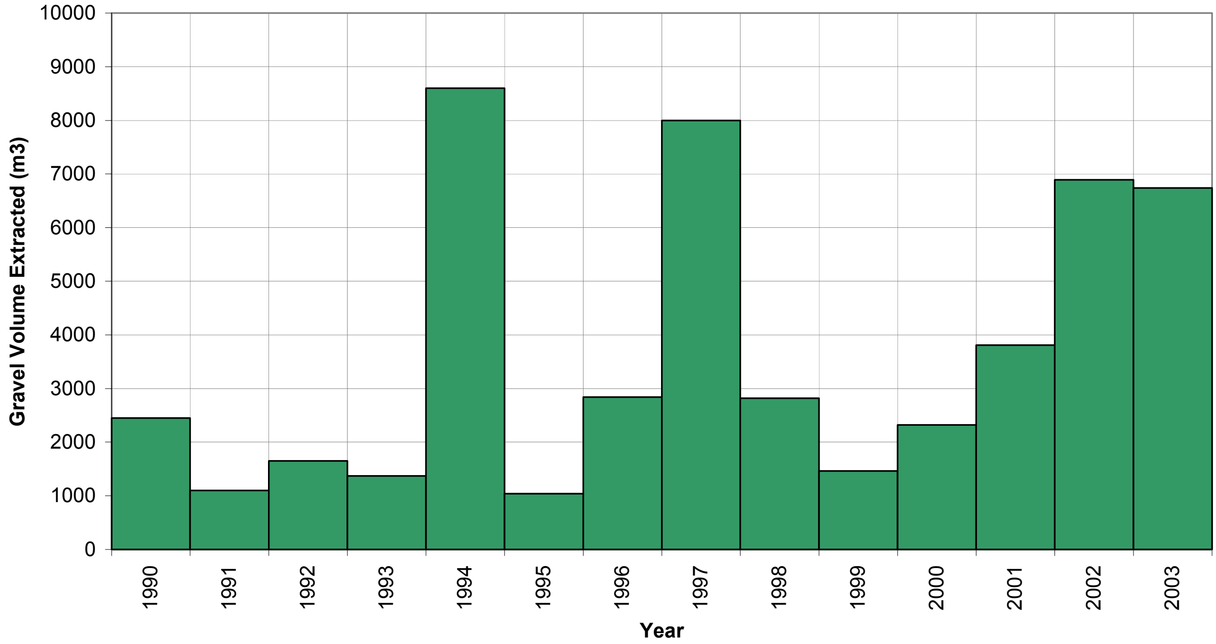
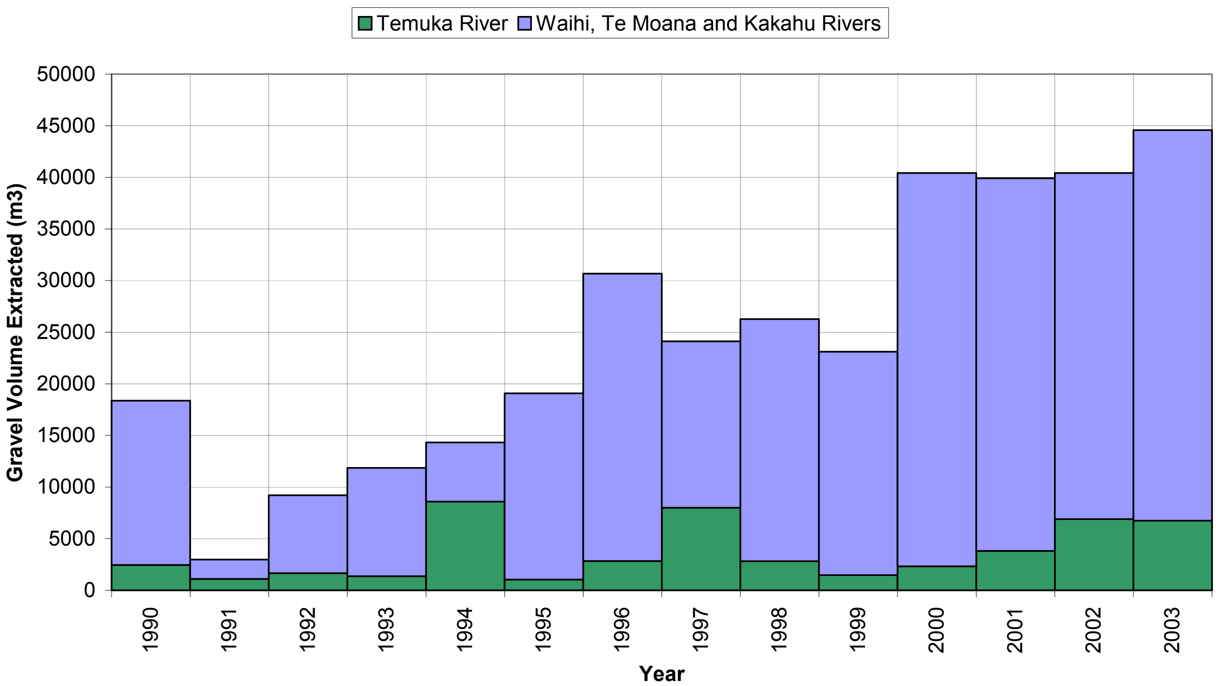



