Natural Environment Regional Monitoring Network River and Stream Channel Monitoring Programme 2000/2001 and 2001/2002

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Cover Photo: Shingle beach on the Otara River near cross-section 32, looking upstream.

Executive Summary

The Environment Bay of Plenty Natural Environmental Regional Monitoring Network (NERMN) River and Stream Channel Monitoring was included as part of the network for the first time in 1993/94.

The River and Stream Channel Monitoring Programme provides Environment Bay of Plenty with:

- Reliable data to identify the quantity of gravel available for extraction and the present extraction rates in the Bay of Plenty region.
- Data to allow setting maximum annual extraction rates available based on river control and river maintenance criteria.
- Data with which Environment Bay of Plenty can meet its statutory obligations under the Resource Management Act, and more effectively manage the region's resources.

Cross section surveys are carried out regularly on 14 rivers and streams, with occasional additional surveys. The data is entered into Environment Bay of Plenty's cross-sections archive system, which is used as the main tool to store and analyse the data.

Completion of the eighth year's monitoring programme adds to the baseline information for comparison with future surveys and allows analysis of 12 sections of rivers and streams. This helps develop an understanding of the movement of gravel in the river systems of the Bay of Plenty region.

The floods experienced in the Eastern Bay of Plenty in July 1998 were a major influence on the changes to gravel volumes over this period. Data analysed for this report has shown a net deposition of some 1,900,000m^3 on the floodplains of the Whakatane-Waimana and Waioeka-Otara schemes, but the majority of this was silt and sand sized particles.

The total volume of extracted material reported has been variable over the last few years:

1992/93 –159,000m^3	1993/94 – 197,000m^3	1994/95 – 241,000m^3
1995/96 – 203,000m^3	1996/97 – 192,000m^3	1997/98 – 147,000m^3
1998/99 – 107,000m^3	1999/00 – 67,000m^3	2000/01– 65,500m^3
2001/02 – 75,000m^3		

In the **Otara River**, with a small extraction rate and relatively substantial deposition on the floodplain and in the main channel before the last survey in 2000, it is recommended that extraction should be increased to keep the river at its recommended bed level. (Refer previous NERMN report).

Following the considerable damage caused by the 1998 storm in the upper **Waioeka Catchment**, it is likely that the supply rate will increase over the next decade and should be carefully monitored and managed. Visual inspection of the Waioeka Gorge suggests some aggradation; new monitoring cross-sections have been established here. (Refer previous NERMN report).

In the **Waimana River**, further extractions should be limited currently in the upper reaches of the river, except where major build-ups are surveyed. It may however be necessary to use a selective combination of extraction and channel reshaping to arrest the degrading processes currently occurring, particularly to thalweg invert levels.

Although river bed levels on the **Whakatane River above Pekatahi Bridge** are on the rise, the previously set extraction limits of 20-30,000m^3 per year from existing beaches should be adhered to until desirable bed levels have been reviewed and met.

Desirable bed levels for the **Ruarepuae Stream** were set in 1986, and surveys in recent years have shown that bed levels are near those desired. Extraction should now be limited to where gravel builds up excessively. (Refer previous NERMN report).

There is little demand for extraction of gravel/sand from the **Rangitaiki River** at present. Gravel or sand extraction is not required, nor should it be encouraged anywhere along the surveyed part of the river at this stage (the heads of the hydro lakes are not surveyed). The exception is in the lower reaches, where morphological processes consequent from the effects of the Edgecumbe earthquake are likely to cause some degradation. This could be artificially encouraged to give adequate flood capacity.

Initial estimates for the **Whirinaki River** indicate supplies are typically of the order of 24,000m^3 per year. Extraction should generally be encouraged, especially in the vicinity of cross-section 4. (Refer previous NERMN report).

Gravel extraction in the **Horomanga River** should cease in the upper part of the reach. In the lower reaches the bed is severely perched and significant extraction is required to avoid undue flooding or avulsion (migration of the river channel). The bed level needs to initially be lowered by an average of 0.50 metres over the 70 metre design fairway width.

Some extraction (of silt and/or sand) may be beneficial in some areas of the **Kaituna River** below Te Matai, if build-ups are excessive. However, the supply of sediment to the coast may be reduced by extraction.

No extraction is carried out in **Tarawera River** at present, and with the lowering of the whole bed it is recommended no sand extraction be allowed in the short to medium term.

When pressure increases on the resource, it may be necessary to redirect extractions more often. The Operations & Rural Services department of Environment Bay of Plenty has moved to ensure that appropriate extraction on the Waioeka River continues and that extraction increases on the Otara River. Extraction on the Waimana and Whakatane rivers has also been directed to certain locations.

Estimates of average annual gravel supply have been included for some rivers, however these are subject to a high degree of uncertainty and the variation from year to year is large.

Contents

Chapter 1: Introduction

1.1 Background

Environment Bay of Plenty initiated a natural environment regional monitoring network (NERMN) in July 1990. In 1993/94 an initial River and Stream Channel Monitoring programme was included as part of this network which also forms an important part of the Impact Assessment monitoring as part of the consent process. This is the eighth year the programme has been included. It assesses and surveys the gravel and sand resources of the Bay of Plenty region and monitors the effect of mining gravel and sand on the river systems.

This report presents the work carried out to date to develop a resource monitoring programme. The gravel resource availability and river yields, demand for aggregate, record keeping and gravel allocation systems are described and discussed.

Gravel has long been taken from some rivers and apart from monitoring by means of cross-sections, little in the way of hard data has been gathered on the effect of this extraction. On some rivers, for example, the Whakatane and Horomanga, there is concern about possible over-extraction, whilst on other rivers, e.g. the Otara, there is concern because of an abundance of gravel.

Sand has long been mined directly from the coast in the Bay of Plenty. There is a strong demand for the resource with sand continuing to be taken from old dune systems. While Environment Bay of Plenty has been in favour of mining to remove excess (but not beach mining, where it is removing more than excess), the demand is recognised. In the long term there is the possibility that extraction may be shifted to some of the region's rivers, e.g. the Kaituna River where the bed level has been rising in some places.

Figure 1.1 shows the gravel extraction sites for 2001/2002 in the river systems of the Bay of Plenty region.

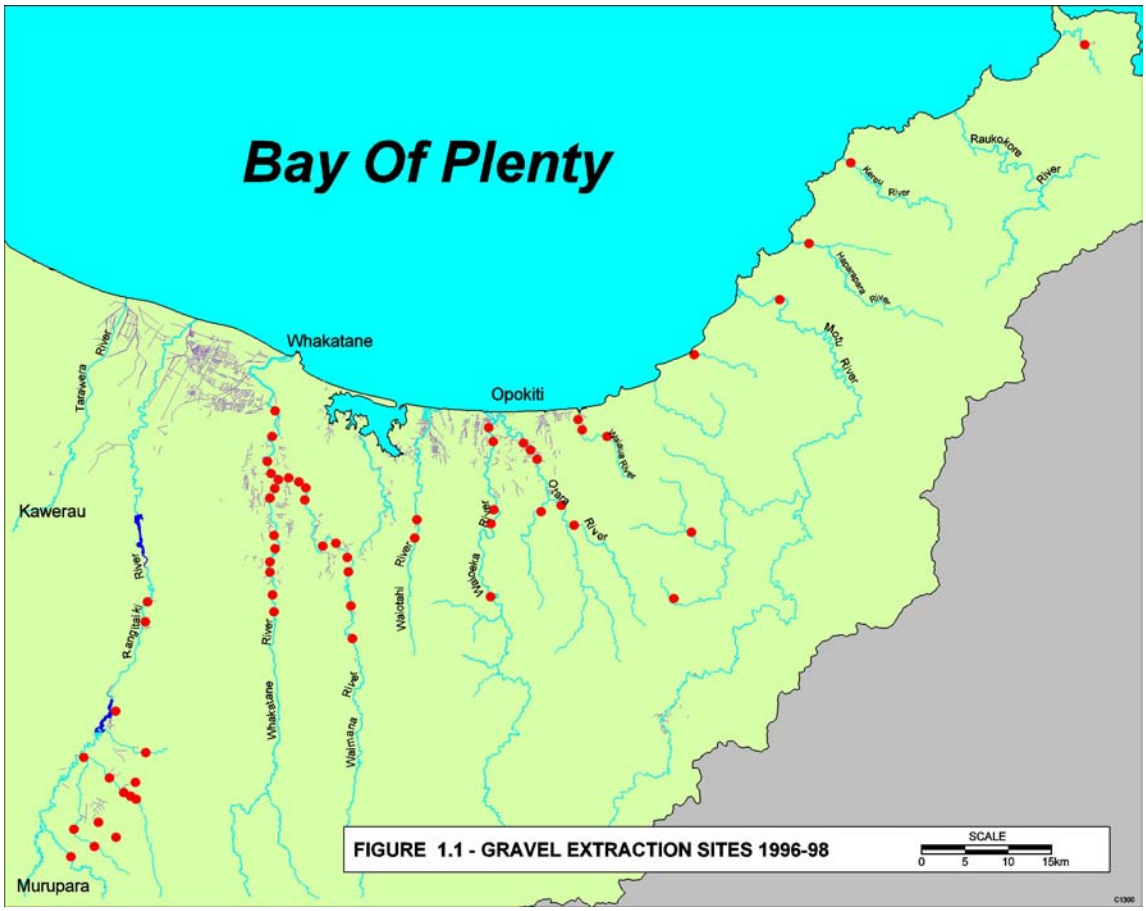


Figure 1.1 Gravel Extraction sites in the Bay of Plenty, 2001/2002

1.2 Specific Objectives of the River and Stream Channel Monitoring Programme

The specific objectives of Environment Bay of Plenty's NERMN River and Stream Channel Monitoring Programme are:

- To provide Environment Bay of Plenty with reliable data to identify the quantity of gravel available for extraction and the present extraction rates in the Bay of Plenty region.
- To provide a basis for setting maximum annual extraction rates.

1.3 Relevant Factors to Consider when Setting Extraction Levels

While this report concentrates on the overall state of the rivers in the region, it is also pertinent to consider the reasons for encouraging or limiting extraction for the stability of river systems. These are illustrated on the next two pages and noted below:

- If the bed level is too high or the waterway congested, flooding is more likely.

- If the bed level is too low, banks are high and have to take the full force of the flow during a flood. Protection works are undermined, more gravel is transported downstream to build up elsewhere. Bank protection works are more costly.

Work needs to be done to define desirable bed levels around the region, for protection of assets of each river scheme and of the public in general.

To encourage stable channels, the following factors need to be promoted:

- Maintaining bed levels within a desirable range

- Maintaining good river alignments

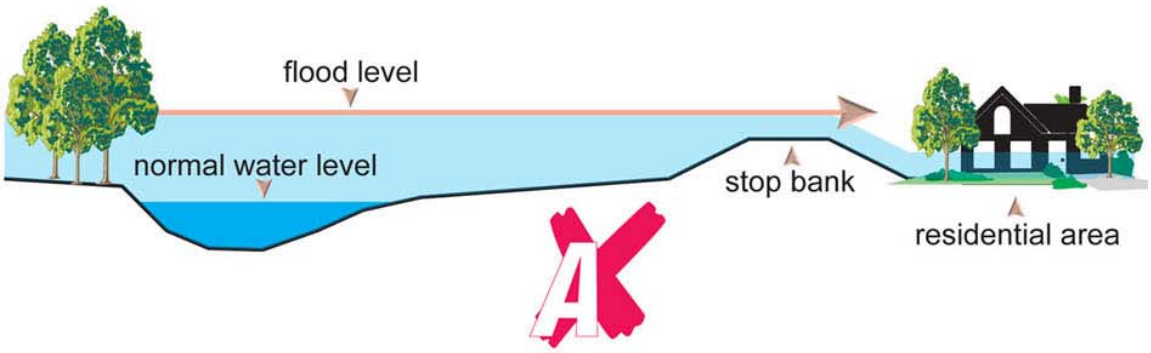
- Keeping roughly in balance with natural supply rates

- Compatibility with existing assets

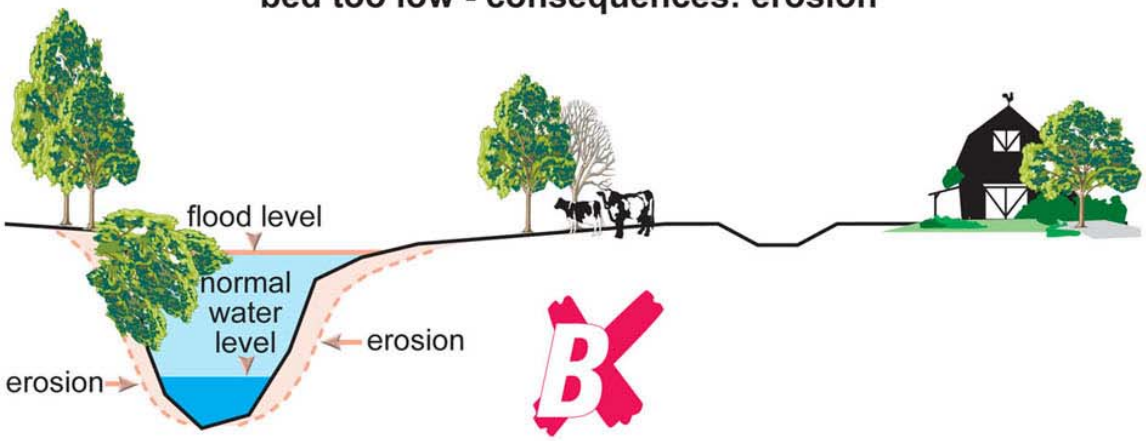
Gravel Extraction Strategy

Optimum Bed Levels

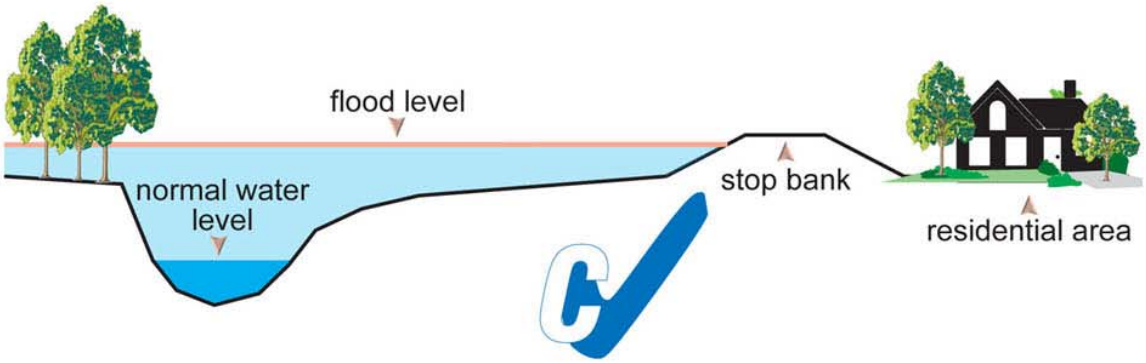
bed too high - consequences: flooding



bed too low - consequences: erosion

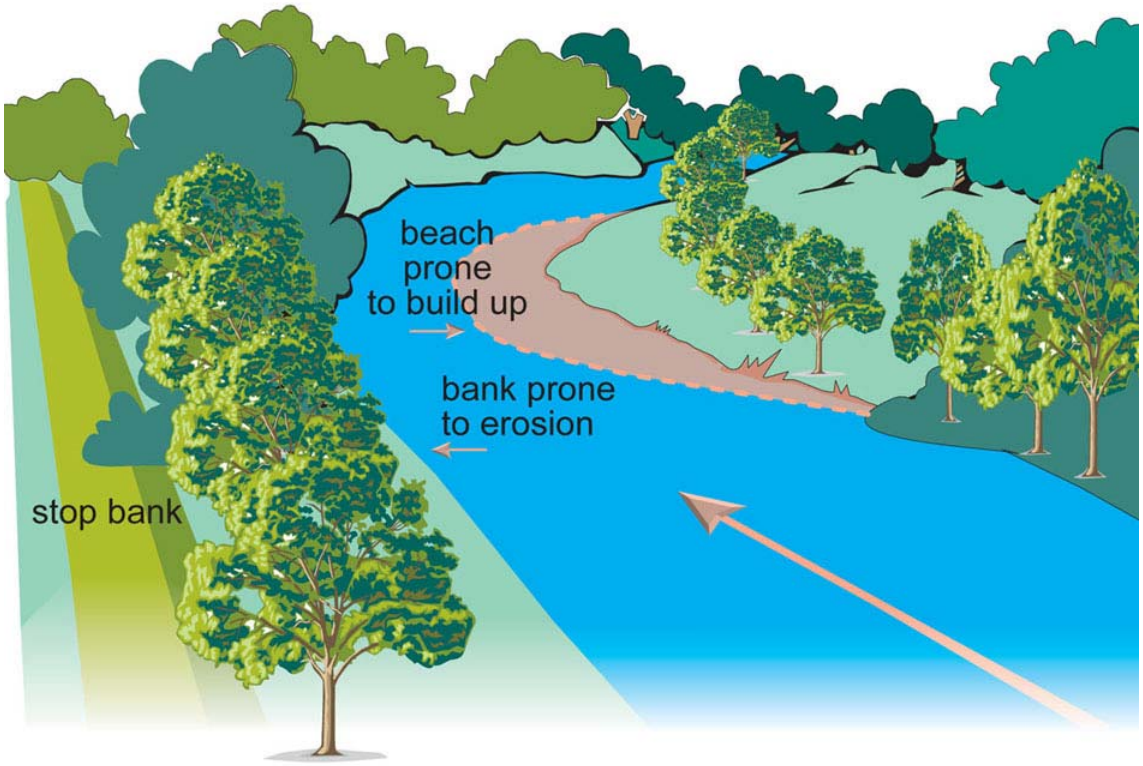


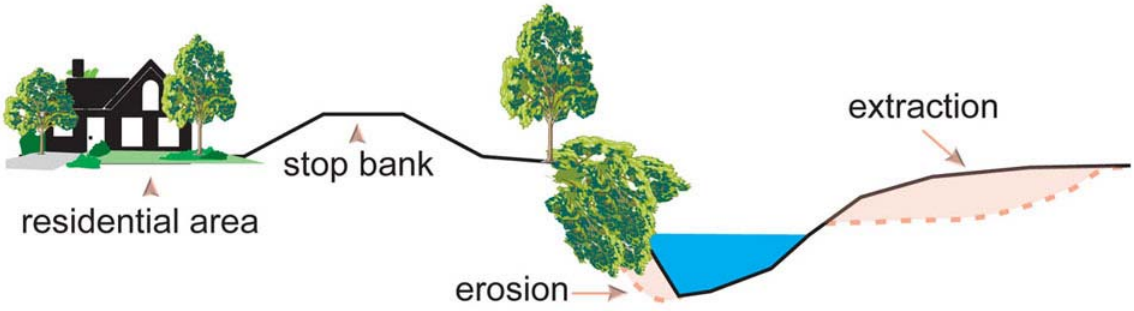
optimum level - consequences: risks kept within reasonable limits



Gravel Extraction Strategy

Remedying Erosion Risk at Bends





Chapter 2: Data Collection and Survey Methods

2.1 Introduction

Prudent river management and the Resource Management Act require an adequate understanding of both the movement of gravel down rivers and the effects of extraction. Before 1993, only intermittent resurveying of river cross sections took place on some rivers. Gravel extraction declaration returns from commercial extractors were not detailed and did not provide sufficient information on the extraction locations.

To effectively monitor gravel extraction, accurate records need to be kept of the amount of gravel removed, and the river cross sections need to be surveyed at regular intervals. Over a sufficiently long period it is possible to determine the average annual rate of deposition.

Environment Bay of Plenty has a comprehensive system of river cross-sections established and these will now be regularly surveyed. The results of the analysis of these surveys will be checked against gravel extraction records to develop an understanding of the movement of gravel in the river systems of the Bay of Plenty region.

Considerable data collection has to be undertaken before the analysis can be carried out. Environment Bay of Plenty is now in a position to make an initial assessment of the resource availability and sustainability, however the variability of supply is large, so ongoing data collection will be required to update these assessments.

2.2 Cross-Sections

The surveyed cross-sections provide the raw data that is entered into the "Ricoda" Software package. Ricoda, developed by NIWA, is Environment Bay of Plenty's cross-section archive system and the main tool to store and analyse the cross-section data. Appendix I sets out the details of Ricoda and how it is used along with gravel extraction records to ascertain gravel transport and extraction rates.

The cross-section surveys are as programmed in Table 2.1. This programme may vary as there is a need to survey the cross-sections after significant freshes in the river systems. For example, the rivers most affected by the major floods in July 1998 were resurveyed ahead of the programmed date.