**Figure 4.2: Whole Catchment Temuka River Gravel Extraction by Year**



# 5. River Bed Changes

Environment Canterbury monitors the Temuka River channel by surveying cross-sections on a regular basis. The reduced data from the cross-section monitoring has been made available to us. Table 5.1 includes the cross-section data.

**Table 5.1: Cross-sectional Data**

| River Section | River Distances (km) | Number of Cross-Sections | Number of Surveys and Survey Dates |
|---|---|---|---|
| Temuka River[1] | 0 to 7.34 | 15 | 6 – 1953, 1959, 1983, 1988, 1994, 2001 |

Notes to table:
1. Environment Canterbury data file: *Temuka Mean Bed Levels.xls*

Environment Canterbury cross-section data used in our analysis is:

- The cross-section locations measured from the Temuka-Opihi confluence.
- The cross-section fairway widths calculated as the difference between the left and right channel offsets.
- The cross-section fairway mean bed levels (MBL).

Our analysis includes estimating the gravel volumes (above MSL) by integrating between adjacent cross-sections assuming linear variations of channel width and MBL along the channel between the cross-sections.

In our analysis we have decided not to use the 1953 and 1959 cross-sections because of the river control scheme built in the 1960's. Those works established a new fairway making mean bed level comparisons across that period meaningless. In addition to this, caution and interpretation is required to make use of the post 1960's data, as the river is likely to have been still adjusting to the realignment, which means a gross assessment of the data would be likely to overestimate long term change.

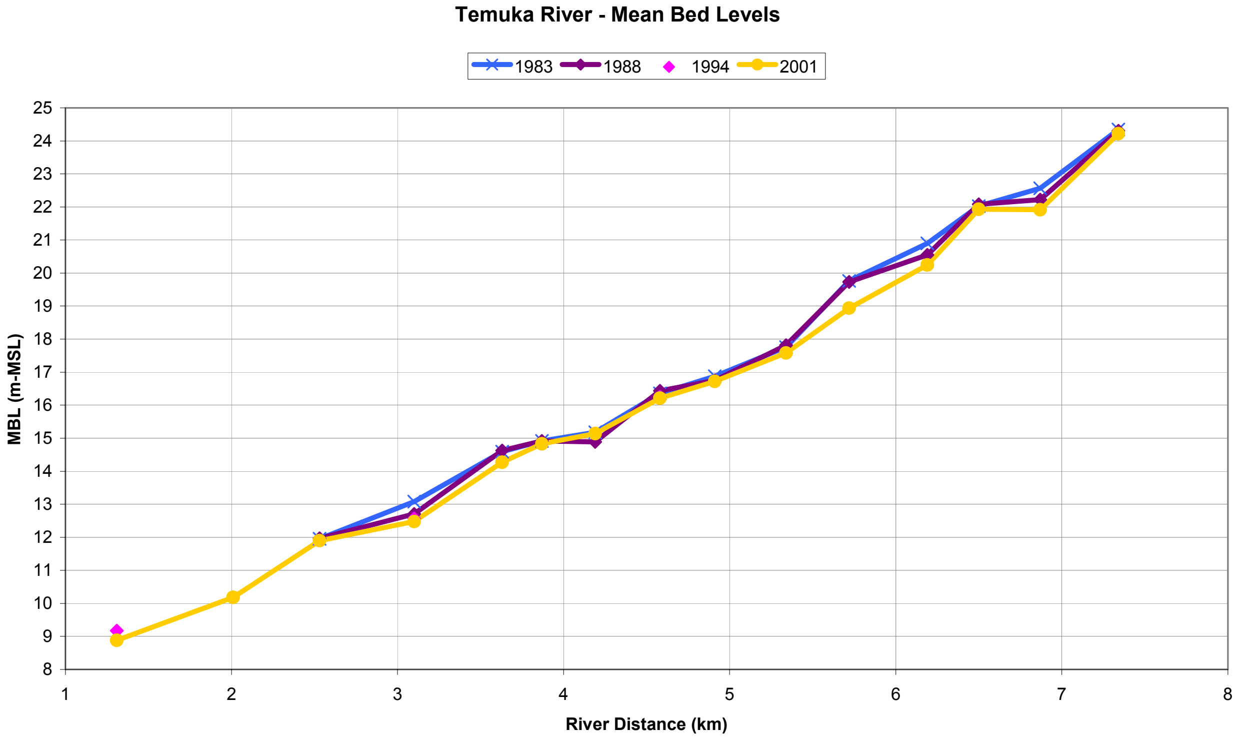
## 5.1 Mean Bed Level Changes

The change in the Temuka River's fairway mean bed level (MBL) over the period from 1983 to 2001 is shown in the following charts. Figure 5.1 shows the MBLs relative to mean sea level and can be interpreted as the river bed profile. Figure 5.2 shows the MBLs relative to the MBLs of the 2001 survey.

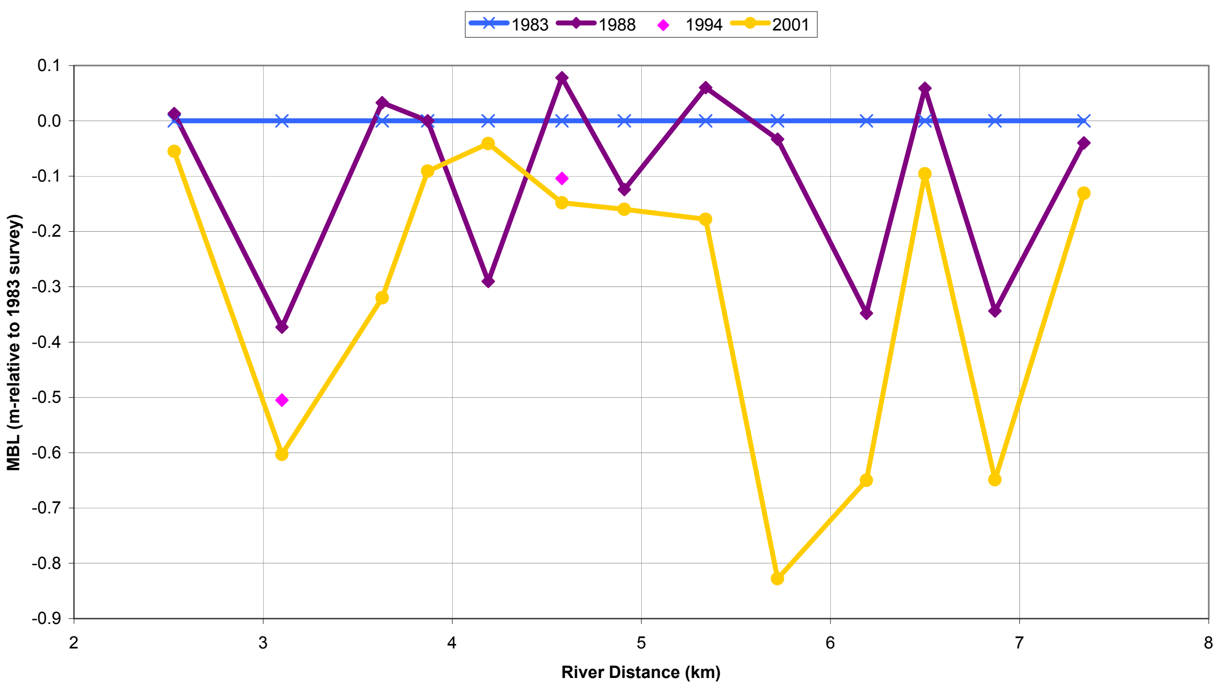
The charts show a general lowering of the bed level with the average MBL falling by 101mm from 1983 to 1988 and a further 203mm from 1988 to 2001.

The river at 3, 6 and 7km has experienced the largest fall in MBL with falls of between 600 and 800mm between 1983 and 2001.