Table 2.1 Cross-Section Survey Programme as at July 2002

River Name	Date of Last Survey	No. of Cross Sections	Cross Section Spacing	Suggested Frequency of Survey	Relative Extraction Pressure	Next Survey due
Otara	October 2000	37	300-800 m	2-5 year	Low	2003
Waioeka	September 2000	20	300-800 m	2-5 year	Med	2003
Waimana *	July 2001	35	400-1200 m	1-2 year	Med	2003
Whakatane (below Pekatahi Bridge)	January 1999	35	300-750 m	2-5 year	Med	2003
Whakatane* (above Pekatahi Bridge)	February 2002	34	500 - 1200 m	1-2 year	Med	2003/04
Rangitaiki (Lower)	April 2002	67	300 - 700 m	3-5 year		2003
Rangitaiki (Waiohau)	February 1996	12	900-1200 m	5 year		2003
Rangitaiki (above Aniwhenua)	November 2001	28	800-1300 m	5 year	High	2006
Whirinaki *	July 1999	7	500-1000 m	1-2 year	Med	2003
Tarawera	October 2000	18	700-1500 m	5 year		2005
Ohutu *	June 1999	6	400-600 m	1-2 year	Med	2003
Mangamate *	June 1999	7	350 - 550 m	1-2 year	Med	2003
Ruarepuae *	June 2000	7	100 m	1-2 year	Med	2003
Horomanga *	August 2001	14	300 - 800 m	1-2 year	Med	2003
Kopuriki *	March 1998	3	250 m	1-2 year	Med	2003
Kaituna (below Te Matai)	September 2001	26	500 - 600 m	3-5 year		2004
Kaituna (above Te Matai)	October 2001	17	400 - 800 m	3-5 year		2004
Mangorewa	October 2001	3	500 m	3-5 year		2004
Waiotahi	-	7				2003
Waikokopu *	1996			2 year	Med	

* More frequent surveys may be appropriate to match extraction activities.

There is no uniform approach to spacing of cross-sections. On some rivers they are only 100m apart while on others they are as far as one kilometre apart. Environment Bay of Plenty will need to assess what distance is appropriate to effectively monitor the river system - in general this will depend on the size of the river. This non-uniformity is not a problem in itself, rather monitoring requirements should be tailored to the level of detail and accuracy of monitoring required for each river. For long-term monitoring, it is more important to be comparing new data with as long a record as possible, so existing sites should in general be maintained.

Cross-section data and in particular plots allow a ready visual appreciation of what is happening in the river at each site.

2.3 Gravel Extraction

Table 2.2 and Table 2.3 show details of the gravel extracted in the Bay of Plenty region from July 2000 to June 2001 and from July 2001 to June 2002, respectively. The information tabled here is taken from the operators' quarterly returns. In the past, operators have not provided details of the sites when submitting their returns. At present they are starting to supply site information with their returns and in the future they may be required to provide details associated with cross-sections where applicable.

Currently, operators' records are in relation to gravel after it has been screened and processed or sold. For river management purposes and determining the amount of material available for extraction, the relevant measure is the total quantity removed from the river, not just the commercial components of the gravel removed.

There is a need to change the basis of operators' records of volumes of gravel extracted from one based on volumes of gravel sold after it is screened to one based on volumes removed from the river. This would form the basis of a more consistent and comprehensive record of the extraction of the resource.

Reliable estimates of the gravel yield can be derived from these records and using the information from the cross-section surveys.

Contractors need to be provided with a set of plans showing the location of the cross-sections when their consent is issued.

The quantity of gravel transported by the river can be derived from "gravel balance" calculations as the difference between net change in river storage (estimated from inter-survey bed level differences), and gravel extracted (estimated from gravel extraction declaration returns over the period between cross-section surveys).

2.4 Aerial Photography

Regular aerial photography enables visual evaluation of gravel accumulations and identification of areas where extraction can be directed to. A regular programme of aerial photography is undertaken on the river systems.

2.5 Benchmark (BM) Locating

The location of each of the benchmarks no longer needs to be accurately defined for the use of RICODA, as a new version of the software allows a different process to be used to determine volumes. Locating the benchmarks is, however, important for other river management work.

The GPS (Global Positioning System) unit has been used to locate the benchmarks to a position accuracy of within 2-4 metres.

There are a total of 746 benchmarks in the cross section survey programme. Most benchmarks were located prior to 1996. The Waioeka River benchmarks have now been located by GPS. A few benchmarks that are difficult to locate because of tree cover have not been precisely located. A few benchmarks are replaced each year through loss or damage, so require relocating. New benchmarks on the Kopuriki, Waikokopu and Waihua streams have not yet been located by GPS.

Table 2.2 Shingle Extraction in the Bay of Plenty 2000/2001

River	Location	Expiry	Consent	Site	Contractor	Shingle Extracted				Subtotal	Cumulative
			No			Sep-00	Dec-00	Mar-01	Jun-01		Total (m^3)
Whakatane River											
	Below Pekatahi										
	Van Boheman	31/05/02	06 0232	1	J Swaps	0	0	0	0	**0**	**0**
	Blacks	30/04/00	06 0235	1	Tracks	491	160	527	479	**1657**	**1657**
	Sykes	31/10/96	05 0372	1	Waiotahi	0	0	0	0	**0**	**1657**
	Pekatahi To Ruatoki Bridge										
	Lyfords		05 0372	1	Waiotahi	0	0	0	0	**0**	**1657**
	Olds Rd	31/10/96	05 0372	2	Waiotahi	0	0	0	0	**0**	**1657**
	Reids Rd	31/10/96	05 0372	3	Waiotahi	5764	4602	6223	7967	**24555**	**26212**
	Lillas			4						**0**	**26212**
	Rawson			5						**0**	**26212**
	Rawson			6						**0**	**26212**
	Richardsons	31/10/96	05 0372	7	Waiotahi	0	0	0	0	**0**	**26212**
	Richardsons	31/10/96	05 0372	8	Waiotahi	0	0	0	0	**0**	**26212**
	Yeoman			9						**0**	**26212**
	Davies			10						**0**	**26212**
	Mahurihuri	31/10/96	05 0372	11	Waiotahi	0	0	0	0	**0**	**26212**
	Above Ruatoki Bridge										
	Te Kaiti Trust	31/10/96	05 0372	12	Waiotahi	0	0	0	0	**0**	**26212**
	Ngati Rongo	31/10/96	05 0372	13	Waiotahi	0	0	0	0	**0**	**26212**
	Opurana	31/10/96	05 0372	14	Waiotahi	0	0	0	0	**0**	**26212**
	Limeworks	31/10/96	05 0372	15	Waiotahi	0	0	0	0	**0**	**26212**
	Waikirikiri	31/10/96	05 0372	16?	Waiotahi	0	0	0	0	**0**	**26212**
Waimana River											
	Below Ruddicks Rd Bridge										
	Waimana Gorge, Dunstans 1	31/10/96	05 0371	1	Waiotahi	0	0	0	0	**0**	**26212**
	Tanatana	30/04/00	06 0284	1	E·B·O·P					**0**	**26212**
	Waimana Gorge, Dunstans 2	31/10/96	05 0371	2	Waiotahi	0	0	0	0	**0**	**26212**
	Wardlaw Rd	30/11/96	05 0449	2	Wilson Brothers	0	0	0	0	**0**	**26212**
	Waimana Gorge, Dunstans 3	31/10/96	05 0371	3	Waiotahi	0	0	0	0	**0**	**26212**
	Waimana Gorge, Dunstans 4	31/10/96	05 0371	4	Waiotahi	0	0	0	0	**0**	**26212**
	Wardlaw/Ruddicks	31/10/96	05 0371	5	Waiotahi	0	0	0	0	**0**	**26212**
	Hodges			6						**0**	**26212**
	Above Ruddicks Rd Bridge										
	Flemings/Clarks	31/10/96	05 0371	6	Waiotahi	0	0	0	0	**0**	**26212**
	Above Waimana Bridge										
	Tanatana/Rokuraku (Bells Rd)		05 0721		EBOP	0	2000	0	0	**2000**	**28212**
	Lowes		05 0371	1	Waiotahi	0	0	0	0	**0**	**28212**
	Mexteds			2						**0**	**28212**
	Lowes/Mexteds	30/11/96	05 0449	1	Wilson Brothers	0	0	0	0	**0**	**28212**
	Lowes/Mexteds	31/10/96	05 0371	7	Waiotahi	0	0	0	0	**0**	**28212**
	Claytons	31/10/96	05 0371	8	Waiotahi	0	0	0	30	**30**	**28242**
	Len Browns	31/10/96	05 0371	9	Waiotahi	0	0	0	0	**0**	**28242**
	Galatea Road Bridge	31/08/08	05 0593	10	Waiotahi	0	0	0	0	**0**	**28242**
	Galatea Road Bridge	30/09/01	05 0737	1	Edelsten	0	0	4950	0	**4950**	**33192**
Horomanga River											
	Above Troutbeck Rd										
	Troutbeck Rd	31/05/98	05 0577	2	Winstones	0	0	0	0	**0**	**33192**
	Galatea Road Bridge	31/08/08	05 0593	1	Waiotahi	0	0	0	0	**0**	**33192**
	Troutbeck Rd	30/11/03	05 0828		Wilson Bros	0	0	0	0	**0**	**33192**
	Troutbeck Rd	30/06/04	05 0851	1	Robinsons Transport	0	0	0	0	**0**	**33192**

River	Location	Expiry	Consent	Site	Contractor	Shingle Extracted				Subtotal	Cumulative
			No			Sep-00	Dec-00	Mar-01	Jun-01		Total (m^3)
	Troutbeck Rd	30/06/04	05 0851	2	Robinsons Transport	0	0	0	0	**0**	**33192**
	Troutbeck Rd	30/06/04	05 0851	3	Robinsons Transport	0	0	0	0	**0**	**33192**
	Troutbeck Rd	30/06/04	05 0851	4	Robinsons Transport	0	0	0	0	**0**	**33192**
	Troutbeck Rd	30/06/04	06 0300	1	Robinsons Transport	0	0	0	0	**0**	**33192**
Mangamate Stream											
	Troutbeck Rd	30/06/04	06 0300	1	Robinsons Transport	0	0	0	0	**0**	**33192**
	Troutbeck Rd		05 0828	1	Wilson Bros	0	0	0	0	**0**	**33192**
Kopuriki Stream											
	Blacks	31/08/08	06 0023	1	Waiotahi	0	0	0	0		**33192**
	Galatea Road Bridge	30/09/01	05 0737	1	Edelsten	0	0	0	0	**0**	**33192**
Waikokopu Stream											
	Galatea Road	30/06/03	05 0593		Waiotahi	0	0	334	0	**334**	**33526**
Waihui Stream											
	Ruatahuna	30/04/00	05 0813	1	Waiotahi	0	0	6449	0	**6449**	**39975**
Waioeka River											
	S/Highway 2 Bridge	31/01/02	05 1060	1	E·B·O·P/M Kennon	0	0	0	0	**0**	**39975**
	S/Highway 2 Bridge	01/06/99	05 0705	1	Waiotahi	0	0	0	0	**0**	**39975**
	S/Highway 2 Bridge	31/12/99	06 0150	1	Works Infrastructure	0	325	0	3000	**3325**	**43300**
	Petersons	01/06/99	05 0705	2	Waiotahi	279	0	796	0	**1075**	**44375**
	S/Highway 2 Bridge	31/01/02	05 1060	2	E.B.O.P/Eastern Bay Concrete	0	0	0	100	**100**	**44475**
	S/Highway 2 Bridge	31/12/99	06 0150	2	Works Infrastructure	0	0	0	3000	**3000**	**47475**
	B Smith	01/06/99	05 0705		Waiotahi	0	0	0	0	**0**	**47475**
	Youngs	01/06/99	05 0705	4	Waiotahi	0	0	0	0	**0**	**47475**
	Browns	01/06/99	05 0705	5	Waiotahi	0	0	0	0	**0**	**47475**
	Browns Pipeline	01/06/99	05 0705	6	Waiotahi	0	0	0	0	**0**	**47475**
	Opotiki Depot	01/06/99	05 0705	7	Waiotahi	3602	3400	4531	4553	**16086**	**63561**
	Michaels	30/04/02	06 0304		Waiotahi	0	0	0	0	**0**	**63561**
	Maxwell			7						**0**	**63561**
	Youngs	31/12/02	05 1060	8	E·B·O·P - ORS	0	0	0	0	**0**	**63561**
	Graemes Bridge	31/12/02	05 1060	9	EBOP - ORS	0	0	0	0	**0**	**63561**
	Wairata	31/12/02	05 1060	10	EBOP - ORS	0	0	0	0	**0**	**63561**
Otara River											
	Scheme Area										
	Gows Road	31/12/02	05 1061	1	E·B·O·P - ORS	215	85	0	0	**300**	**63861**
	Gows Road	31/12/02	05 1061	1	E·B·O·P - ORS	0	0	0	0	**0**	**63861**
	Gows Road	31/12/02	05 1061	1	E·B·O·P - ORS	0	0	0	0	**0**	**63861**
	Carters	31/12/02	05 1061	1	E.B.O.P - ORS/EBC	0	0	0	200	**200**	**64061**
	Goult	?	?	2	Waiotahi Contractors	0	0	0	0	**0**	**64061**
	Goult	31/12/02	06 0151	2	E·B·O·P - ORS	0	0	0	0	**0**	**64061**
	Lockhead		?	3	Waiotahi Contractors	0	0	0	0	**0**	**64061**
	EBA5	31/12/99	06 0151	3	Works Infrastructure	0	0	0	0	**0**	**64061**
	Carters	?	06 0151	4	Waiotahi Contractors	1387	0	0	0	**1387**	**65448**
	Carters	?	05 1061	4	M Kennon	300	0	276	0	**576**	**66024**
	Carters	31/12/02	05 1061	4	E·B·O·P - ORS	0	0	0	0	**0**	**66024**
	Kellers	31/12/02	05 1061	5	E·B·O·P - ORS	0	0	0	0	**0**	**66024**
	Kellers	31/12/02	05 1061	5	E·B·O·P - ORS	0	0	0	0	**0**	**66024**
	Kellers	31/12/02	05 1061	5	E·B·O·P - ORS	0	0	0	0	**0**	**66024**
	M Brown	31/12/02	05 1061	6	E·B·O·P - ORS	0	0	0	0	**0**	**66024**
	Watsons	31/12/02	05 1061	?	E·B·O·P - ORS	0	0	0	0	**0**	**66024**
Waiotahi River											
	Youngs		05 0722	1	Wilson Brothers	0	3500	500	0	**4000**	**70024**
East Coast Rivers											
Hawai River											

River	Location	Expiry	Consent	Site	Contractor	Shingle Extracted				Subtotal	Cumulative
			No			Sep-00	Dec-00	Mar-01	Jun-01		Total (m^3)
	SH35 Bridge	30/06/01	05 0780	1	Waiotahi Metal	0	0	0	0	**0**	**70024**
					Total	**12038**	**14072**	**24586**	**19329**	**70024**	**70024**

Table 2.3 Shingle Extraction in the Bay of Plenty 2001/2002

River	Location	Expiry	Consent	Site	Contractor	Shingle Extracted				Subtotal	Cumulative
			No			Sep-01	Dec-01	Mar-02	Jun-02	(m^3)	Total (m^3)
Whakatane River											
	Below Pekatahi										
	Van Boheman	31/05/02	06 0232	1	J Swaps	0	0	0	0	**0**	**0**
	Blacks	30/04/00	06 0235	1	Tracks	176	1123	656	1527	**3482**	**3482**
	Sykes	31/10/96	05 0372	1	Waiotahi		0	0	5909	**5909**	**9391**
	Pekatahi To Ruatoki Bridge										
	Lyfords		05 0372	1	Waiotahi	0	0	0	0	**0**	**9391**
	Reids Rd	31/10/96	05 0372	3	Waiotahi	5093	6073	5710	0	**16876**	**26267**
	Lillas			4						**0**	**26267**
	Rawson			5						**0**	**26267**
	Richardsons	31/10/96	05 0372	7	Waiotahi	0	0	0	0	**0**	**26267**
	Yeoman			9						**0**	**26267**
	Davies			10						**0**	**26267**
	Mahurihuri	31/10/96	05 0372	11	Waiotahi	0	0	0	0	**0**	**26267**
	Above Ruatoki Bridge										
	Te Kaiti Trust	31/10/96	05 0372	12	Waiotahi	0	0	0	0	**0**	**26267**
	Ngati Rongo	31/10/96	05 0372	13	Waiotahi	0	0	0	0	**0**	**26267**
	Opurana	31/10/96	05 0372	14	Waiotahi	0	0	0	0	**0**	**26267**
	Limeworks	31/10/96	05 0372	15	Waiotahi	0	0	0	0	**0**	**26267**
	Waikirikiri	31/10/96	05 0372	16?	Waiotahi	0	0	0	0	**0**	**26267**
Waimana River											
	Below Ruddicks Rd Bridge										
	Waimana Gorge, Dunstans 1									**0**	**26267**
	Waimana Gorge, Dunstans 2			2	Waiotahi	0	0	52	0	**52**	**26319**
	Wardlaw Rd	30/11/96	05 0449	2	Wilson Brothers	0	1100	0	0	**1100**	**27419**
	Waimana Gorge, Dunstans 3			3	Waiotahi	0	0	304	0	**304**	**27723**
	Waimana Gorge, Dunstans 4			4	Waiotahi	0	0	0	0	**0**	**27723**
	Wardlaw/Ruddicks			5	Waiotahi	0	0	0	0	**0**	**27723**
	Above Ruddicks Rd Bridge										
	Flemings/Clarks		05 0371		Waiotahi	48	0	0	0	**48**	**27771**
	Above Waimana Bridge										
	Tanatana/Rokuraku (Bells Rd)		05 0449		Wilson Bros	0	0	0	0	**0**	**27771**
	Lowes									**0**	**27771**
	Mexteds									**0**	**27771**
	Lowes/Mexteds	30/11/96	05 0449	1	Wilson Brothers	0	0	1766	1550	**3316**	**31087**
	Lowes/Mexteds	31/10/96	06 0284	7	Waiotahi	0	0	0	0	**0**	**31087**
	Claytons	31/10/96	06 0284	8	Waiotahi	0	0	0	2114	**2114**	**33201**
	Len Browns	31/10/96	06 0284	9	Waiotahi	0	0	0	0	**0**	**33201**
Horomanga River											
	Above Troutbeck Rd										
	Galatea Road Bridge	31/08/08	05 0706	10	Waiotahi	0	0	0	0	**0**	**33201**
	Galatea Road Bridge	30/09/01	05 0737	1	Edelsten	0	0	0	0	**0**	**33201**
	Galatea Road Bridge	31/08/08	05 0706	1	Waiotahi	0	0	0	0	**0**	**33201**
	Troutbeck Rd	30/11/03	05 0828		Wilson Bros	3000	0	5204	0	**8204**	**41405**
	Troutbeck Rd	30/06/04	05 0851	1	Robinsons Transport	0	0	0	0	**0**	**41405**

River	Location	Expiry	Consent No	Site	Contractor	Shingle Extracted Sep-01	Dec-01	Mar-02	Jun-02	Subtotal (m^3)	Cumulative Total (m^3)
	Troutbeck Rd	30/06/04	06 0300	1	Robinsons Transport	0	0	0	0	**0**	**41405**
Mangamate Stream											
	Troutbeck Rd	30/06/04	06 0300	1	Robinsons Transport	0	0	0	0	**0**	**41405**
	Troutbeck Rd		05 0828	1	Wilson Bros	0	0	0	6007	**6007**	**47412**
Kopuriki Stream											
	Blacks	31/08/08	06 0023	1	Waiotahi	0	0	0	0	**0**	**47412**
	Galatea Road Bridge	30/09/01	05 0737	1	Edelsten	0	0	0	0	**0**	**47412**
Waikokopu Stream											
	Galatea Road	30/06/03	05 0706		Waiotahi	0	0	0	430	**430**	**47842**
Waihui Stream											
	Ruatahuna	30/04/00	06 0443	1	Waiotahi	628	0	0	0	**628**	**48470**
Waioeka River											
	S/Highway 2 Bridge	31/01/02	05 1060	1	E·B·O·P/M Kennon	0	0	0	0	**0**	**48470**
	S/Highway 2 Bridge	01/06/99	05 1060	1	E·B·O·P/Works Infrastructure	1800	0	0	416	**2216**	**50686**
	S/Highway 2 Bridge	31/12/99	05 1060	1	E·B·O·P/Waiotahi	0	0	0	0	**0**	**50686**
	Petersons (Robbie's)	01/06/99	05 0705	3	E·B·O·P/Waiotahi	286	2619	12	4513	**7430**	**58116**
	S/Highway 2 Bridge	31/01/02	05 1060	2	E.B.O.P/Eastern Bay Concrete	50	0	80	40	**170**	**58286**
	S/Highway 2 Bridge	31/12/99	05 1060	2	E·B·O·P	0	0	0	0	**0**	**58286**
	B Smith		05 1060		E·B·O·P	0	0	0	0	**0**	**58286**
	Youngs	01/06/99	05 1060	4	E·B·O·P	0	0	0	0	**0**	**58286**
	Browns	01/06/99	05 1060	5	E·B·O·P	0	0	0	0	**0**	**58286**
	Browns Pipeline	01/06/99	05 1060	6	E·B·O·P	0	0	0	0	**0**	**58286**
	Opotiki Depot	01/06/99	05 1060	7	E·B·O·P/Waiotahi	4432	5868	4335	0	**14635**	**72921**
	Michaels	30/04/02	06 0304		Waiotahi	72	0	0	0	**72**	**72993**
	Maxwell			7						**0**	**72993**
	Youngs	31/12/02	05 1060	8	E·B·O·P - ORS	0	0	0	0	**0**	**72993**
	Graemes Bridge	31/12/02	05 1060	9	EBOP - ORS	0	0	0	0	**0**	**72993**
	Wairata	31/12/02	05 1060	10	EBOP - ORS	0	0	0	0	**0**	**72993**
Otara River											
	Scheme Area										
	Gows Road	31/01/02	05 1061	1	E·B·O·P - ORS	0	0	0	0	**0**	**72993**
	Gows Road	31/01/02	05 1061	1	E·B·O·P - ORS	0	0	0	0	**0**	**72993**
	Gows Road	31/01/02	05 1061	1	E·B·O·P - ORS	0	0	0	0	**0**	**72993**
	Carters	31/01/02	05 1061	1	E.B.O.P - ORS/EBC	205	200	200	135	**740**	**73733**
	Goult	31/12/02	05 1061	2	E·B·O·P - ORS	0	0	0	0	**0**	**73733**
	Lockhead		?	3	EBOP-Waiotahi Contractors	0	0	0	0	**0**	**73733**
	EBA5	31/12/99	05 1061	3	E·B·O·P-Works Infrastructure	0	0	0	0	**0**	**73733**
	Carters	?	05 1061	4	EBOP-Waiotahi Contractors	446	51	0	0	**497**	**74230**
	Carters	?	05 1061	4	E·B·O·P-M Kennon	583	0	213	0	**796**	**75026**
	Carters	31/12/02	05 1061	4	E·B·O·P - ORS	0	0	0	0	**0**	**75026**
	Kellers	31/12/02	05 1061	5	E·B·O·P - ORS	0	0	0	0	**0**	**75026**
	Kellers	31/12/02	05 1061	5	E·B·O·P - ORS	0	0	0	0	**0**	**75026**
	Kellers	31/12/02	05 1061	5	E·B·O·P - ORS	0	0	0	0	**0**	**75026**
	M Brown	31/12/02	05 1061	6	E·B·O·P - ORS	0	0	0	0	**0**	**75026**
	Watsons	31/12/02	05 1061	?	E·B·O·P - ORS	0	0	0	0	**0**	**75026**
Waiotahi River											
	Youngs		05 0448	1	Wilson Brothers	0	0	0	0	**0**	**75026**
East Coast Rivers											
Hawai River											
	SH35 Bridge									**0**	**75026**
					Total	**16819**	**17034**	**18532**	**22641**	**75026**	**75026**

Chapter 3: Results

3.1 Introduction

The data collected allows a comparison with the previously collected baseline information. Environment Bay of Plenty can now develop a methodology to allocate gravel extraction in each resource area. The following pages summarise the situation that exists at present in each of our river/stream systems.