## Figure 5.1: Temuka River MBL Relative to MSL




## Figure 5.2: Temuka River MBL Relative to 1983 Levels

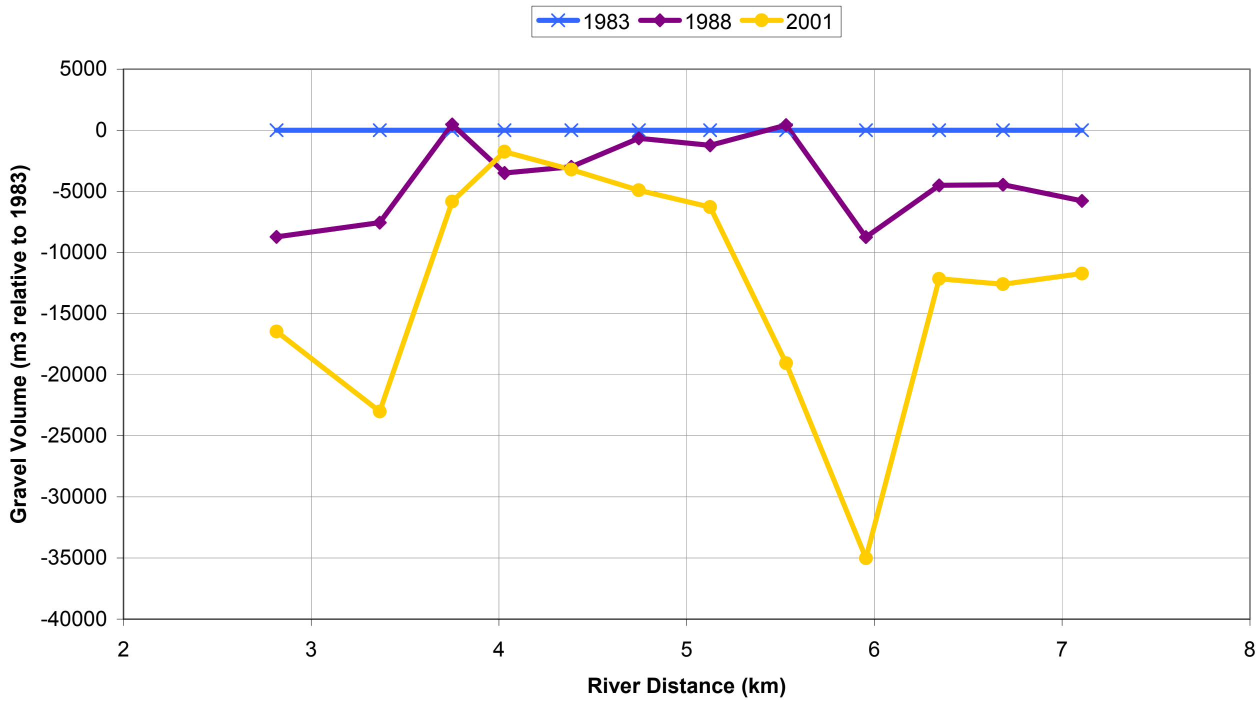



Over the period 1983 to 2001 for all common cross-sections the MBL has fallen. However in the period from 1988 to 2001 there has been some recovery in limited areas, as at 4.2km.

## 5.2 Gravel Volume Changes

The change in the Temuka River's fairway gravel volumes over the period from 1983 to 2001 is shown in Figure 5.3:

**Figure 5.3: Temuka River Fairway Only Gravel Volumes Relative to 1983 Survey**




The chart describes a similar pattern to that discussed in Section 5.1 with an obvious overall loss of gravel.

As discussed above some of the changes indicated by the MBL data may not be a true representation of long term change as recent changes to the river alignment and also the lowering of bed levels in the Opihi River below and the Waihi River above the Temuka River are felt in the river. With this in mind the more extreme falls in MBL (leaving an average drop in MBL of about 170mm) have been left out of the gravel volume change analysis below.

The changing volume of gravel in the Temuka River in terms of absolute volumes and rate of loss for is shown in the Table 5.2. The volumes in the table include some extrapolation of the data to extend the effective range of the data to include the river from 0km to 7.34km.

**Table 5.2: Temuka River Gravel Volume Change**

| Period | Gravel Volume Change ($m^3$) | Rate of Change ($m^3$/year) |
|---|---|---|
| 1988 to 2001 | -115,600 | -8,900 |

# 6. Gravel Supply

Using the available data the gravel supply in the Temuka River can be best estimated using a conservation of volume approach over the river reach. Put simply, gravel entering either leaves or remains in the reach. In mathematical terms for a given reach of river (refer also to accompanying schematic below):

$$\frac{\Delta V_g}{\Delta t} = Q_{g.in} - Q_{g.out} \qquad \textit{(Eqn. 1)}$$

where:

$\Delta V_g$ = change in volume of gravel ($m^3$)

$\Delta t$ = time elapsed (y)

$Q_{g.in}$ = total volume rate of gravel into river reach ($m^3$/y)

$Q_{g.out}$ = total volume rate of gravel out of river reach ($m^3$/y)

Gravel leaves the reach either by extraction or by being transported down-river. Gravel enters the reach either from upstream, side tributaries or bank erosion. Building this into Equation. 1 gives us Equation 2.

$$\frac{\Delta V_g}{\Delta t} = Q_{g.river.in} - Q_{g.river.out} - Q_{g.extraction} \qquad \textit{(Eqn. 2)}$$

where:

$Q_{g.river.in}$ = volume flow rate of gravel into river reach from upstream, side tributaries or bank erosion ($m^3$/y).

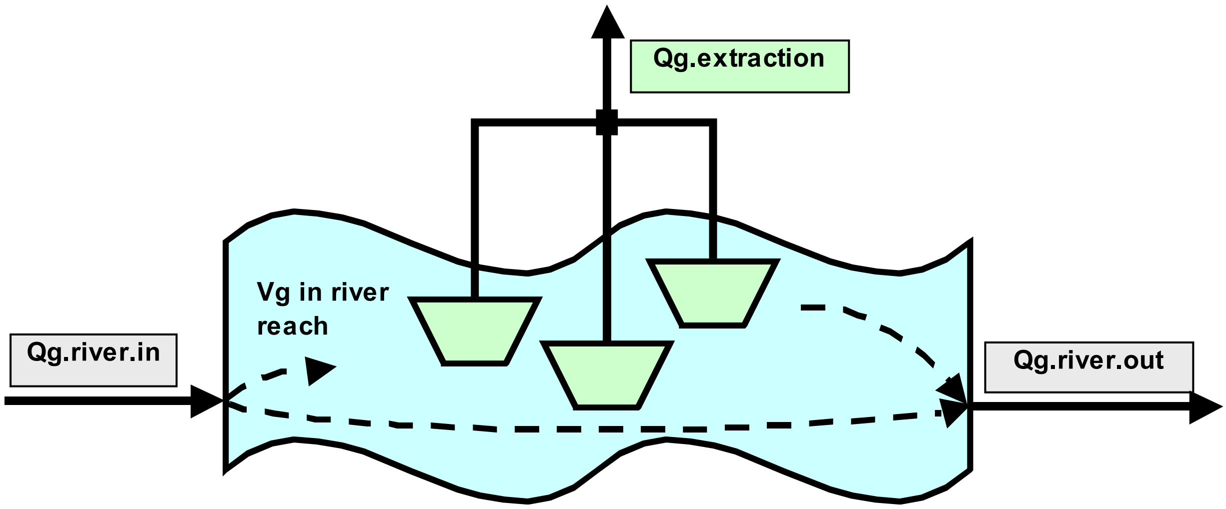
$Q_{g.river.out}$ = volume flow rate of gravel out of river reach by downstream transport ($m^3$/y)

$Q_{g.extraction}$ = volume flow rate of gravel extracted from river reach ($m^3$/y)

Equation 2 can be solved for $Q_{g.river.net}$ (the difference between $Q_{g.river.in}$ and $Q_{g.river.out}$) from the recorded extraction rates and bed level surveys. To estimate the absolute values of $Q_{g.river.in}$ and $Q_{g.river.out}$ we use catchment erosion rate estimates to assess $Q_{g.river.in}$ and then solve for $Q_{g.river.out}$ as the remaining unknown.

Figure 6.1 shows a schematic of the gravel volume flows and changes.

**Figure 6.1: Schematic Representation of Change in Gravel Volumes**




Gravel extraction data is available from 1990 to 2003. The useable MBL surveys extend from 1983 to 2001. The following analysis is based on the average observed rates of extraction from 1990 to 2001 and gravel volume change from 1988 to 2001.