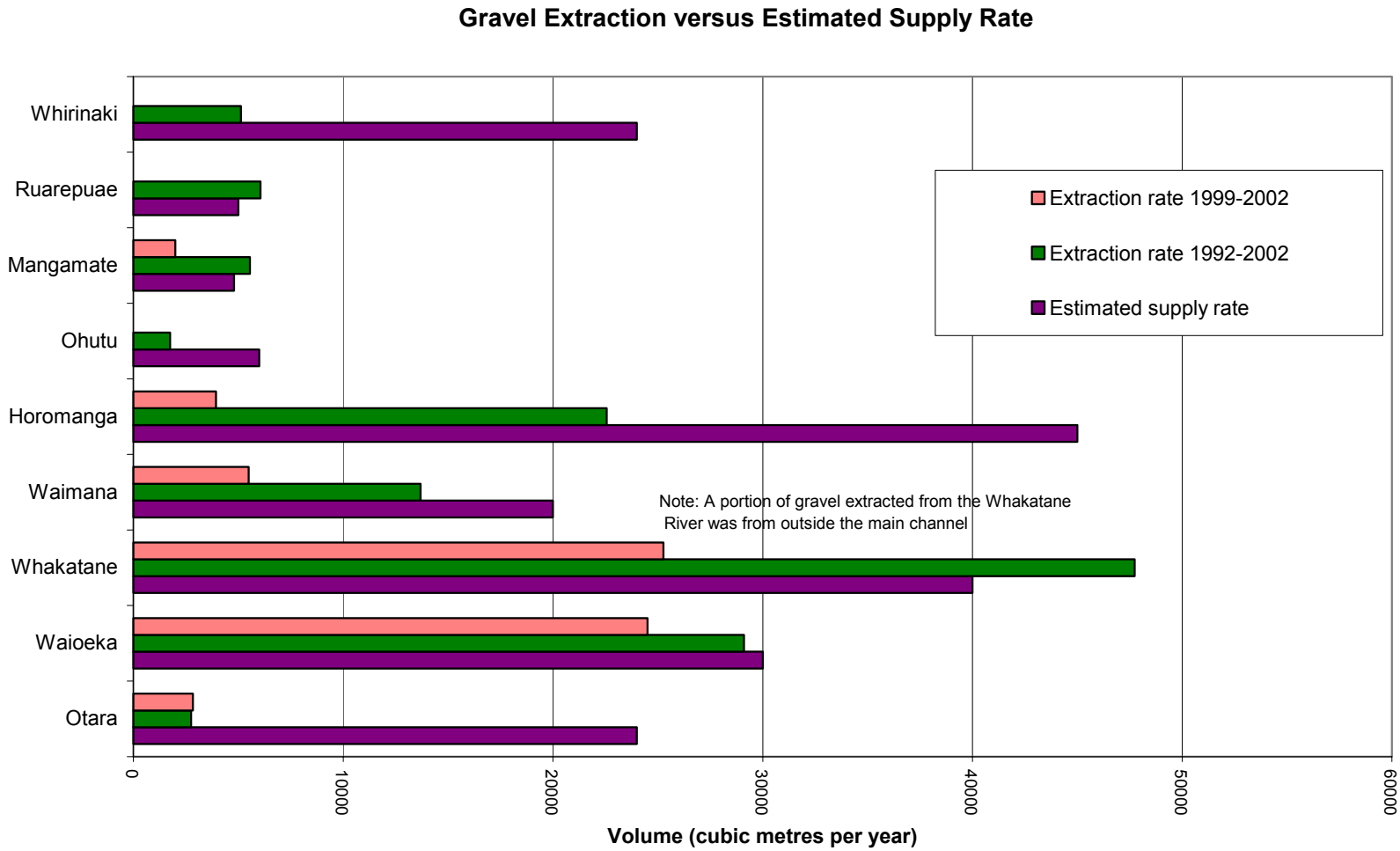
The floods in July 1998 have caused significant changes to gravel volumes and will affect the management of gravel for several years. The analysis has been more complex than in the past because of the need to separate out changes in gravel volumes from deposition of silt. For the wider rivers with obvious floodplains, this has been done by defining the limits of the main channel (the "design channel"), and running the analysis separately for the full channel width as well as the active channel width. Material within the active channel limits is assumed to be predominantly gravel, whereas material outside these limits is assumed to be silt or sand.

Table 3.1 Comparison of Riverbed Volume Changes between the reports 1998/99, 1999/2000, and 2000-2002

River	Floodplain deposition (m^3) (mainly silt and sand)			Active channel change (m^3) (mainly gravel)		
	1998/99	1999/00	2000/02	1998/99	1999/00	2000/02
Otara	204,500	310,800	---	57,600	83,400	---
Waioeka	510,000	176,100	---	2,500	6,000	---
Waimana	493,000	65,000	60,000	3,000	-165,000	-47,300
Whakatane below Treatment Plant (XS1 – XS14)	---	---	---	---	---	---
Whakatane from Treatment Plant to Pekatahi (XS15 - XS25)	141,200	---	---	40,700	---	---
Whakatane above Pekatahi (XS25a – XS44)	300,800	19,300	-2,600	18,600	40,300	78,300
Ruarepuae Stream	---	---	---	---	760	---

During the 1998 floods, an estimated (net) 1,900,000m^3 of sediment was deposited on the floodplains of the Whakatane-Waimana and Waioeka-Otara schemes, the majority of which was sand and silt sized particles. But it is evident from the surveys taken in between the years 1999 and 2000 that there has actually been a loss of this sediment in the Whakatane-Waimana scheme and to a lesser extent in the Waioeka floodplain whilst the Otara River sees continuing deposition on its floodplains due to settlement of the silt (refer Table 3.1).

Figure 3.1 shows estimates of average gravel supply rates and short and medium term (2yr and 10yr) extraction rates for many of the Bay of Plenty rivers. Note that these are indicative estimates only and should be revised as more information becomes available. Gravel supply will vary greatly from year to year.


Gravel Extraction versus Estimated Supply Rate
Whirinaki
Ruarepuae
Mangamate
Ohutu
Horomanga
Waimana
Whakatane
Waioeka
Otara
Extraction rate 1999-2002
Extraction rate 1992-2002
Estimated supply rate
Note: A portion of gravel extracted from the Whakatane River was from outside the main channel
0
10000
20000
30000
40000
50000
60000
Volume (cubic metres per year)

3.2 Otara River

The Otara River has not been resurveyed since the last NERMN report. The amount of gravel extracted during 2000/2001 and 2001/2002 was 2,463 m^3 and 2,033 m^3, respectively.

A baseline survey was done in 1993 with resurveys in January 1996, October 1998 and July 2000. A comparison has also been made with surveys in 1966 and 1980, although some interpretation is required when assessing these older surveys which may not have been in exactly the same place as more recent surveys.

Little extraction is carried out on this river, and some 2,200m^3 per year averaged over the decade ended in 1999 was estimated. 4,026 m^3 of gravel was extracted in 1999/2000 and the average extraction for the last five years (1995 to 2000) has increased slightly to 2,352 m^3.

The volume analysis has been split into a "design width", (which attempts to describe the changes in gravel volume in the main river channel), and the full surveyed width, (which includes changes of the berms that are more likely to contain a large proportion of silt and sand). The gravel/sand interface across and down the river will change with time, but the comparison is still useful.

The full width analysis indicates there has been an overall increase in bed levels at almost every cross-section since 1966, with an average rate of deposition at 88,000 m^3 per year. The deposition between October 1998 and August 2000 was around one and a half (1.5) times as high as the deposition between March 96 and October 98 (including the floods of July 1998) at **394,000 m^3**. The major sites of deposition were sections 31-36, where around 293,000 m^3 of material was deposited. The most significant effect of this deposition is likely to be a reduced floodway capacity of the river between sections 31 – 36, although the propensity for channels to meander may also increase. Floodway capacity is being examined as part of the Floodplain Management Plan for the Waioeka-Otara scheme. (Sections 12 and 31 prior to 1993 were left out of the analysis, as their locations do not appear to correspond with more recent cross-sections).

The design width analysis shows that net deposition within the normal channel and immediate fairway has increased to about 83,400 m^3 between October 1998 and July 2000 as compared to 57,600 m^3 between 1996and 1998.

Since 1993, there seems to be a trend of increase net deposition of gravel in the river. Between sections 16 to 26, there has been a marked increase in bed level. The most significant gain is at section 34, where 24,910 m^3 of gravel was deposited. A net deposition of 725,200 m^3 on the floodplain was also observed, with only 142,200 m^3 of this within the design channel main fairway. This shows that a large proportion of the deposition that has occurred is outside the main fairway, on the floodplain between the stopbanks. In general, a loss of gravel has occurred above section 34, with gains at most sections below section 34.

The Operations and Rural Services Department of Environment Bay of Plenty has moved to increase extraction on this river by obtaining resource consent to remove gravel at specific sites. It may also be necessary to encourage removal of silt and sand (for use as fill) from the main fairway or consider top-up of stopbanks to retain floodway capacity.

The long-term analysis put the average net supply rate of deposited material into this system to around 55,600 m^3 annually, although only a portion is gravel. In 1996 to 2000, this portion was around 20%. Analysis of data collected since 1993 shows that the gravel supply rate is expected to average 20,000m^3 per year.

With a small extraction rate and relatively substantial deposition on the floodplain and in the main channel over the past four years, it is recommended that extraction should be increased in this river to keep the river at its recommended bed level.

3.3 Waioeka River

The Waioeka River has not been resurveyed since the last NERMN report. The amount of gravel extracted during 2000/2001 and 2001/2002 was 19,086 m^3 and 24,523 m^3, respectively.

A baseline survey was completed in October 1993, with resurveys carried out in January 1996, September 1998 and September 2000. A comparison has also been made with surveys in 1966 and 1980, although some interpretation is required when assessing these older surveys that may not have been in exactly the same place as more recent surveys.

A moderate amount of extraction, some 29,000m^3 on average over the last ten years, is taken from the Waioeka River each year. 45,000m^3 were removed in 1997/1998, 36,000m^3 was removed in 1998/99 and 25,440m^3 in 1999/2000.

Over the full width of the sections, a net increase in volume of material stored of 512,000 m^3 has been calculated between 1996 and 1998 and 182,000 m^3 has been calculated between 1998 and 2000. Gains are evident at all cross-sections above the confluence with the Otara River except at cross-sections 3, 8, 11 to13, and 18 to 19. The largest gains are at cross sections 19 and 20, with estimated gains in the region of 80 – 90,000 m^3. A large portion of this gain is silt and sand sized particles. The largest loss is at cross-section 12 with an estimated 20,000 m^3 of material lost.

The net increase in volume of material over the full width the river between 1996 and 1998 includes an increase of 100,000m^3 at section 19. The total material stored is larger than that of 1999/2000. Most of it is the contribution from the flood of July 1998. Between 1993 and 1996 there was net aggradation of some 24,000m^3, mostly between cross-sections 10 and 16.

Within the design width of the river fairway, there were gains amounting to only 5,980 m^3 between September 1998 and September 2000. It is worth noting that the reach between the river mouth and section 4 were not resurveyed in 2000 and therefore in not inclusive of the value stated above. A largest loss was noted at cross-section 12, where scouring of the bed has been observed. Conversely, the bed level has aggraded at cross-sections 9-10. Sections 15 to 17 have all experienced some right bank erosion. The thalweg level has decreased by some 2m at section 7, but has increased by around 1.5m at section 9. The small channel volume change indicates this river system is fairly stable at the moment.

The large difference between the deposition on the floodplain and the deposition within the channel suggests that most of the deposition is made up of silt deposited on the floodplain.

The Operations and Rural Services department of Environment Bay of Plenty has moved to control extraction on this river by obtaining resource consent to remove gravel at specific sites. The purpose is prevent potential flooding in some areas

(although the river has widened in some places) and decrease stability of river meander pattern that may occur due to continued aggradation of the river bed. Gravel extraction in appropriate locations can reduce the flood risk and help to stabilise the river. The main deposition within the fairway in between 1996 and 1998 has been in the stretch from section 10 to section 14 and at sections 7 and 8, whereas, in 1999 to 2000, the main deposition within the fairway has been at sections 9 to 10 and 14 to 15.

Over the longer term, comparisons with surveys in 1966 and 1980 show further deposition of some 350,000m^3, mostly since 1980 (although diversion cuts in the 1970's may affect the validity of the 1966 calculations). All section except 2, 12, 13, and 20 have aggraded since 1966, particularly 5, 6, 7, 14 and 15. Gravel extraction over the last 10 years, 30,083m^3 per year, is very similar to the estimated long term supply rate of 30,000m^3 per year in this river (inclusive of the large silt deposition in 1998).

No particular need to change typical gravel extraction practices on this river is evident from the analysis, even following the major flood in 1998. However, a catchment condition survey carried out after the flood showed there was considerable damage caused to the upper Waioeka catchment by this storm. Therefore, it is likely that the supply rate will increase over the next decade and should be carefully monitored and managed. Visual inspections of the Waioeka Gorge suggest some aggradation; new monitoring cross-sections have been established here.

Sediment build-up on the berms is of more concern for flood capacity. In the first July 1998 flood peak, overtopping of rural stopbanks (between section 16 and 17) at below design flood flows indicate that bed and/or berm levels may have increased in this reach in recent years.

3.4 Waimana River

A cross-section resurvey was completed in July 2001. Moderate extraction is carried out on this river: 33,890m^3 in 1996/97, 16,400m^3 in 1997/98, 10,580m^3 in 1998/99, 7,530 m^3 in 1999/2000, 2,030 m^3 in 2000/2001, and 6,934 m^3 in 2001/2002.

The analysis has tried to separate out changes in gravel volumes and silt deposition by dividing each cross-section into the "active channel" and the wider floodplain since 1992.

In the active channel, between 1992 and 1996, the major losses were in the gorge, below section 10, where some 120,000m^3 were lost, and between sections 20 and 30, where some 85,000m^3 were lost. 51,000m^3 were gained between sections 13 and 19 and 49,000m^3 were gained between sections 30 and 32. Above cross-section 13, 64,000m^3 was lost between 1992 and 1994, but 81,000m^3 were gained between 1994 and 1996. The largest losses were at cross-sections 6a, 7, 20 and 29, while the largest gains were at cross-sections 14, 15 and 30-32.

In the active channel, between 1996 and 1998, the net bed change over the whole length surveyed was a tiny 3,000m^3 (aggradation). The major losses (bank erosion) observed at cross-section 3, 4, 5, 23, 25, 29, 30, and 31 were entirely compensated for by a rise in level, particularly at cross-section 1, 6a, 19, 20, 26, 27, 28, 32, and 33. Relatively small cross-section changes were observed between cross-section 7 and 16 and a bank erosion of about 60m wide was observed at cross-section 3.

From the analysis of the river active channel changes between 1998/1999, it was observed that there had been a large decrease in the river channel volume, amounting to a net loss of 165,000 m^3 of material. Most of this degradation is centred on the channel stretch between cross sections 29-32. There was bank erosion at cross-sections 7, 30, 31, 32 and 33 and a decrease in bed level at cross-sections 10a and 14. Conversely bed aggradation was observed at cross-section 18 and 19. Sections 22 and 23 experienced a build up of gravel on the left bank and a loss on the right bank, suggesting a small change beginning in the river meandering pattern. There was a large amount of bank erosion at cross-section 29, which was somewhat tempered by an increase in the bed level. The large losses in the upper reaches of the river suggest that the excess of gravel that was apparent in 1998 has moved downstream.

The analysis of the 2001 survey shows that a total volume of **47,000m^3** has been lost in the active channel since the previous survey in 1999. Again, losses are centred around cross-sections 27 to 32 where a total volume of 78,500m^3 was lost. Bed levels have dropped in this reach too, and bank erosion seems to be an ongoing process. An estimated volume of 212,500m^3 was eroded from the banks in this reach. 12,000m^3 were lost at cross-sections 23 to 25, and 16,000m^3 were lost just above the confluence into the Whakatane River at cross-sections 1 to 6 with the river degrading in this lower reach. Bank erosion is also observed at cross-sections 18 and 24. Rising river levels and the highest volume gains were observed between cross-sections 17 and 19.

It is noted that cross-section 33 has not been included in the volume analysis for the recent survey as the data suggests there may have been a survey error. The situation at cross-section 33 will be assessed again with the upcoming survey.

Also, the 2001 surveys at cross-sections 13 and 29 were incomplete and therefore have been omitted from the analysis. To still be able to get volume figures at and around these cross-sections it has been assumed that the change in cross-sectional area was zero and the volumes have been calculated from this assumption.

Over the full floodplain width, the overall loss for 1998/1999 was calculated to be 100,000 m^3. Since this is smaller than the design channel losses, one can assume that there has been some build up of silt along the floodplain. This amounted to aggradation on the floodplain to the order of 62,700 m^3. The major losses (of around 40,000 m^3 and 60,000 m^3) were found at sections 29 and 30, where there had been major gains in 1996/1998. It can be argued that the river has returned these sections to their equilibrium levels. The previous analysis (1996 to 1998) showed a net aggradation of some 496,000 m^3 of material, which was attributed to a build up of silt along the floodplain. The river system appears to have naturally balanced itself.

Over the full width including the floodplain, the 2001 survey showed an overall volume gain of **12,500m^3**. Taking into the account the losses in the active channel this suggests that there has been a build up on the floodplains of 60,000m^3. Major losses were observed at cross-sections 30 to 32 (50,000m^3), and cross-sections 4 to 6 (41,500m^3). (Some of the cross-sections had an incomplete survey done on the floodplains. Therefore these cross-sections were limited to the active channel widths for the volume analysis.)

Extraction has generally been encouraged in past years over much of the river. From the river cross-section change analysis of 1996/1998, it was suggested that extraction should be directed to the upper reaches (sections 26-32) of the surveyed area if possible, although desirable levels have not yet been defined.