To estimate the gravel inflow we use the reported bed load figures from the Opihi and Orari River Catchment erosion studies by Cuff, (1974, 1981) and sediment ratings, de Joux, 1981) which are 20 to about $80m^3/km^2/yr$ using the total catchment area. These figures are based on gravel trapped behind shingle traps on the Opihi River and using the erosion rating for those catchments to derive a figure for the whole catchment from the erosion rating of all the other subcatchments. They also include abrasion as discussed in erosion study on the Orari (Cuff, 1981) which estimated it at about 40% but it depends upon the ratio of greywacke and argilite.

Extrapolating these figures to the Temuka River with a catchment area of $570km^2$ gives a corresponding bed load input from the catchment of between 15,000 to $25,000m^3/yr$ depending upon the actual erosion in the catchment. The amount of the bed load that reaches the Temuka River is also a function of extractions upstream in the tributary rivers (Te Moana and Waihi).

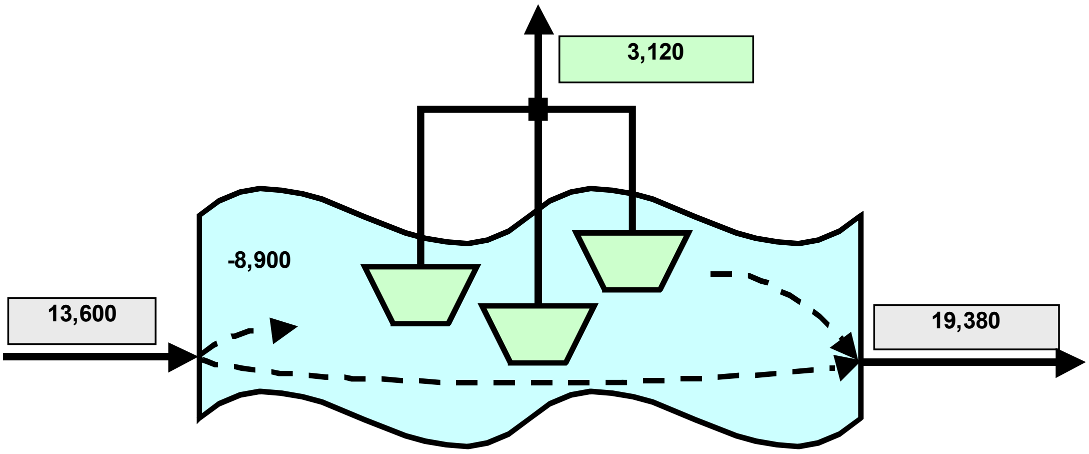
Thus, for the Temuka River the following observed and derived quantities are used in Eqn. 2.

| | | |
|---|---|---|
| $\Delta V_g / \Delta t$ | $-8,900m^3/yr$ | (averaged over 1988 to 2001) |
| $Q_{g.ext}$ | $3,120m^3/yr$ | (refer Section 4) |
| $Q_{g.river.in}$ | $13,600m^3/yr$ | |
| to yield $Q_{g.river.out}$ = | $19,380m^3/yr$. | |

The figures indicate that the river is scouring and picking up sediment from its bed and banks.

The estimated annual average gravel volume flows, extractions and volume changes (all in $m^3/yr$) are shown in the Figure 6.2. The grey coloured boxes show the river bedloads, the light green box shows the gravel extraction and the pale blue box shows the rate of gravel volume change in the river reach.

**Figure 6.2: Temuka River - Schematic Representation of Change in Gravel Volumes**




As reported in Section 3.1, a theoretical rate of aggradation can be estimated from the adaptation of a sediment model derived for the analysis of aggradation to the North Ashburton River. According to this method aggradation of the Temuka River can be expected at a rate of about between 10,000 and 14,000$m^3$/yr. To reconcile this with the sediment budget above one must consider the possible restriction of the sediment supply from upstream due to high levels of extractions in the Te Moana and Waihi Rivers and possible back scour from the Opihi River resulting from bed level lowering in that river.

# 7. Discussion and Recommendations

The gravel budget shows that currently there is no sustainable gravel supply in the Temuka River. The budget could change if the tributary rivers (Te Moana and Waihi) and the Opihi River are managed sustainably in the future.

The proxy design bed level indicated to us by Environment Canterbury is the 2001 bed level, which is that of the latest survey. Therefore the latest survey shows no excess gravel that could be targeted for extraction.

Extractions from the Temuka River should cease until such time as gravel levels can be shown to be above the design bed levels.

# 8. References

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