However, in light of the analysis of the 1998/1999 and 2001 data where large material losses and bank erosion were observed between cross-section 27 to 32, it is advisable to limit gravel extraction at the upper reach of the river until further evidence of aggradation is confirmed by survey. It may however be necessary to use a selective combination of extraction and channel reshaping to arrest the degrading processes currently occurring.

Some extraction on higher beaches at cross-section 22 and 23 may be desirable to achieve adequate floodway capacity down the river. A careful assessment of desirable bed levels is needed, over the whole of the river before any major extraction can be carried out.

Close monitoring will need to continue over the next few years to assess the effects of extraction, the river training works of the Middle Reaches scheme and the effects of the floods in July 1998. Extraction should be discouraged from the gorge until desirable bed levels have been established.

The average gravel extraction rate on this river over the last 9 year is 14,000m^3 per year (although this seems to be decreasing), whereas the gravel supply rate is estimated to around 20,000 m^3 per year. This indicates this level of extraction is sustainable in the long term. The loss of volume in the active channel should be carefully monitored and extraction adjusted accordingly. Of the estimated net supply rate of gravel into the Waimana River, a considerable throughput is to the Whakatane River. There may be a lag of several years before a wave of gravel passes completely through the system.

3.5 Whakatane River above Pekatahi Bridge

Resurveys were completed in February 2002. Again, at cross-sections 25a to 44 the analysis was run on the full width as well as the “active channel” width, where the gravel is assumed to be mainly stored. In the braided reach above cross-section 44 this distinction has not been made as the gravel can potentially be stored throughout the cross-section.

Significant gravel extraction is carried out in this reach (above the Pekatahi Bridge) of the river, however, the amount taken is mainly decreasing from year to year: In 2000/2001 and 2001/2002, 24,600m^3 and 16,900m^3 respectively, were removed, compared to 20,400m^3 in 1999/2000, 39,700m^3 in 1998/99 and 59,400m^3 in 1997/98. Average extraction on the whole river since 1996 is around 38,400m^3 per year, of which 37,100m^3 has been extracted from above the Pekatahi Bridge. A portion of the extraction has been from outside the “design channel”, to allow bed levels to aggrade in some places. Staff undertake regular visual inspections to monitor gravel extraction and in some areas extractions have ceased.

Within the active channel, there has been a gain of 40,267m^3 between 1998 and 2000 whilst, the gain between April and December 1998 was 18,551m^3. In between 1998 and 2000, major gains were made at cross sections 30 and 33b, with around 22,000m^3 and 12,000m^3 deposited respectively. On cross-sections 58 and 59 the left side of the bank has eroded heavily, while the right bank has been built up somewhat. Sections 60 and 61 have heavy erosion on their right banks with build up on the left. This suggests the beginning of a change in the rivers meander pattern.

For the active channel width between cross-section 25a and 44, the 2002 survey shows a **volume gain of 78,000m^3** since the previous survey in 2000. Again, major gains were observed at cross-section 30 with over 12,000m^3, and at cross-sections 28 and 37 with over 9,000m^3 each. A long-section plot of the minimum bed levels confirms that the river is recovering with significant aggradation in this reach.

Within the full floodplain width of the river, the last NERMN report has noted an overall loss of 77,900m^3 between the 1998 and 2000 survey. This figure was calculated using some incomplete cross-section surveys and has been revised for this report. By adjusting the offset limits in order to exclude those incomplete parts of the survey, the calculated volume changes differ from the ones calculated in the previous report and result in an overall **volume gain of 55,000m^3** for the period December 1998 to September 2000. The largest volume gains were at cross-sections 26, 27 (Pekatahi Bridge) and 55.

The 2002 survey shows that since the 2000 survey there has been again a **volume gain of 92,000m^3** within the full floodplain width of the river. The largest volume gains are around cross-sections 44 and 45 with 21,200m^3 and 20,000m^3 respectively. Volume losses were observed at cross-section 31, where a shingle pit on the right floodplain affects the volume calculations, 32, 38, 39, and 51 to 56. Bed levels have dropped in the reach of cross-sections 51 to 57 (except at cross-sections 54), and have risen at cross-sections 47 and 48. Bank erosion has occurred at the right bank of cross-section 53 and 54.

The long-term extraction rate for this part of the river has decreased from an estimated 72,000m^3 per year over the last 20 years to around 48,000 m^3 over the past ten years. The estimated supply rate is around 40,000 m^3.

For the integrity of the existing bank protection works, an ideal minimum bed level was estimated in 1996 to be between the 1996 minimum bed level at each cross-section and 0.5m higher, i.e. some recovery was desired along most of the river. In places, the ideal bed level may be higher still, so as the recovery target is approached, a careful review of desirable levels will be required, (based on balancing the risks of erosion, aggradation and flooding). It is proposed that until adequate recovery is achieved, extraction should be suspended within the active channel over the reach from approximately 1km upstream of the confluence of the Waimana River to Ruatoki Bridge and also in the lower reaches of the Waimana River.

A comparison of the 2002 survey to the 1996 survey shows that the minimum bed levels have risen by up to one metre over most of the river reach, except at cross-section 49, 54, and 55, where it has dropped by about half a metre. A significant rise of almost four metres occurred at cross-section 47, where the main channel has been filled in over time. Whilst thalweg levels are improving, a significant volume of gravel is required to effect the recovery of bed levels yet.

A limit for the active river of around 20-30,000m^3 per year from the existing beaches should continue to aid recovery over the next few years - any extra demand should be met by widening the floodway where appropriate (e.g., extraction should target where the river floodway are deem too narrow ahead of traditional beaches). There are significant resources available in some areas. Following the large input of gravel in 1998, it is likely that some beaches and floodway constrictions will develop where extraction is desirable, especially above Ruatoki. However, it is also desirable that some throughput to the rest of the river is allowed.

There is a diversity of viewpoints on how the gravel in the vicinity of the Holmes bend should be managed. On the one hand there is strong pressure for the extraction in this reach to be ceased until bed levels recover and bank erosion problems are reduced, both through the reach and downstream. Management was adjusted during the 1990's to encourage recovery of bed levels. This viewpoint was again strongly enunciated following significant erosion during the July 1998 floods at the Holmes bend. Factors causing this erosion were several, including undermining caused by lower than optimum bed levels, the extreme nature of the succession of events (cumulatively at least a one in one hundred years event) and severe sharpness of the bend. This recovery has already occurred in the first one kilometre above the confluence with the Waimana River. The July 2002 survey shows levels upstream of this to also be showing some recovery. On the other hand there is a view that the river should remain entrenched to avoid the severe adverse effects forecast from overflows onto the surrounding farmland. This occurred several times in the 1960s, with large scale deposition of silt and debris. Had the river not been entrenched in July 1998 similar adverse effects were likely. It is difficult to exactly balance these opposite objectives. Current river management practices also focus on emulating the natural processes of a river as far as practicable, as these have been shown to often produce the least adverse effects in terms of erosion (although not always, particularly where adverse river misalignments occur due to geological or other factors). In the meantime the policy of allowing some bed recovery should continue, with careful monitoring. Possibly a hydraulic model of the reach should be produced to define optimum bed levels.

3.6 Whakatane River below Pekatahi Bridge

The Whakatane River below Pekatahi Bridge has not been resurveyed since 1998. The amount of gravel extracted during 2000/2001 and 2001/2002 was 1,657 m^3 and 9,391 m^3, respectively.

A comparison of changes within the design channel above section 15 (assumed to be gravel), reveals a net deposition of 99,000m3 from 1990 to 1998. The largest increases have been at cross-sections 17a, 18 and 24 to 24/25; at these sections particularly from 1996 to 1998. (A larger but more general increase occurred from 1993 to 1996). From 1963 to 1990, there was little overall change; sections 16, 17a and 24/25 went down while most other sections went up. The volume analysis indicates that a general loss from 1977 to 1985 has been regained by 1999.

The 1999 NERM report observed that over the full width of cross-sections and the whole reach to the mouth, there has been a substantial 190,000m^3 loss of material since 1996. The lower 8km of the river (except section 1), has lost 383,000m^3 of material, while the next 10km has gained 193,000m^3 of material (about 41,000m^3 of this is assumed to be gravel). The loss of material from lower reaches is likely to result in an increased tidal prism encouraging movement of water through the river mouth, but may also increase erosion if deep pools have been created.

Substantial deposition of material must have occurred at or just beyond the Whakatane River mouth as a result of the floods in July 1998. A rough measure of the quantity deposited can be made by adding the estimated suspended sediment transported past the Valley Rd recorder station (3.3 million tonnes, equivalent to about 1.6 million cubic metres in situ), to the loss of material below this point (320,000m^3). This gives a total of around 2 million cubic metres. This material is now providing good replenishment to the beach at Ohope, particularly at West End.

3.7 Ruarepuae Stream

The Ruarepuae Stream has not been resurveyed since the last NERMN report. No gravel was extracted during 2000/2001 and 2001/2002, nor between the surveys in April 1998 and June 2000.

Between April 1998 and June 2000, the stream had a net volume gain of 762m^3 of material. The main area of aggradation was at cross-section 4 where the bed level has been raised with a gain of around 1,000m^3. However this was countered by a loss of 900m^3 at cross-section 2 where erosion of the left bank and a small drop in the bed level occurred. Thus, it can be assumed that currently the Ruarepuae Stream is a very stable system.

Around 14,000m^3 was extracted between March 1995 and January 1997, during which the volume changes have been calculated to be a loss of 7,000m^3. Between January 1997 and April 1998, there was no reported extraction, and only a negligible net change volume was observed. Some gravel was lost at cross-section 6, but there were compensating gains at other cross-sections.

The Ruarepuae Stream has had high rates of extraction in the past (up to 21,000m^3 per year), but has reduced in recent years, and there has been no extraction over the past five years. A desirable bed level was set in 1986, and surveys in recent years have shown that bed levels are near those desired. Extraction should now be limited to where gravel builds up excessively.

Estimates put average gravel supply at around 5,000m^3 per year, although because the catchment is very steep, the supply is likely to be irregular.

3.8 Rangitaiki River

The Rangitaiki River has been resurveyed in November 2001 at the cross-sections above Aniwhenua (Upper Rangitaiki River) and in April 2002 at the cross sections below Te Teko (Lower Rangitaiki River). The cross sections at Waiohau have not been resurveyed since the last NERMN report. There was no shingle extracted during 2000/2001 and 2001/2002.

Below Te Teko surveys have been done in June 1987, October 1993, December 1995, January 1999 and April 2002. The recent 2002 survey was limited to cross-sections 1a to 18. Part of the 1987 data is incompatible with the more recent surveying – comparisons have been made where possible.

Following previous volume losses since 1993, from January 1999 to June 2002 a volume gain of 55,000m^3 has taken place in the reach of cross-sections 1a to 18. At cross-sections 5-8 and 15 the left stop banks have been raised between the two survey dates. When setting the offset limits to exclude the stopbanks at the cross-sections where stopbanks have been raised, the resulting volume figures only insignificantly differ. Figures provided in the Appendix therefore represent calculations including these stopbanks. Minimum bed levels have risen since the last survey at all cross-sections except at cross-sections 13 and 14.

The factors that have influenced the changing rate of loss/gain may include:

- Floods, particularly in July 1998, may have transported more sediment from upstream.
- Conversely, the Rangitaiki River has not experienced a significant flood between January 1999 and April 2002. Thus there has been no ability to flush sediment from the lower reaches.
- Matahina Power Station – may limit sediment transport, especially of larger grain sizes. While the repair works were underway, more sediment than normal may have passed the station.
- Changes to the river gradient following the earthquake in 1987 may have slowed as the river readjusts to a new gradient. Losses have been similar both above and below the fault scarp.

No extraction is carried out in the lower reaches below Matahina, nor was any reported in the upper reaches of the river in this period. Previous extractions above Lake Aniwhenua have been minor (e.g. 3,000m^3 was extracted in 1994/95).

There was no new survey done in the in the Waiohau area. The last surveys were undertaken in February 1993 and March 1996. The changes in bed level then were relatively minor, with an overall loss of 6,000m^3 over the 11km surveyed. The largest changes were at and just upstream of the Galatea Rd bridge.

Above Aniwhenua surveys were done in December 1992, March 1996 and November 2001. Between 1996 and 2001 a total volume of 95,000m^3 was gained. Main volume gains were observed at cross-sections 3 to 5, and 11. Minimum bed levels have slightly dropped at cross-sections 1, 7, 12, and 14 to 18, while they have risen at cross-sections 2 to 4, and 24.

Gravel or sand extraction is not required, nor should it be encouraged anywhere along the surveyed part of the river at this stage (the heads of the hydro lakes are not surveyed). There is little demand for extraction of gravel/sand from the river at present. The consents for extraction in the Waiohau section have expired.

In the lower reaches morphological processes consequent from the effects of the Edgecumbe earthquake are likely to cause some further degradation. This could be artificially encouraged to give adequate flood capacity.

3.9 Whirinaki River

The Whirinaki River has not been resurveyed since the 1998/99 NERMN report. It was surveyed in November 1994, November 1997 and July 1999. There was no gravel extracted during 2000/2001 and 2001/2002.

In the river channel between 1994 and 1997, the main changes in volume were a 28,000m^3 loss above cross-section 7 and a 46,000m^3 gain near cross-sections 4 and 5. (The calculation has included more of cross-section 4, so is slightly different to the previous report). The net gain for the river was 17,000m^3. Between 1997 and 1999, the loss above section 7 was replaced (31,000m^3) while further gains (especially at section 4), amounted to 30,000m^3. The net gain for the river was 82,000m^3 (Nov 1994 to Jul 1999).

Gravel extraction has been irregular, averaging 12,000m^3 between1992 and 1996, but nil in the last six years. Gravel extraction has concentrated on resources near cross-sections 6 and 7, but the net volume change has been small at these sites. It is recommended that extraction be encouraged at the aggrading reaches near cross-sections 4 and 5. Some extraction can occur at existing sites if a desired river alignment is identified and worked to. The level of extraction appears to have been similar to the supply rate in recent years, although the floods in 1998 have brought a surplus of material.

Detailed design is required to define desirable bed levels at each cross-section.

Initial estimates indicate supplies are typically of the order of 24,000m^3 per year. Extraction should generally be encouraged, especially in the vicinity of cross-section 4.

3.10 Horomanga River

The Horomanga River has been resurveyed in July 2001. Some new cross-sections were established and surveyed in December 2001 (to improve the precision of the volume calculations), but these are not yet included in the report as there is no data to compare them to. They will be utilised for analysis following the next survey. Surveys have been done intermittently since 1956 on this river.

The river has traditionally had a high extraction rate, hence a good picture can be built up of the effect of extraction. Considerable extraction was carried out in the Horomanga River until 1996, averaging 55,000m^3 annually since 1979. Extractions have dropped considerably to 19,000m^3 in 1996/97, 9,000m^3 in 1997/98, 500m^3 in 1998/99, 3,600m^3 in 1999/2000, none in 2000/2001, and 8,204m^3 during 2001/2002.

Previous reports indicated that the supply of gravel appeared to have been smaller between 1991 and 1996 than prior to 1991 (15,000m^3 per year as opposed to 45,000m^3 per year).

The new survey data shows a loss of 61,000m3 over the whole reach of the river since the 1999 survey. Sections 9 to 12 lost over 74,000m^3 in total, where almost 56,000m^3 are lost between cross-sections 9a and 11. This adds up to a loss of 78,000m^3 since 1996, giving an average loss of 13,000m^3 per year for the past six years.

The data suggests that gravel extraction should cease in the upper part of the reach. In the lower reaches the bed is severely perched and significant extraction is required to avoid undue flooding or avulsion (migration of the river channel). The bed level needs to initially be lowered by an average of 0.50 metres over the 70 metre design fairway width.

Work to create a stable river pattern has continued with plantings and gravel extraction directed to areas which have a higher than desirable bed level. The desirable level to which extraction can take place should now be reviewed in light of the apparent reduction in supply. In the past there was surplus gravel, but we may now have reached the stage where extraction must meet supply since there is no longer an overall surplus of gravel.

Supply of gravel is dependent on many processes within the catchment. The Horomanga is a particularly long, narrow catchment in steep country, which will tend to produce an irregular supply on the floodplain, depending on slip activity, where material is stored within the catchment, and when floods occur.

Desirable bed levels that limit both erosion and flooding should be set to maintain a stable river profile. Extraction should then be limited to the input as measured by subsequent surveys. In recent years, the net change in volume appears to have varied from a loss of about 30,000m^3 to a gain of 17,000m^3 per year, however, over the longer term net change in volume has averaged a gain of 45,000m^3. Mangamate Stream.

The Mangamate Stream has not been resurveyed since the 1998/99 NERMN report. While there was no gravel extracted during 2000/2001, there were 6,003m^3 extracted during 2001/2002.

The last survey for this stream was carried out in June 1999. And between January 1997 and June 1999, there was only a small net loss of 2,000m^3 between cross-sections 1 and 8. Cross-section 9 has experienced a much larger change, with a loss of 128m^2 of cross-sectional area – the right bank has eroded by about 5m while the bed has dropped by about 1m. If this is representative, the net loss in this vicinity is estimated at 26,000m^3.

Overall, since 1993 up to 1999, all cross-sections have lost material and the stream appears to have lost about 85,000m^3.

About 15,000m^3 of gravel was extracted between August 1995 and January 1997, but there was a net gain of 2,000m^3 in this time. Previously, there had been a loss of about 58,000m^3 since May 1993, despite extraction of only 16,000m^3. A substantial proportion of this calculated loss is from one eroding bank at cross section 9; the bank is 13m high and has moved back about 15m in six years. The material from this bank has not reappeared at any particular cross-section – most other sections appear relatively unchanged over this time, with slightly lower bed levels than in 1993. A proportion of this loss may be silt and sand sized fractions that are less likely to remain on the riverbed once mobilised.

Little extraction has taken place between January 1997 and June 2000. Extraction should not be encouraged on this stream unless bed levels rise or a detailed design is undertaken.

Desirable bed levels have not been defined for this stream. Initial estimates put average gravel supply at around 4,000 - 7,000m^3 per year, although the stream appears to be steep enough to transport significant quantities of gravel right through the system.

3.11 Ohutu Stream

The Ohutu Stream has not been resurveyed since the 1998/99 NERMN report, and there was no gravel extracted since. The last survey for this stream was carried out in June 1999.

The net change between the January 1997 and June 1999 surveys is a loss of about 4,000m^3. Bed levels have dropped slightly at cross-sections 1 to 5. Section 6 rose moderately. And only a small amount of extraction (2,400m^3) has taken place in 1996-99.

Desirable bed levels have not been defined for this stream. Initial estimates put average gravel supply at around 5,000 - 8,000m^3 per year, although the stream appears to be steep enough to transport significant quantities of gravel right through the system to the Horomanga River. If any extraction is to take place, it is more likely to be beneficial in the vicinity of section 6, which also rose prior to 1995.

3.12 Kopuriki Stream

Kopuriki Stream has not been resurveyed since March 1998. There was an amount of 4,950m^3 of gravel extracted during 2000/2001, and no gravel was extracted during 2001/2002.

Baseline surveys were carried out in 1996 following applications to extract gravel from this stream. No estimates of long term supply have been made, however minor resources exist within the stream floodway. A desirable bed level and meander pattern has been established.

The stream was resurveyed in March 1998, with calculations showing an increase of 10,000m^3. No extraction has been reported in this time, although resource consent applications have been made to extract from this stream.

3.13 Waikokopu Stream

Waikokopu Stream (Waiohau) has not been resurveyed since the baseline survey of 1996.

Extraction commenced on this stream in mid-1997, following a baseline survey and establishment of desirable meander pattern and bed levels in December 1996. 1700m^3 of gravel was removed in 1997/98, around 1000m^3 in both 1998/1999 and 1999/2000, 334m^3 in 2000/2001, and 430m^3 in 2001/2002.

3.14 Waihua Stream

Waihua Stream (Waiohau) has not been surveyed since the 1997/1998 NERMN report.

A baseline survey and establishment of desirable meander pattern and bed levels was carried out in December 1996. No extraction has taken place.

3.15 Waihui Stream

Waihui Stream (Ruatahuna, tributary of Whakatane River) has not been surveyed since the 1996/1997 NERMN report.

A baseline survey and establishment of desirable meander pattern and bed levels was done in December 1996. Approximately 14,000m^3 of gravel has been extracted in 1998/1999, just about 3,800m^3 in 1999/2000, an 6,449m^3 in 2000/2001, and only 628m^3 in 2001/2002.

3.16 Kaituna/Mangorewa Rivers

These rivers have been resurveyed in October 2001. The previous survey was in May/June 1997. During this report period the Kaituna River sustained a major flood event (1 May 1999). This event would have transported significant quantities of sediment.

The 2001 survey below Te Matai shows an over all net volume gain of 163,000m^3, following a net gain of 39,000m^3 between February 1995 and June 1997. The thalweg profile shows that minimum bed levels have significantly risen around cross-section 13 to 16, where the bed levels used to be particularly deep. The volume gain at these sections was over 106,000m^3. Minimum bed levels have dropped near the river mouth from cross-section 1a to 4. At cross-section 12 the channel has shifted towards the left by about 15 metres.

No extraction has been carried out in this river in recent years (since the major works of the Lower Kaituna River Scheme). Some extraction (of silt and/or sand) may be beneficial in some areas of the Kaituna River below Te Matai, if build-ups are excessive. However, the supply of sediment to the coast may be reduced by extraction. To date, build-ups do not appear to have adversely affected predicted flood levels significantly (the predicted flood levels were reviewed in September 1998 based on the 1997 cross-sections), but there have been reports of more difficulty in navigation. Build-ups may also be forcing the river to the outside of bends, which may increase erosion at these sites.

Above Te Matai, the survey shows a total loss of 13,000m^3. Compared to the net losses of 57,000m^3 between October 1993 and June 1997 and 56,000m^3 between 1990 and October 1993 this shows that volume losses have slowed down considerably in the recent years. The major losses have been at cross-sections 40, 41, and 44.

The Mangorewa River has been resurveyed in October 2001. Since the previous survey in June 1997 the reach of 2.4 km has gained a volume of 25,000m^3. Since 1990 the volume gain was 16,000m^3. The minimum bed level at cross-section 1 has dropped about 0.5 metres since the last survey, while it has risen at cross-section 3 by about 0.4 metres, and the channel has slightly shifted towards the left here. Cross-section 2 shows a significant build up of silt from floods on the left berm.

3.17 Tarawera River

The Tarawera has been resurveyed in October 2000. Baseline surveys were completed in September 1993, with resurveys done in March 1998. Some cross-sections near the mouth have been resurveyed between these dates also.

Since the previous survey in March 1998 the benchmarks had been resurveyed as well, and most of them had settled slightly over time. As this has some effect on the volume calculations, the volume loss between 1998 and 2000 might really be less than shown in the figures.

The 2000 survey shows a volume loss of 87,000m^3 since 1998. With the volume loss of 83,000m^3 between 1993 and 1998, this adds up to a total loss of 170,000m^3 since 1993. The trend of dropping minimum bed levels which was observed from the 1998 survey is continuing at most of the cross-sections, particularly at cross-sections 5 to 8 where bed levels have dropped by up to 1 metre since 1993.

The riverbed is particularly mobile because of its low-density particles. The river is relatively straight, so flows fairly quickly down the floodplain. The bed level drop indicates the supply of sediment has been less than the transporting capacity of the river.

No extraction is carried out in this river at present, and with the lowering of the whole bed, it is recommended no sand extraction be allowed in the short to medium term. This analysis clearly shows there are factors other than extraction that may cause degradation.

3.18 Other Locations

Some minor extraction is carried out occasionally in some other streams and rivers, e.g. Hikurangi, Haparapara, and Hawai Rivers. Consents have expired for most of these and have not been reapplied for.

4,000m^3 were removed from the Waiotahi River in 2000/2001, and 5,300m^3 in 1997/98 (with consent). There was no gravel removed in 2002/2001, 1999/2000, and 1998/99. If extractions continue at this rate, regular surveys will be required. Four parties either have consent or have applied for consent to extract from this river, although the quantities involved are fairly small.

Interest has been shown in extracting from the Motu, Kereu, Waiaua, Petipeti, Whitikau, Raukokore and Whangaparaoa Rivers. Cross-section surveys may need to be set up to assess and monitor the resources if the extent of extraction and the quantities involved are significant.

In other streams, the levels of extraction are minor, 100 to 500m^3, and do not warrant detailed monitoring.

Chapter 4: Conclusion

The continuing accumulation of data will allow Environment Bay of Plenty to set and refine appropriate rates and volumes for each section of river.

Definition of desirable bed levels at each cross-section would aid gravel management and development of stable river channels. A balance of risks of erosion, aggradation and deposition is required.

For most rivers, allocations will be advised to each contractor as part of the resource consent process. The Operations and Rural Services department of Environment Bay of Plenty has moved to secure resource consents for extraction on the Waioeka, Otara and Waimana rivers to better manage the allocation of resources and to ensure sufficient gravel is removed for flood control purposes.

Allocation on other rivers, in terms of sites and volumes, tends to be in response to a request for the gravel. With there being, in most instances, an abundance of gravel, this is satisfactory. However, as demand begins to exceed supply, as is happening in some locations, allocations in terms of sites and volumes need to be rigorously controlled in terms of maximum annual extraction rates, minimum bed levels and defined extraction locations.

This can only be done when sufficient data exists and a full understanding of the resource is gained. Initial estimates of gravel supply have been included where possible to aid the consent process. These will need to be refined as data and understanding increase.

In many cases, extraction records are in terms of reaches of river (e.g. between Pekatahi and Ruatoki Bridges on the Whakatane River), and may need to be further defined to match with cross-section information to allow for detailed analysis within a reach. Having said this, Environment Bay of Plenty is interested in long-term trends and the health of each river as a whole. An ongoing assessment of the information required will continue.

The 1998 floods caused massive deposition on the floodplains of the affected rivers. Some of this deposition has been counteracted by settlement of the sediment. Further deposition has also occurred. The Waioeka-Otara scheme is still experiencing considerable deposition on their floodplains, and in the design channel in the case of the Otara River. Consequently, it is recommended that extraction on the Otara River be encouraged and extraction on the Whakatane River continues to be limited within the active channel to those reaches where it is beneficial. Extraction on the Waioeka and Waimana rivers should be carefully directed to appropriate locations. The cross-section monitoring programme should be extended to include the Waiotahi River if extraction continues at present rates.

References

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Appendices

Appendix I – Ricoda

Appendix II - River Summaries

Appendix I – Ricoda

1 Introduction

The Ricoda software package has a number of "processes" which allow capture, archiving, correction, presentation and analysis of cross-section data.

Ricoda accepts data in a number of different formats called "kinds". Each "kind" of data has its own characteristics.

2 Kinds

2.1 Sections

Cross-sections always contain the bed level measured to a survey datum, so they are always in terms of a reduced level (RL), i.e. all levels are known as a height above or below a fixed point, e.g. Moturiki datum, a fixed point on Moturiki Island near Tauranga.

Ricoda can also store data for long-sections. Long-sections run up a river and are used to describe elevations of the river bed. Long-sections can be entered manually, or are derived from cross-section data.

3 Reaches

A reach is a group of cross-sections that are linked together for the purposes of multi section analysis.

The sections must be stored in the same file, be to a common datum, and be defined in order of increasing upstream distance.

The reach description is stored in the file with the sections. A reach has a time associated with it, and this is a very important parameter in carrying out the analysis.

4 Attributes

An attribute file exists with each batch of data. Attributes are additional information that pertain to sections and reaches, but do not vary in time.

The attributes for a cross-section consist of a section title, plus geographical information. You can enter the upstream distance of the cross-section and this will be transferred into the reach definition when creating a reach. The following is an example of the information contained in a cross section attribute file:

Section Number _____ 50

River Name: Whakatane River _____ *Section Name L39R _____*

Aquacode _____ *NWASCA River Number_____*

Upstream Distance _27235.000m *Grid Reference _____ : _____*

Left Pin: Name 39L_ Easting 2859561.570m Northing 6336756.020m RL ___16896

Right Pin: Name 39R_ Easting 2860211.710m Northing 6336881.170m RL ___ 19396

Units of Stage Discharge Rating Curve (1=litres/sec, 1000=millilitres(s) ____0

Comment: (Plan No W347 sh 16 for sections before 1990) RLs as of 1991 survey

Left Stopbank : *Offset _____ 0mm*

Right Stopbank: *Offset _____ 0mm*

The pin positions are important for sections because they define the offset origin and orientation of the section.

5 Processes

There are a number of processes available in the Ricoda software package, but the main features being used for gravel analysis are the "plot" and "volume" processes.

5.1 Plotting Processes

There are a number of plotting processes that allow the Ricoda data to be presented in a pictorial form. The most commonly used for analysis is "PLGRAPH" which plots cross-sections or long sections for a given time and offset range.

Figure 1 and 2 are examples of plots of cross-sections on the Whakatane River.

Graphical outputs are very useful and by visual inspection of the plot it can be seen whether aggradation or degradation is occurring.

The other plot that is regularly used is "PLLONG" which plots a long-section by deriving it from cross-sections in a reach definition.

Figure 3 is a plot of the long-section of the Whakatane River showing the mean bed level and the thalweg level (lowest point in a cross-section) at two different points in time. This is useful for obtaining a feel as to what is happening in the river system.

5.2 Volume Process

This process is used as one of the main tools for analysis of gravel movement.

By running the process for a particular reach at different times it is possible to see where the volume is changing between the sections.

The volume is calculated from a horizontal datum, defined by the datum option, and the bed level of the river.

Since the 1997/98 report, a change has been made to the way the volume function calculates volumes. There are now two options: a simple end-area method, which multiplies the change in cross-section area at two cross-sections by the distance between them, and a more complicated general surface algorithm which takes into account the orientation of the cross-sections. The two methods can give quite different results from the same cross-section information.

The end-area method has been assessed as being the most appropriate for calculating the volumes for this report. This is because the cross-sections are generally a long distance apart compared to their width. Changes in the channel cross-section between measured cross-sections, around a bend, say, are much greater than the error introduced by assuming the cross-sections are parallel. Thus, the error in the calculations is much more related to the distance between the cross-sections than the method of calculation.

Appendix II - River Summaries

Volume calculations and graphs for the following rivers and streams are presented on the next pages:

- Waimana River
- Whakatane River
- Rangitaiki River
- Horomanga River
- Kaituna/Mangorewa Rivers
- Tarawera River

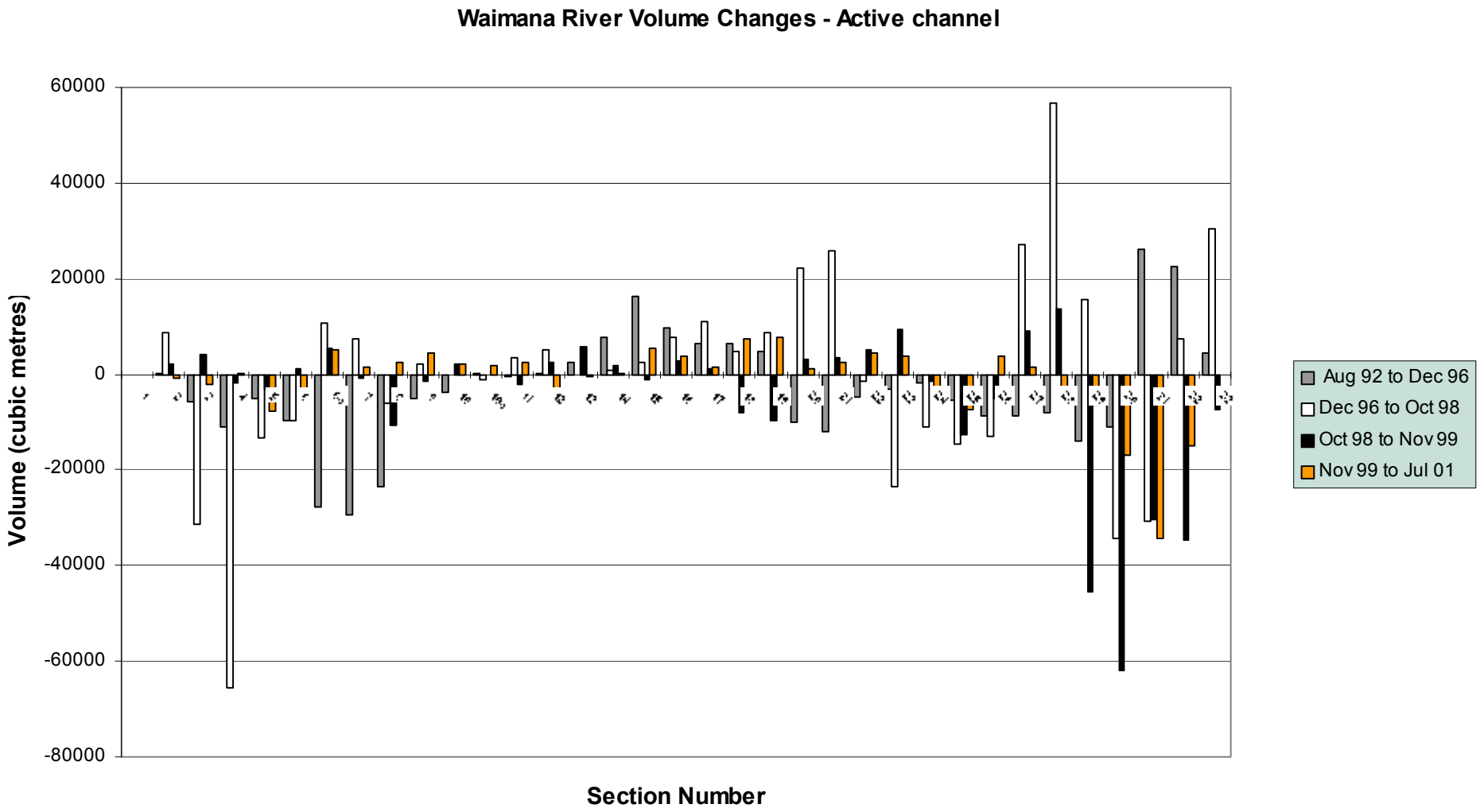
Waimana River Volume Changes - Active Channel														Bank erosion			
			Area Changes (m^2)						Volume Changes (m^3)						Area	Volume	Area	Volume
Section	Ricoda Section	Upstream dist (km)	Aug 92 to Dec 96	Dec 96 to Oct 98	Oct 98 to Nov 99	Nov 99 to Jul 01	Aug 92 to Nov 99	Aug 92 to Jul 01	Aug 92 to Dec 96	Dec 96 to Oct 98	Oct 98 to Nov 99	Nov 99 to Jul 01	Aug 92 to Nov 99	Aug 92 to Jul 01	Oct 98 to Nov 99	Oct 98 to Nov 99	Nov 99 to Jul 01	Nov 99 to Jul 01
1	1	0.43	1	26	5	3	32	35										
2	2	0.98	0	6	2	-7	8	1	187	8790	2137	-901	11114	10213		0		0
3	3	1.60	-19	-107	10	0	-116	-116	-5830	-31357	4010	-2136	-33177	-35313		0		0
4	4	2.61	-3	-23	-14	1	-40	-39	-11150	-65510	-1696	93	-78356	-78263		0		0
5	5	3.27	-12	-18	4	-23	-26	-49	-5164	-13408	-3048	-7574	-21620	-29194		0		0
6	6	4.03	-13	-8	0	8	-21	-13	-9801	-9541	1308	-5552	-18034	-23586		0		0
6a	7	4.83	-56	34	14	4	-8	-4	-27749	10697	5478	5117	-11574	-6457		0		0
7	8	5.43	-41	-10	-18	1	-69	-68	-29336	7380	-950	1441	-22906	-21465		0		0
8	9	6.44	-4	-3	-4	4	-11	-7	-23347	-6139	-10785	2552	-40271	-37719		0		0
9	10	7.16	-10	9	-1	9	-2	7	-4980	2187	-1505	4607	-4298	309		0		0
10	11	7.79	-3	-9	8	-2	-4	-6	-3729	-60	2161	2235	-1628	607		0		0
10a	12	7.99	3	-4	-8	20	-9	11	39	-1262	-90	1793	-1313	480		0		0
11	13	8.49	-5	18	0	-9	13	4	-489	3588	-2097	2408	1002	3410		0		0
12	14	9.08	6	-2	9	0	13	13	81	5043	2442	-2949	7566	4617		0		0
13	15	9.74	3	1	10		14	14	2562	-125	5860		8297	7882		0		0
14	16	10.40	21	2	-4	1	19	20	7629	985	1823	44	10437	10481		0		0
15	17	11.23	19	4	1	11	24	35	16383	2450	-1052	5285	17781	23066		0		0
16	18	12.04	5	15	6	-2	26	24	9568	7887	2692	3815	20147	23962		0		0
17	19	12.95	10	8	-2	5	16	21	6506	11184	1308	1508	18998	20506		0		0
18	20	13.67	8	4	-20	15	-8	7	6391	4742	-8153	7357	2980	10337	7.2	2574	10	3432
19	21	14.61	2	14	-1	1	15	16	4674	8581	-9648	7627	3607	11234		3402		4536
20	22	15.17	-37	67	11	3	41	44	-9850	22305	3022	1055	15477	16532	8.9	2470		0
21	23	15.83	0	12	-1	4	11	15	-12093	25862	3398	2348	17167	19515		2937		0
22	24	17.04	-8	-14	9	3	-13	-10	-4745	-1387	5089	4465	-1043	3422		0		0
23	25	17.82	0	-46	15	7	-31	-24	-3149	-23396	9361	3747	-17184	-13437		0		0
24	26	18.41	-6	10	-19	-21	-15	-36	-1712	-10890	-1335	-4447	-13937	-18384	40	11900	30	8925
25	27	19.18	-8	-48	-13	2	-69	-67	-5473	-14527	-12755	-7465	-32755	-40220		15300		11475
26	28	20.12	-10	20	3	6	13	19	-8830	-13019	-5127	3840	-26976	-23136	6	2835		0
27	29	20.66	-22	81	31	-1	90	89	-8572	27156	9081	1383	27665	29048		1605	60	16050
28	30	21.50	3	54	1	-14	58	44	-8061	56760	13650	-6037	62349	56312	6.5	2730	35	40068
29	31	22.46	-31	-21	-96		-148	-148	-13986	15696	-45363		-43653	-49919	139.5	70080	42	37152
30	32	23.81	16	-30	4	-25	-10	-35	-10989	-34410	-61903	-16772	-107302	-124074		94163	37	53325
31	33	24.95	31	-25	-58	-35	-52	-87	26207	-30747	-30284	-34390	-34824	-69214	85.2	48564	39	43320
32	34	25.98	13	39	-10	6	42	48	22676	7257	-34679	-15088	-4746	-19834	45.9	67844	5	22770
33	35	26.68	-1	49	-11		37		4326	30285	-7295		27316		43.6	31325		
Total			**-148**	**105**	**-137**	**-25**	**-180**	**-242**	**-101806**	**3057**	**-164945**	**-47272**	**-263694**	**-338282**	**383**	**-357729**	**258**	**-241053**
grey indicates where 2001 surveys have been omitted due to incomplete or suspect survey.															deposits	192784		193781
It has been assumed that the area change was zero and the volume change accordingly calculated. IP																54%		80%

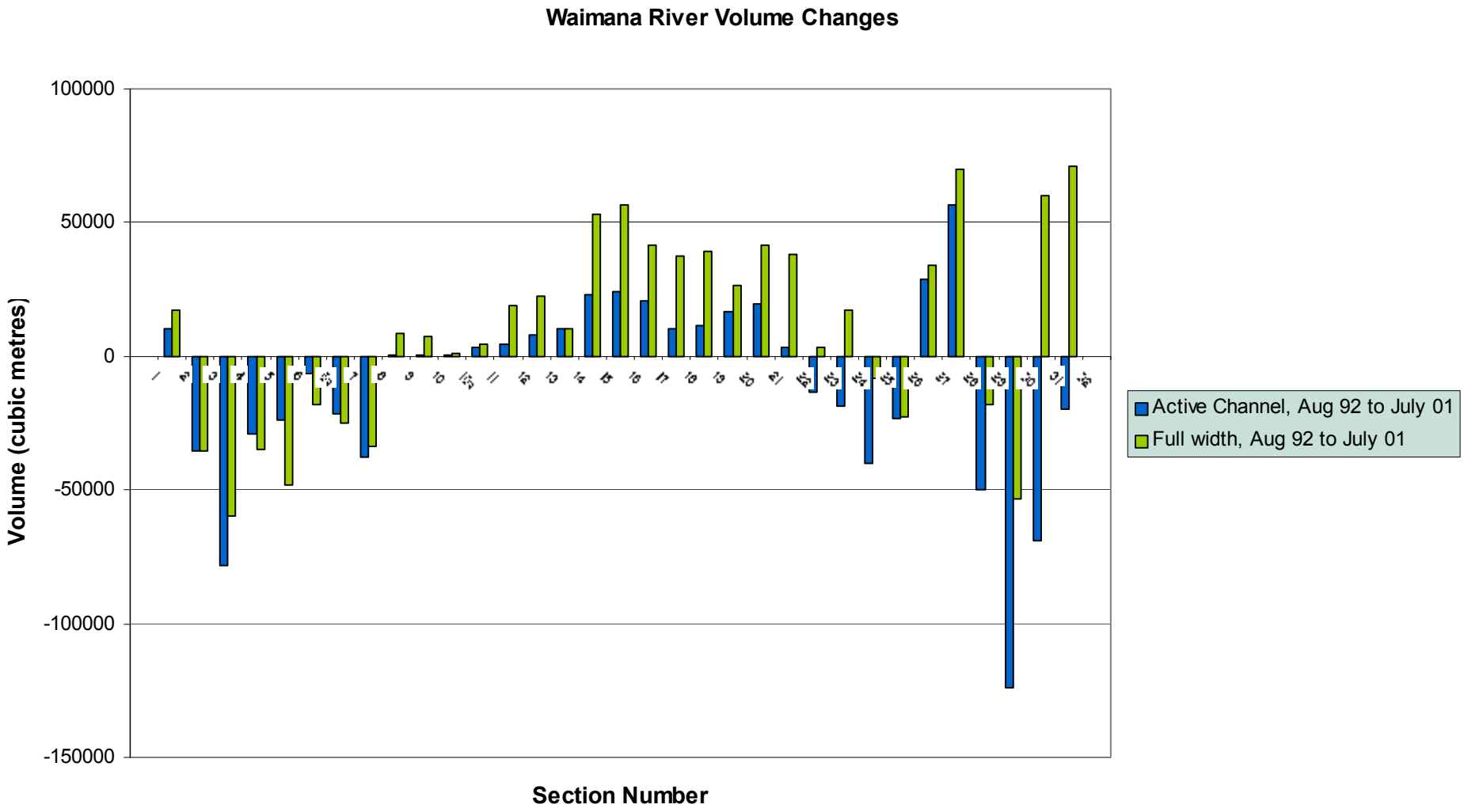
Waimana River Volume Changes - Full width including floodplain

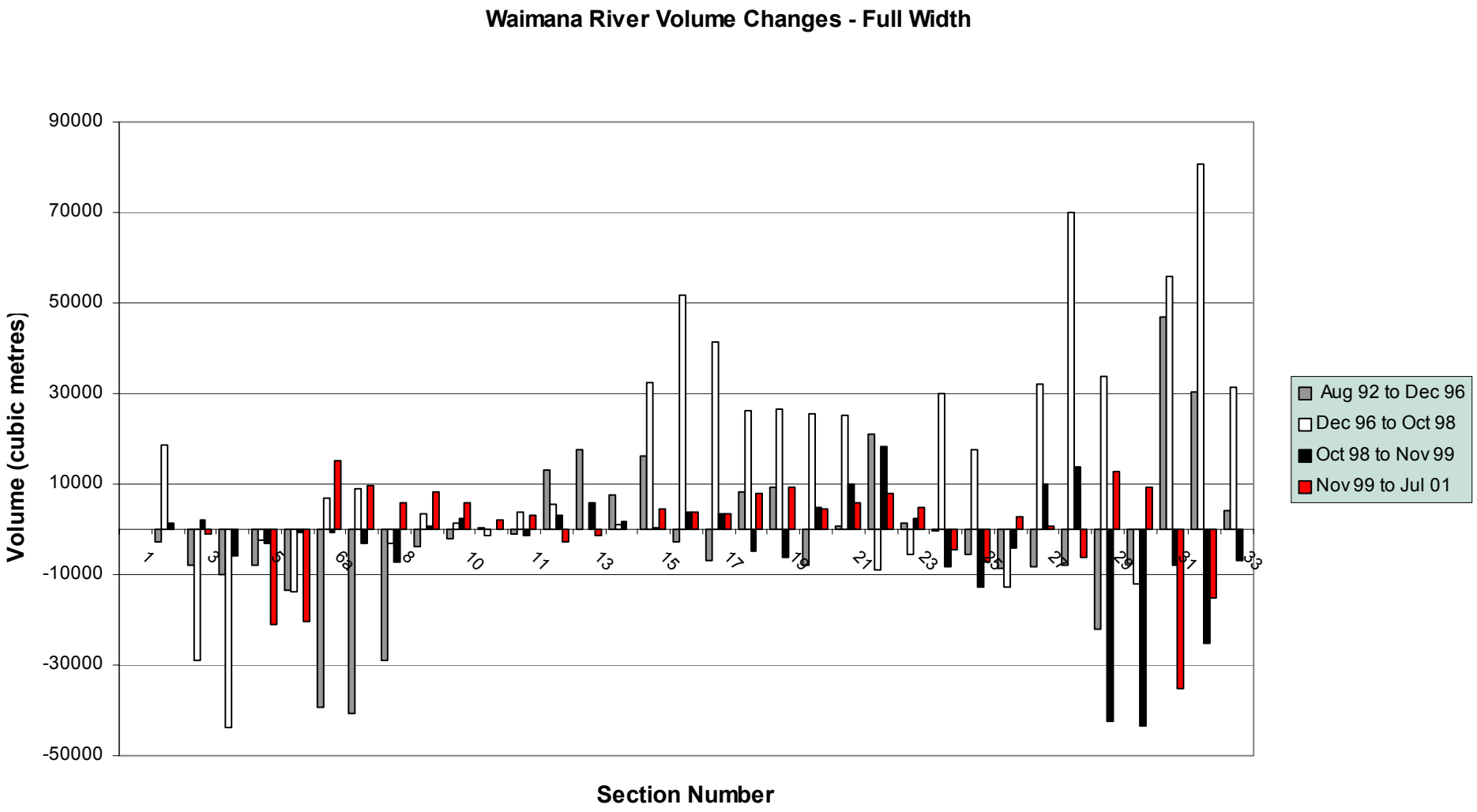
Section	Ricoda Section	Upstream dist (km)	Area Changes (m^2)						Volume Changes (m^3)					
			Aug 92 to Dec 96	Dec 96 to Oct 98	Oct 98 to Nov 99	Nov 99 to Jul 01	Aug 92 to Nov 99	Aug 92 to Jul 01	Aug 92 to Dec 96	Dec 96 to Oct 98	Oct 98 to Nov 99	Nov 99 to Jul 01	Aug 92 to Nov 99	Aug 92 to Jul 01
1	1	0.43	1	60	4	4	65	69	0	0	0	0	0	0
2	2	0.98	-10	7	1	-4	-2	-6	-2737	18477	1460	-76	17200	17124
3	3	1.6	-15	-101	6	0	-110	-110	-7768	-28882	2206	-1186	-34444	-35630
4	4	2.61	-5	14	-17	0	-8	-8	-10139	-43869	-5834	153	-59842	-59689
5	5	3.27	-19	-21	8	-64	-32	-96	-8090	-2446	-3081	-21187	-13617	-34804
6	6	4.03	-16	-16	-10	10	-42	-32	-13438	-13926	-598	-20351	-27962	-48313
6a	7	4.83	-82	33	7	27	-42	-15	-39241	6787	-805	15148	-33259	-18111
7	8	5.43	-53	-3	-17	5	-73	-68	-40572	8892	-2941	9531	-34621	-25090
8	9	6.44	-4	-3	3	7	-4	3	-28959	-3151	-7276	5804	-39386	-33582
9	10	7.16	-6	13	-1	16	6	22	-3712	3607	591	8225	486	8711
10	11	7.79	-1	-9	9	3	-1	2	-2199	1425	2416	5867	1642	7509
10a	12	7.99	3	-4	-8	20	-9	11	248	-1271	48	2228	-975	1253
11	13	8.49	-7	20	2	-7	15	8	-950	3913	-1531	3190	1432	4622
12	14	9.08	51	-1	8	-2	58	56	13066	5426	3110	-2775	21602	18827
13	15	9.74	3	1	10		14	14	17695	-125	5860		23430	22218
14	16	10.4	21	2	-4	1	19	20	7629	985	1823		10437	10481
15	17	11.225	19	76	4	10	99	109	16255	32248	182	4430	48685	53115
16	18	12.035	-25	51	6	-1	32	31	-2764	51629	3892	3737	52757	56494
17	19	12.95	10	39	2	7	51	58	-6834	41284	3344	3478	37794	41272
18	20	13.665	13	34	-15	14	32	46	8359	26200	-4834	7866	29725	37591
19	21	14.61	7	22	3	6	32	38	9319	26702	-6194	9332	29827	39159
20	22	15.165	-36	70	15	10	49	59	-7874	25401	4764	4385	22291	26676
21	23	15.825	37	6	16	7	59	66	533	25050	9948	5807	35531	41338
22	24	17.04	-2	-21	15	5	-8	-3	21116	-9031	18347	7819	30432	38251
23	25	17.815	5	8	-9	6	4	10	1427	-5367	2502	4687	-1438	3249
24	26	18.41	-6	93	-20	-21	67	46	-174	29984	-8374	-4388	21436	17048
25	27	19.175	-8	-48	-13	2	-69	-67	-5668	17428	-12837	-7390	-1077	-8467
26	28	20.12	-10	21	5	4	16	20	-8491	-12680	-4201	2866	-25372	-22506
27	29	20.655	-21	98	32	-2	109	107	-8183	31987	9835	650	33639	34289
28	30	21.495	2	69	2	-13	73	60	-7985	70152	13945	-6355	76112	69757
29	31	22.455	-48	1	-90		-137	-137	-22014	33628	-42471		-30857	-17983
30	32	23.805	37	-20	26	-27	43	16	-7531	-12044	-43324		-62899	-53445
31	33	24.945	45	118	-39	-35	124	89	46935	56000	-7779	-35017	95156	60139
32	34	25.98	13	38	-9	6	42	48	30388	80646	-25072	-15088	85962	70874
33	35	26.68	-2	51	-11		38		4053	31282	-7053		28282	
Total			**-109**	**698**	**-79**	**-6**	510	**466**	**-58300**	**496341**	**-99932**	**12550**	338109	**322377**

Waimana River Volume Changes - Floodplain only

Section	Ricoda Section	Upstream dist (km)	Area Changes (m^2)						Volume Changes (m^3)					
			Aug 92 to Dec 96	Dec 96 to Oct 98	Oct 98 to Nov 99	Nov 99 to Jul 01	Aug 92 to Nov 99	Aug 92 to Jul 01	Aug 92 to Dec 96	Dec 96 to Oct 98	Oct 98 to Nov 99	Nov 99 to Jul 01	Aug 92 to Nov 99	Aug 92 to Jul 01
1	1	0.43	0	34	-1	1	33	34	0	0	0	0	0	0
2	2	0.98	-10	1	-1	3	-10	-7	-2924	9687	-677	825	6086	6911
3	3	1.6	4	6	-4	0	6	6	-1938	2475	-1804	950	-1267	-317
4	4	2.61	-2	37	-3	-1	32	31	1011	21641	-4138	60	18514	18574
5	5	3.27	-7	-3	4	-41	-6	-47	-2926	10962	-33	-13613	8003	-5610
6	6	4.03	-3	-8	-10	2	-21	-19	-3637	-4385	-1906	-14799	-9928	-24727
6a	7	4.83	-26	-1	-7	23	-34	-11	-11492	-3910	-6283	10031	-21685	-11654
7	8	5.43	-12	7	1	4	-4	0	-11236	1512	-1991	8090	-11715	-3625
8	9	6.44	0	0	7	3	7	10	-5612	2988	3509	3252	885	4137
9	10	7.16	4	4	0	7	8	15	1268	1420	2096	3618	4784	8402
10	11	7.79	2	0	1	5	3	8	1530	1485	255	3632	3270	6902
10a	12	7.99	0	0	0	0	0	0	209	-9	138	435	338	773
11	13	8.49	-2	2	2	2	2	4	-461	325	566	782	430	1212
12	14	9.08	45	1	-1	-2	45	43	12985	383	668	174	14036	14210
13	15	9.74	0	0	0	0	0	0	15133	0	0	-797	15133	14336
14	16	10.4	0	0	0	0	0	0	0	0	0	0	0	0
15	17	11.225	0	72	3	-1	75	74	-128	29798	1234	-855	30904	30049
16	18	12.035	-30	36	0	1	6	7	-12332	43742	1200	-78	32610	32532
17	19	12.95	0	31	4	2	35	37	-13340	30100	2036	1970	18796	20766
18	20	13.665	5	30	5	-1	40	39	1968	21458	3319	509	26745	27254
19	21	14.61	5	8	4	5	17	22	4645	18121	3454	1705	26220	27925
20	22	15.165	1	3	4	7	8	15	1976	3096	1742	3330	6814	10144
21	23	15.825	37	-6	17	3	48	51	12626	-812	6550	3459	18364	21823
22	24	17.04	6	-7	6	2	5	7	25861	-7644	13258	3354	31475	34829
23	25	17.815	5	54	-24	-1	35	34	4576	18029	-6859	940	15746	16686
24	26	18.41	0	83	-1	0	82	82	1538	40874	-7039	59	35373	35432
25	27	19.175	0	0	0	0	0	0	-195	31955	-82	75	31678	31753
26	28	20.12	0	1	2	-2	3	1	339	339	926	-974	1604	630
27	29	20.655	1	17	1	-1	19	18	389	4831	754	-733	5974	5241
28	30	21.495	-1	15	1	1	15	16	76	13392	295	-318	13763	13445
29	31	22.455	-17	22	6	0	11	11	-8028	17932	2892	19140	12796	31936
30	32	23.805	21	10	22	-2	53	51	3458	22366	18579	26226	44403	70629
31	33	24.945	14	143	19	0	176	176	20728	86747	22505	-627	129980	129353
32	34	25.98	0	-1	1	0	0	0	7712	73389	9607	0	90708	90708
33	35	26.68	-1	2	0		1		-273	997	242		966	
Total			**39**	**593**	**58**	**19**	**690**	**709**	**43506**	**493284**	**65013**	**59822**	**601803**	**661625**

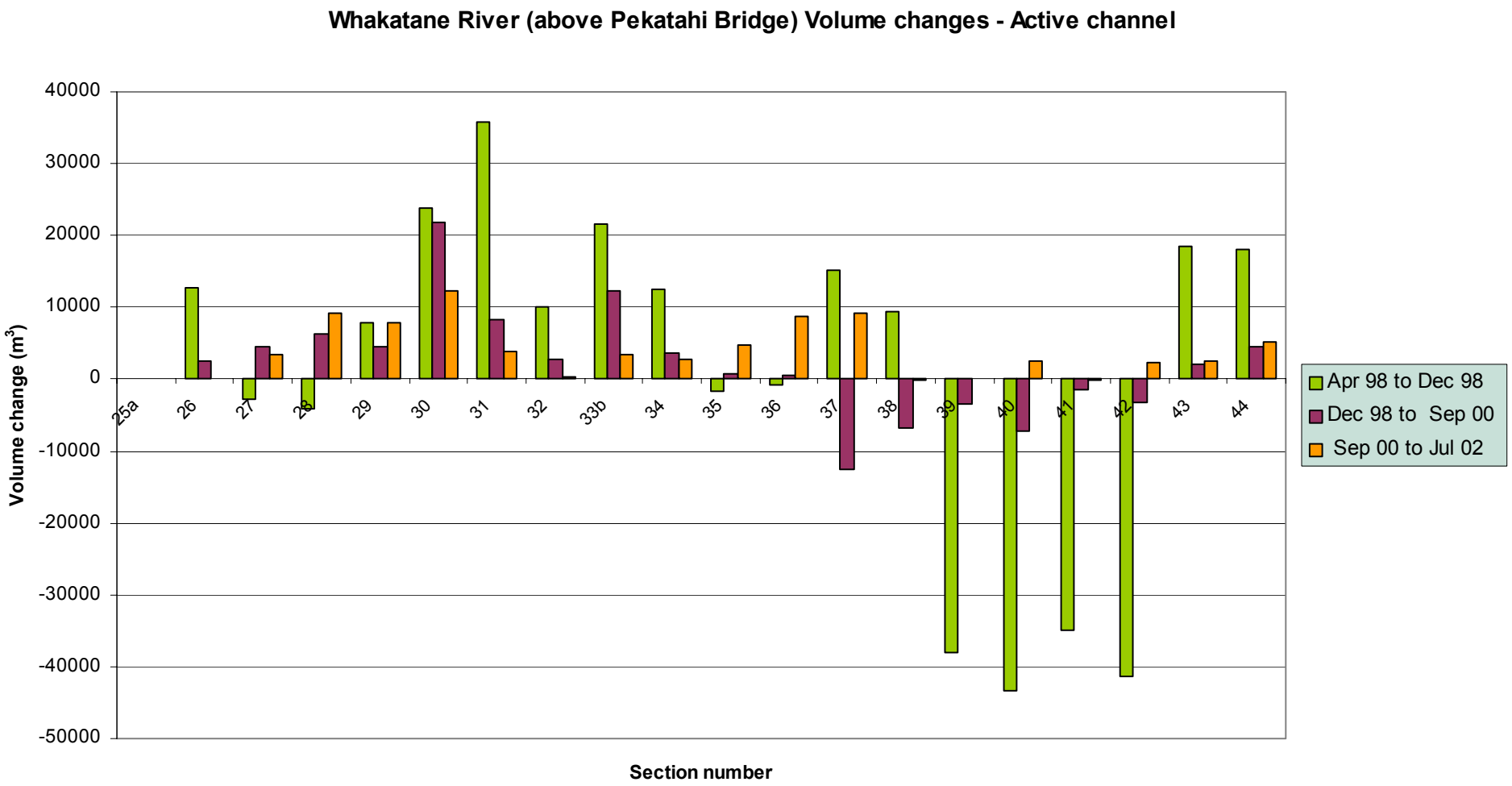

Waimana River Volume Changes - Active channel
60000
40000
20000
0
-20000
-40000
-60000
-80000
Volume (cubic metres)
Section Number
Aug 92 to Dec 96
Dec 96 to Oct 98
Oct 98 to Nov 99
Nov 99 to Jul 01

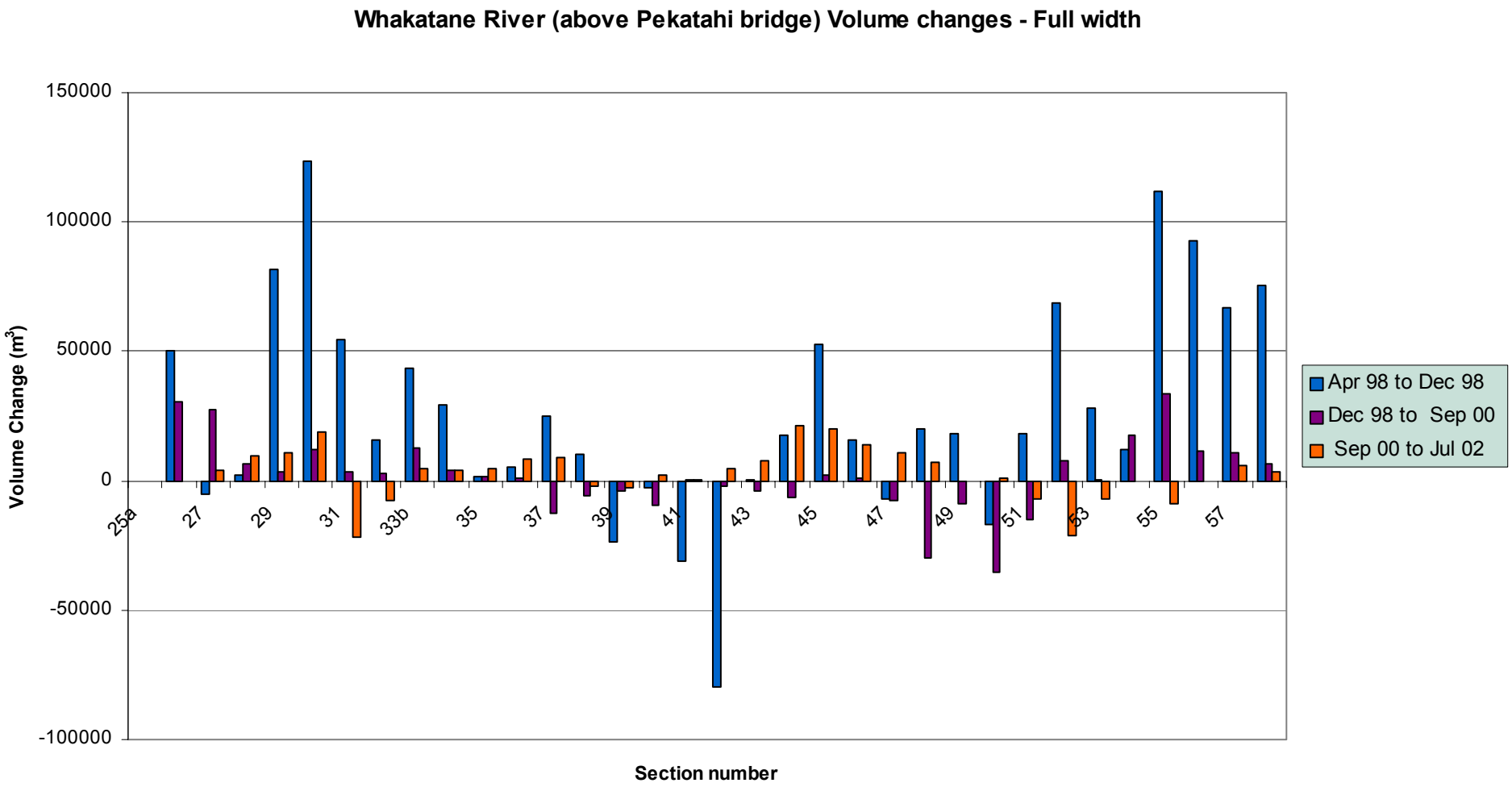

Waimana River Volume Changes
100000
50000
0
-50000
-100000
-150000
Volume (cubic metres)
Section Number
Active Channel, Aug 92 to July 01
Full width, Aug 92 to July 01


Waimana River Volume Changes - Full Width
Volume (cubic metres)
90000
70000
50000
30000
10000
-10000
-30000
-50000
1
3
5
6
8
10
11
13
15
17
19
21
23
25
27
29
31
33
Section Number
Aug 92 to Dec 96
Dec 96 to Oct 98
Oct 98 to Nov 99
Nov 99 to Jul 01

Whakatane River Volume Changes above Pekatahi Bridge new data new data

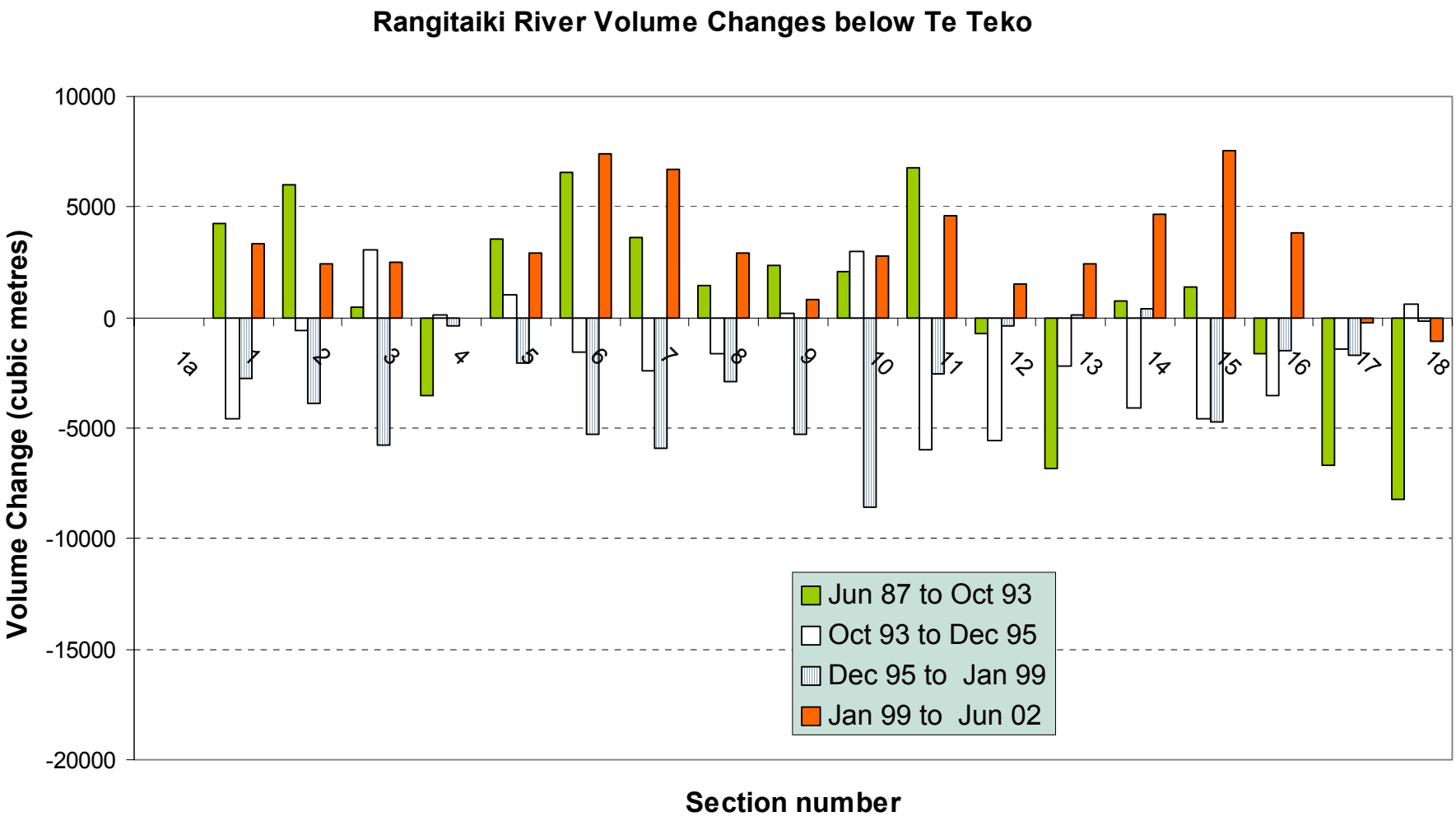
			Active Channel						Design Width (post flood)		Full width					
			Area Changes (m^2)			Volume Changes (m^3)			Area	Volume	Area Changes (m^2)			Volume Changes (m^3)		
Section number	Ricoda number	Distance (km)	Apr 98 to Dec 98	Dec 98 to Sep 00	Sep 00 to Jul 02	Apr 98 to Dec 98	Dec 98 to Sep 00	Sep 00 to Jul 02	Apr 98 to Dec 98	Apr 98 to Dec 98	Apr 98 to Dec 98	Dec 98 to Sep 00	Sep 00 to Jul 02	Apr 98 to Dec 98	Dec 98 to Sep 00	Sep 00 to Jul 02
25a	36	18.19	12	5	0	0	0	0	21	0	90	9	0	0	0	0
26	37	19.01	19	1	0	12691	2637	0	24	18672	32	65	0	50302	30465	0
27	38	19.72	-27	12	10	-2676	4579	3514	-30	-1975	-48	12	11	-5352	27330	3891
28	39	20.595	17	3	11	-4188	6210	9185	21	-3908	52	3	11	2320	6377	9734
29	40	21.355	4	9	9	7873	4502	7822	19	15337	162	6	17	81604	3144	11012
30	41	22.515	37	28	12	23820	21783	12215	43	36268	51	16	14	123410	12290	18731
31	42	23.285	56	-7	-2	35865	8313	3816	64	41092	91	-7	-70	54787	3299	-21506
32	43	23.515	32	31	5	10160	2712	388	31	10940	44	31	5	15694	2706	-7546
33b	44	24.05	49	15	8	21611	12249	3527	48	21253	119	16	13	43716	12388	4680
34	45	24.53	5	0	3	12619	3727	2712	4	12606	4	0	3	29441	3831	3795
35	46	25.12	-10	3	12	-1772	763	4644	-12	-2306	2	5	12	1727	1550	4444
36	47	25.601	7	0	23	-833	622	8685	17	1184	20	0	23	5226	1264	8514
37	48	26.185	45	-43	8	15150	-12620	9218	43	17635	65	-43	8	24949	-12620	9214
38	49	26.61	-1	11	-8	9373	-6765	-36	5	10097	-16	15	-16	10345	-5869	-1804
39	50	27.235	-121	-22	9	-38086	-3417	153	-116	-35148	-58	-29	7	-23361	-4186	-2957
40	51	28.025	12	4	-2	-43311	-7153	2554	11	-41763	52	4	-2	-2413	-9790	1922
41	52	28.58	-137	-10	2	-34956	-1495	-121	-139	-35503	-164	-4	3	-31155	120	340
42	53	29.55	52	3	3	-41402	-3139	2254	60	-38451	0	-1	6	-79648	-2161	4381
43	54	30.06	21	5	7	18587	2150	2599	38	24814	1	-16	25	213	-4134	7629
44	55	30.785	29	7	7	18026	4609	5148	29	24026	47	-2	34	17504	-6463	21210
45	56	31.63							26	23190	77	8	14	52513	2328	20085
46	57	32.17							-47	-5571	-18	-3	37	16006	1194	13692
47	58	32.66		All checked and ok! IP					-13	-14743	-10	-27	5	-6788	-7552	10599
48	59	33.405							4	-3637	63	-53	13	19864	-29950	6934
49	60	33.715							40	6750	55	-3	-12	18336	-8650	27
50	61	34.44							-31	3204	-101	-94	14	-16704	-35299	710
51	62	34.955							16	-3946	173	37	-42	18380	-14869	-6967
52	63	35.695							24	14802	13	-15	-16	68815	7894	-21082
53	64	36.635							-32	-3886	46	15	1	27872	124	-7015
54	65	37.275							36	1040	-8	39	-2	11806	17536	-265
55	66	38.675							90	88011	168	9	-11	111556	33612	-8638
56	67	39.475							4	37700	63	19	9	92435	11156	-511
57	68	40.26							62	25713	108	9	5	66983	11116	5656
58	69	41.66							0	43030	0	0	0	75503	6556	3273
Total			**101**	**55**	**117**	**18551**	**40267**	**78277**	**360**	**286527**	**1114**	**109**	**88**	**875886**	**54737**	**92182**

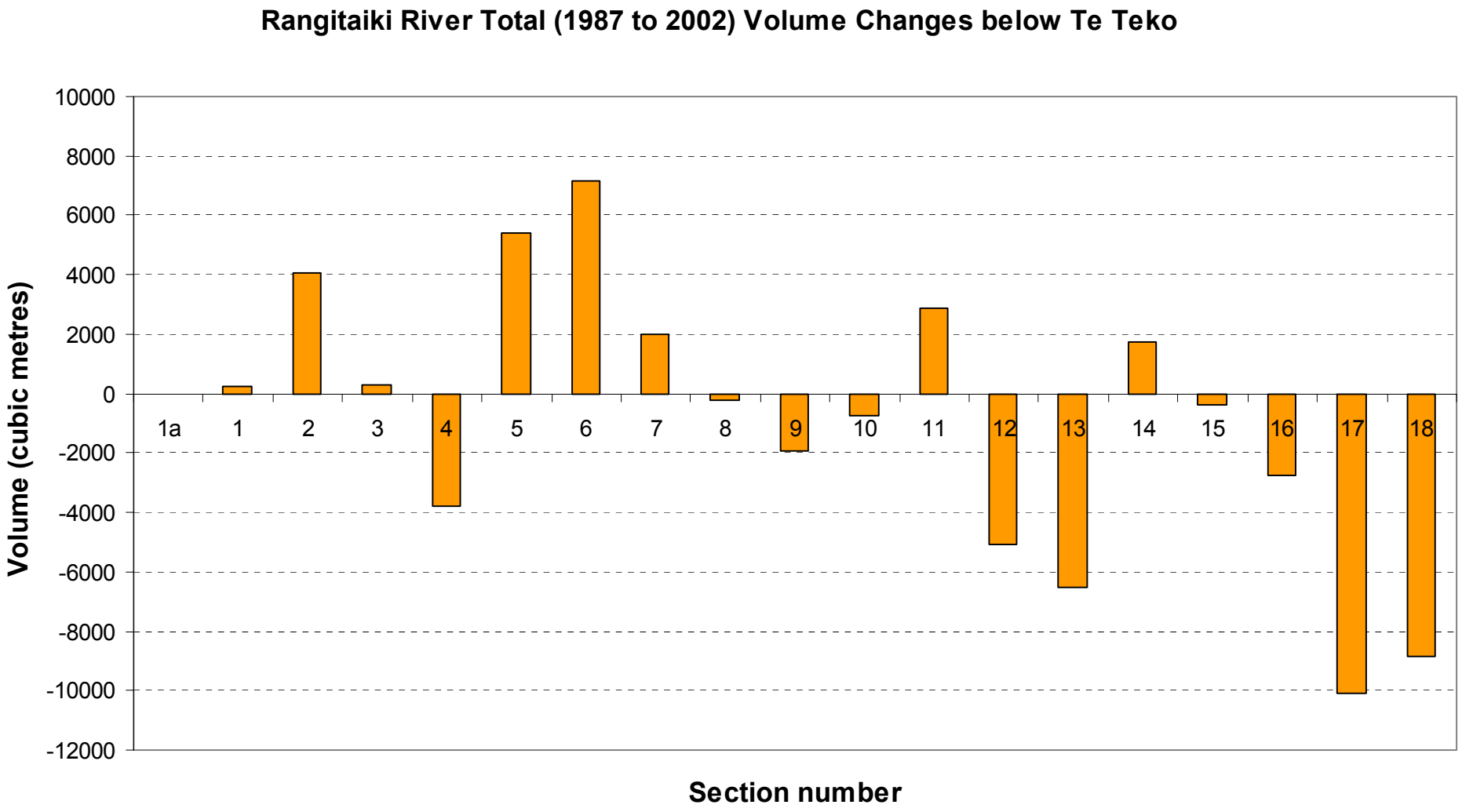

Whakatane River (above Pekatahi Bridge) Volume changes - Active channel
Volume change (m3)
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
25a
26
27
28
29
30
31
32
33b
34
35
36
37
38
39
40
41
42
43
44
Section number
Apr 98 to Dec 98
Dec 98 to Sep 00
Sep 00 to Jul 02


Whakatane River (above Pekatahi bridge) Volume changes - Full width
150000
100000
50000
0
-50000
-100000
Volume Change (m3)
25a
27
29
31
33b
35
37
39
41
43
45
47
49
51
53
55
57
Section number
Apr 98 to Dec 98
Dec 98 to Sep 00
Sep 00 to Jul 02

Lower Rangitaiki River stopbanks raised!!

Location	Section Number	Ricoda Number	Distance (km)	Area Change (m^2) Jun 87 to Oct 93	Oct 93 to Dec 95	Dec 95 to Jan 99	Jan 99 to Jun 02	Jun 87 to Jun 02	Volume Change (m^3) Jun 87 to Oct 93	Oct 93 to Dec 95	Dec 95 to Jan 99	Jan 99 to Jun 02	Jun 87 to Jun 02
Mouth	1a	1	0	0	0	0	0	0	0	0	0	0	0
	1	2	0.58	15	-16	-10	12	1	4271	-4602	-2778	3356	247
	2	3	0.89	24	12	-15	5	26	6004	-587	-3845	2464	4036
	3	4	1.43	-22	-1	-6	5	-24	436	3085	-5776	2527	272
	4	5	1.68	-6	2	3	-5	-6	-3520	103	-361	-31	-3809
	5	6	2.23	18	2	-10	15	25	3547	1013	-2047	2892	5405
	6	7	2.63	15	-11	-15	21	10	6595	-1595	-5258	7425	7167
	7	8	3.04	4	-2	-13	11	0	3613	-2422	-5884	6671	1978
	8	9	3.43	4	-6	-2	3	-1	1415	-1616	-2905	2897	-209
Greig Rd	9	10	3.81	9	7	-26	1	-9	2356	189	-5260	784	-1931
	10	11	4.17	3	9	-22	15	5	2078	2998	-8565	2759	-730
	11	12	4.63	26	-35	11	5	7	6781	-5986	-2558	4612	2849
	12	13	4.96	-31	1	-12	4	-38	-714	-5561	-353	1536	-5092
	13	14	5.37	-3	-12	13	8	6	-6849	-2226	111	2448	-6516
	14	15	5.77	6	-8	-11	15	2	732	-4083	385	4694	1728
	15	16	6.34	-1	-8	-5	11	-3	1372	-4594	-4719	7562	-379
	16	17	6.74	-6	-10	-2	8	-10	-1612	-3498	-1464	3798	-2776
	17	18	7.11	-30	2	-8	-9	-45	-6673	-1459	-1730	-233	-10095
	18	19	7.43	-21	2	6	3	-10	-8214	603	-138	-1095	-8844
	19	20	7.94	-14	8	4			-9217	2661	2662		
	20	21	8.2	7	-11	-13			-963	-340	-1262		
I	21	22	8.75	-28	3	-14			-5615	-2105	-7635		
I	22	23	9.15	-23	-6	-27			-9963	-637	-8191		
I	23	24	9.51	9	-52	-1			-2569	-10422	-4986		
I	24	25	9.89	-24	-2	-16			-2993	-10084	-3277		
I	25	26	10.39	-9	-19	-7			-8332	-5205	-5713		
I	26	27	10.74	2	2	8			-1145	-3050	210		
Edgecumbe	27	28	11.19	-1	-49	12			406	-10600	4510		
I	28a	29	11.34		5	-14				-3264	-79		
I	28b	30	11.54		-21	0				-1533	-1351		
I	29	31	11.85		-5	1				-3928	201		
	30	32	12.14		14	-18				1345	-2437		
	31	33	12.51		-13	11				119	-1191		
	32	34	12.86		6	0				-1326	2115		
	33	35	13.23		-2	3				758	605		
	34	36	13.68		1	6				-157	1834		
	35	37	14.08		-3	6				-412	2373		
	36	38	14.49		-2	15				-1212	4435		
	37	39	14.86		-41	12				-8169	5032		
	38	40	15.11		-13	26				-6704	4661		
	39	41	15.46		6	-20				-1248	1009		
	40	42	15.77		-14	-2				-1425	-3294		
	41	43	15.96		3	2				-1039	36		
	41a	44	16.16		-8	0				-451	224		
	42	45	16.54		-5	11				-2540	2100		
	43a	46	16.97		-34	-1				-8421	2180		
	43b	47	17.14		-36	6				-5910	423		
	43c	48	17.46		-10	10				-7360	2617		
	44	49	17.85		2	-9				-1573	236		
	45	50	18.25		-3	-10				-169	-3900		
	46	51	18.61		-7	7				-1807	-494		
	47a	52	19.12		-30	8				-9509	3958		
	47b	53	19.34		-21	10				-5607	1930		
	48	54	19.56		-20	-7				-4526	317		
	49	55	20.08		-25	-6				-11961	-3275		
	50	56	20.36		-23	-9				-6803	-2120		
	51a	57	20.61		8	-26				-1867	-4393		
	51b	58	20.96		-59	17				-8920	-1566		
	51c	59	21.31		-19	6				-13644	3907		
	52	60	21.61		-2	-7				-3048	-354		
	53	61	22.03		-4	-21				-1268	-6032		
	54	62	22.24		-10	0				-1554	-2211		
	55	63	22.953		8	5				-1096	1843		
	56	64	23.456		-7	0				-112	1301		
I	57	65	23.757		16	25				1146	3842		
Te Teko	58	66	24.16		-1	-13				2912	2515		
I	59	67	24.55		2	-5				306	-3578		
			Total	**-77**	**-565**	**-159**	**128**	**-64**	**-28773**	**-191997**	**-63408**	**55066**	**-16699**
			Total 1987 to 2002:					**-673**					**-229112**


Rangitaiki River Volume Changes below Te Teko
Volume Change (cubic metres)
10000
5000
0
-5000
-10000
-15000
-20000
1a
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Jun 87 to Oct 93
Oct 93 to Dec 95
Dec 95 to Jan 99
Jan 99 to Jun 02
Section number

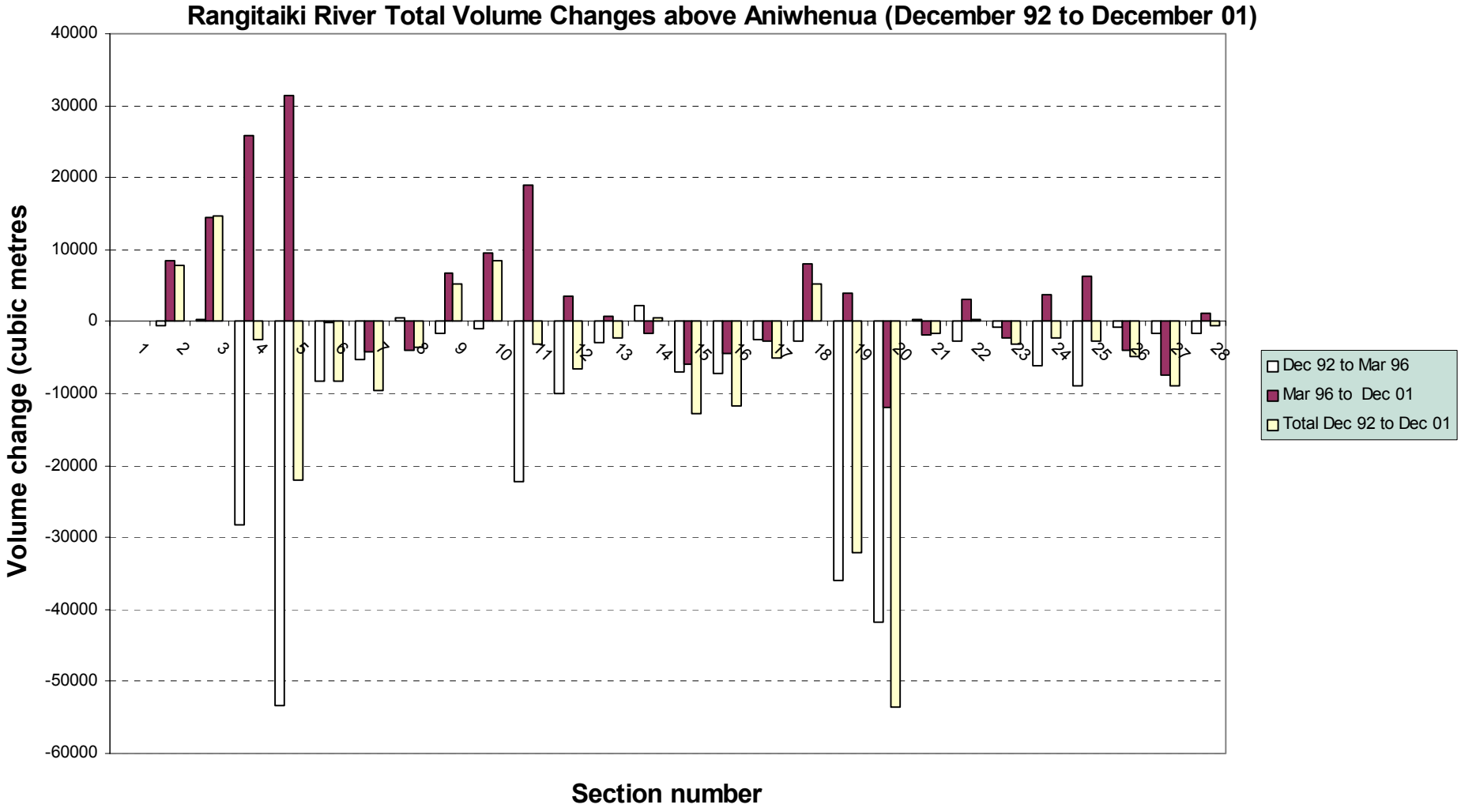

Rangitaiki River Total (1987 to 2002) Volume Changes below Te Teko
Volume (cubic metres)
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
1a
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Section number

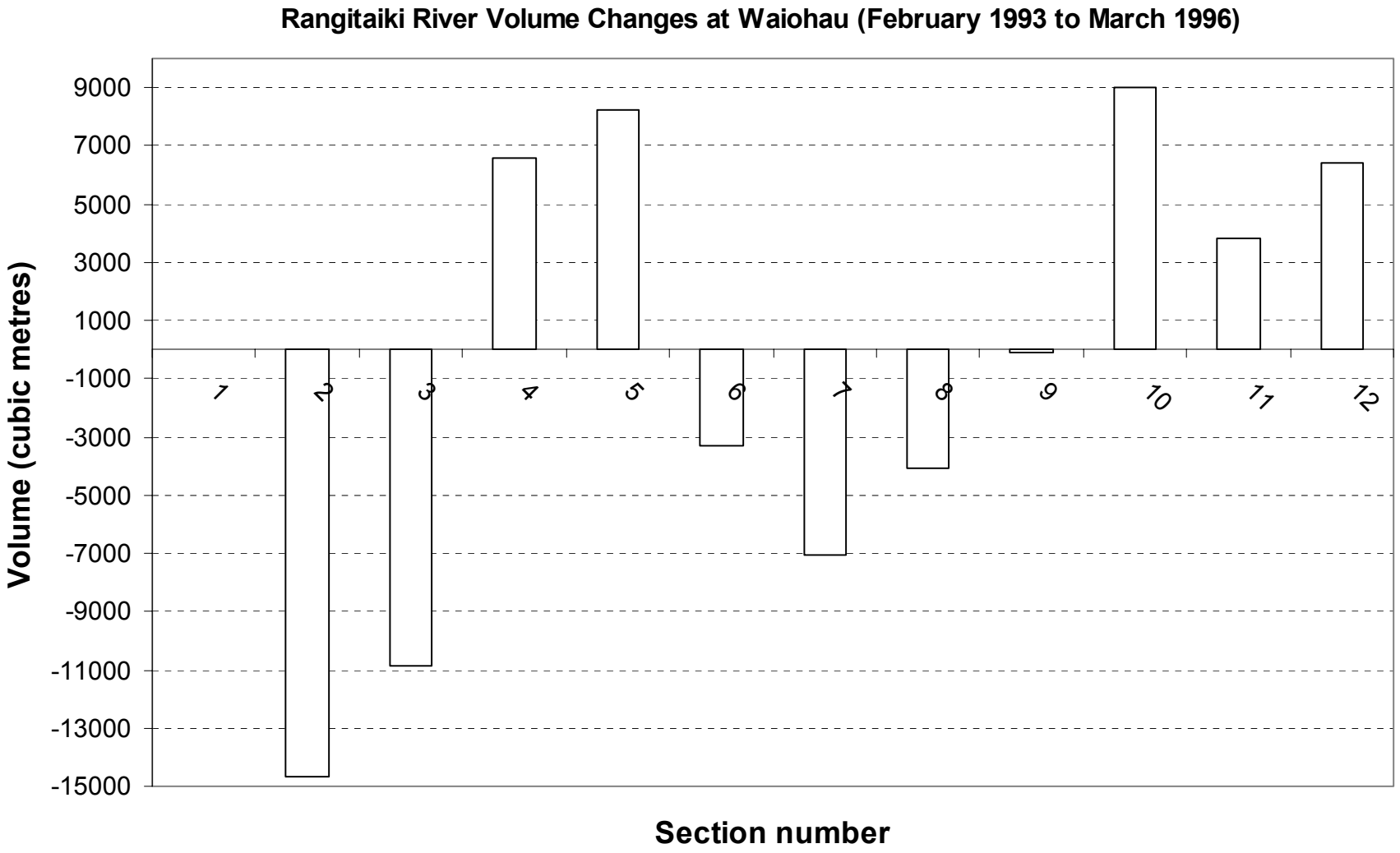
Rangitaiki River above Lake Aniwhenua
Changes Dec 1992, March 1996, Dec 2001

			Area change (m^2)			Volume change (m^3)		
Location	Section	Upstream dist (km)	Dec 92 to Mar 96	Mar 96 to Dec 01	Dec 92 to Dec 01	Dec 92 to Mar 96	Mar 96 to Dec 01	Dec 92 to Dec 01
Rabbit Rd	1	67.350	-7	7	0	0	0	0
	2	68.190	6	12	18	-559	8361	7802
	3	69.065	-6	21	15	224	14440	14664
	4	69.920	-61	40	-21	-28243	25823	-2420
	5	71.470	-8	1	-7	-53425	31464	-21961
Horomanga	6	72.130	-17	-1	-18	-8288	-48	-8336
	7	72.965	4	-9	-5	-5358	-4130	-9488
opp Haumea Rd	8	74.055	-3	2	-1	516	-4040	-3524
	9	75.060	-1	13	12	-1557	6796	5239
	10	75.865	-2	11	9	-973	9499	8526
	11	77.240	-30	16	-14	-22142	18918	-3224
	12	77.820	-4	-4	-8	-10001	3485	-6516
	13	78.980	-1	5	4	-3020	652	-2368
	14	80.060	5	-8	-3	2256	-1708	548
	15	81.025	-20	-3	-23	-7004	-5878	-12882
	16	81.740	-1	-8	-9	-7255	-4518	-11773
opp Mangamate Rd	17	83.030	-2	4	2	-2392	-2708	-5100
	18	83.860	-4	15	11	-2661	7971	5310
opp Jolly Rd	19	84.850	-69	-7	-76	-36050	3904	-32146
	20	86.110	3	-12	-9	-41711	-11865	-53576
	21	86.715	-2	6	4	319	-1934	-1615
opp Whirinaki Rd	22	87.475	-6	3	-3	-2750	3103	353
Whirinaki	23	89.040	4	-5	-1	-766	-2339	-3105
	24	90.055	-16	13	-3	-6185	3833	-2352
	25	90.980	-3	1	-2	-8967	6222	-2745
	26	91.760	1	-10	-9	-800	-3969	-4769
	27	93.100	-3	-1	-4	-1584	-7332	-8916
Murupara	28	93.560	-4	5	1	-1710	1064	-646
	Total		**-247**	**107**	**-140**	**-250086**	**95066**	**-155020**

Rangitaiki River at Waiohau
Changes Feb 1993 to March 1996

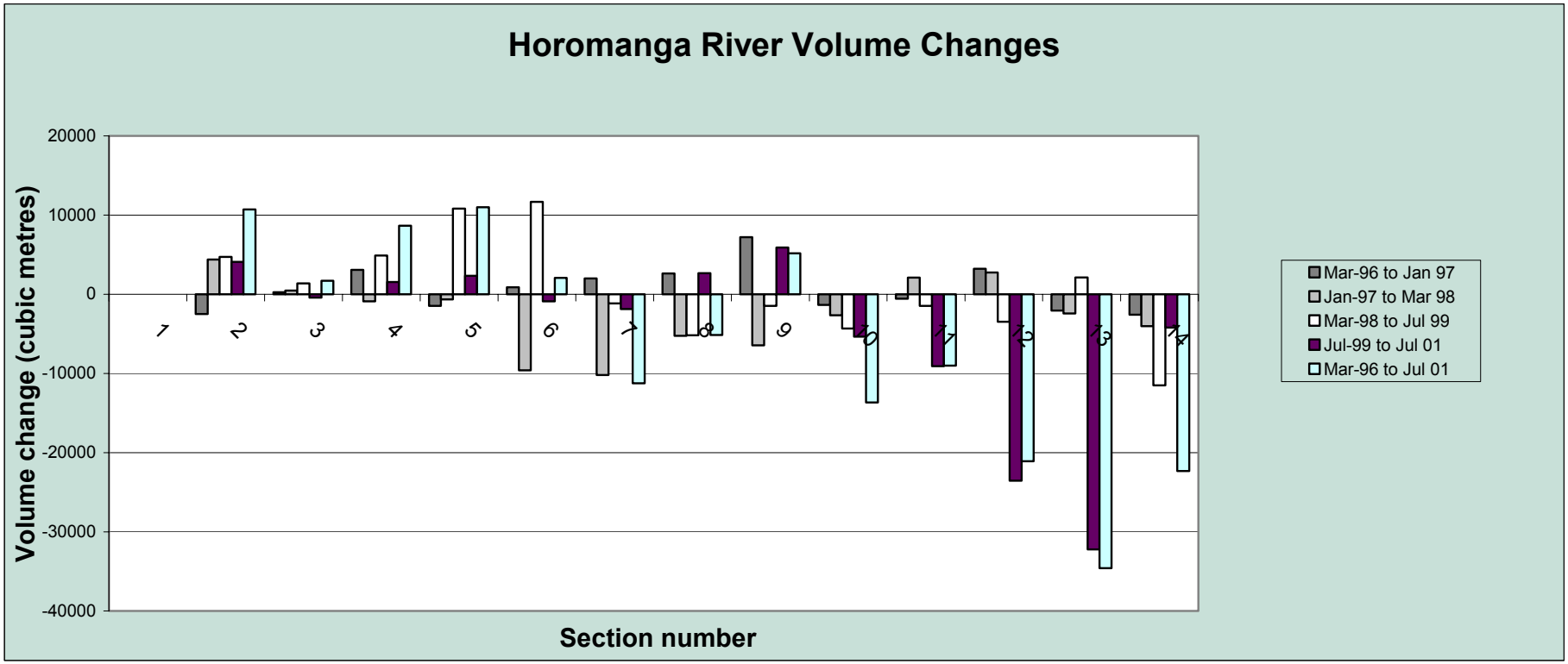
Location	Section	Upstream dist (km)	Area Change	Volume Change
Galatea Rd	1	43.995	-15	
	2	44.835	-20	-14660
	3	45.965	0	-10865
	4	47.030	13	6583
Kaiwhakinokino	5	48.170	2	8247
	6	49.200	-9	-3317
	7	50.285	-5	-7068
Waikokopu	8	51.185	-5	-4063
	9	51.975	4	-110
Waihua	10	53.255	10	9005
	11	53.760	6	3802
Mangamako	12	55.000	5	6419
	Total		**-14**	**-6027**


Rangitaiki River Total Volume Changes above Aniwhenua (December 92 to December 01)
Volume change (cubic metres
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
Section number
Dec 92 to Mar 96
Mar 96 to Dec 01
Total Dec 92 to Dec 01


Rangitaiki River Volume Changes at Waiohau (February 1993 to March 1996)
Volume (cubic metres)
9000
7000
5000
3000
1000
-1000
-3000
-5000
-7000
-9000
-11000
-13000
-15000
1
2
3
4
5
6
7
8
9
10
11
12
Section number

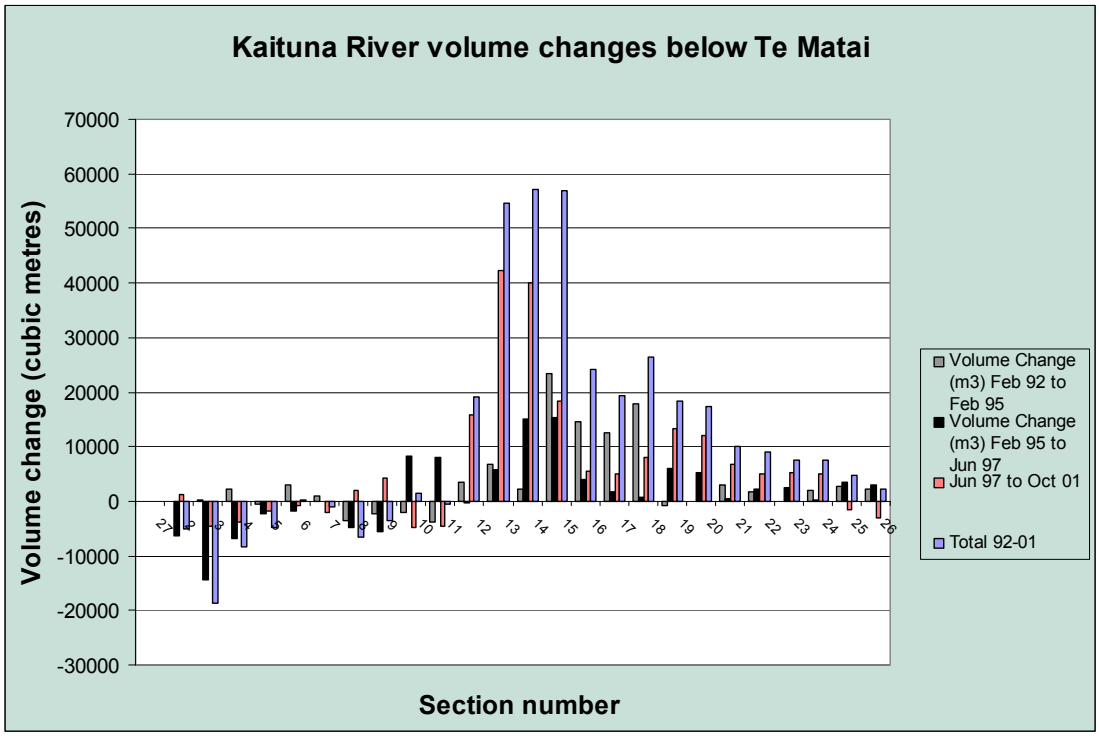
Horomanga River Volume Changes
Surveyed Mar 96, Jan 97, Mar 98, Jul 99, Jul 01

Section number	Ricoda number	Distance (km)	Volume Change (m^3) Mar-96 to Jan 97	Jan-97 to Mar 98	Mar-98 to Jul 99	Jul-99 to Jul 01	Mar-96 to Jul 99	Mar-96 to Jul 01	Area Change (m^2) Mar-96 to Jan 97	Jan-97 to Mar 98	Mar-98 to Jul 99	Jul-99 to Jul 01	Mar-96 to Jul 99	Mar-96 to Jul 01
1	1	0.256	0	0	0	0	0	0	-6	6	2	10	2	12
2	2	0.968	-2487	4401	4722	4097	6636	10733	-1	6	12	1	17	18
2a	3	1.128	278	470	1382	-410	2130	1720	5	0	5	-6	10	4
3	4	1.760	3089	-872	4875	1552	7092	8644	5	-2	10	11	13	24
4	5	2.552	-1489	-657	10812	2318	8666	10984	-9	1	18	-6	10	4
5	6	3.520	899	-9619	11677	-878	2957	2079	11	-21	7	3	-3	0
6	7	4.312	1991	-10206	-1159	-1867	-9374	-11241	-6	-5	-9	-8	-20	-28
7	8	4.976	2609	-5240	-5170	2653	-7801	-5148	14	-11	-6	16	-3	13
8	9	5.688	7204	-6456	-1478	5903	-730	5173	7	-8	2	1	1	2
9	10	6.512	-1354	-2642	-4340	-5348	-8336	-13684	-10	1	-12	-14	-21	-35
9a	11	6.920	-552	2100	-1478	-9091	70	-9021	7	9	5	-31	21	-10
10	12	7.360	3199	2748	-3486	-23546	2461	-21085	7	4	-21	-76	-10	-86
11	13	8.016	-2065	-2437	2144	-32241	-2358	-34599	-13	-11	28	-23	4	-19
12	14	8.416	-2577	-4027	-11515	-4208	-18119	-22327	1	-10	-85	1	-94	-93
		Total	**8745**	**-32437**	**6986**	**-61066**	**-16706**	**-77772**	**12**	**-41**	**-44**	**-121**	**-73**	**-194**

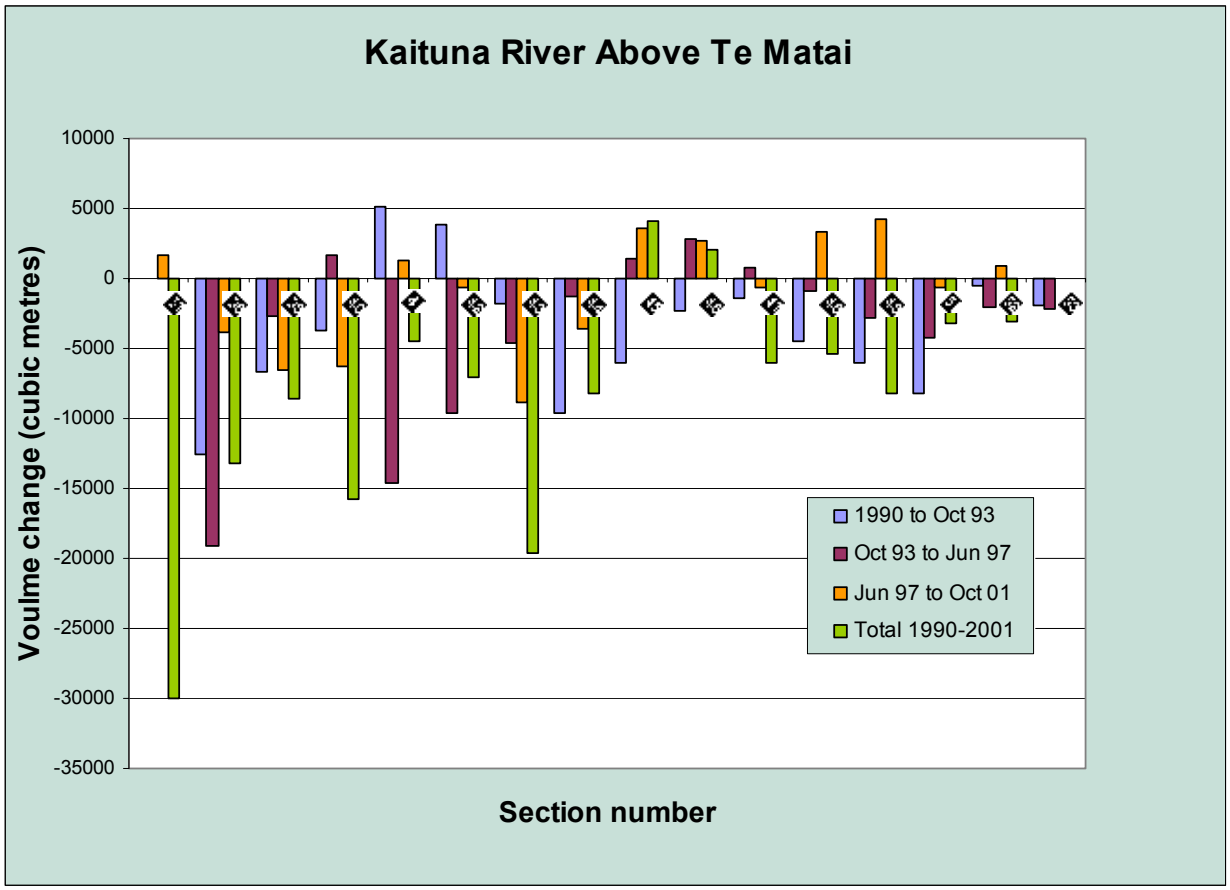

Horomanga River Volume Changes
Volume change (cubic metres)
20000
10000
0
-10000
-20000
-30000
-40000
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Section number
Mar-96 to Jan 97
Jan-97 to Mar 98
Mar-98 to Jul 99
Jul-99 to Jul 01
Mar-96 to Jul 01

Kaituna River below Te Matai - Volume changes
Surveys Feb 92, Feb 95, Jun 97, Oct 01

Location	River Section	Ricoda XS No	Distance (km)	Volume Change (m^3) Feb 92 to Feb 95	Feb 95 to Jun 97	Jun 97 to Oct 01	Feb 92 to Oct 01	Area Change (m^2) Feb 92 to Feb 95	Feb 95 to Jun 97	Jun 97 to Oct 01	Feb 92 to Oct 01
River mouth	1a	27	0.130	0	0	0	0	0	-3	19	16
	2	2	0.482	0	-6247	1214	-5033	-11	-33	-12	-56
	3	3	1.005	349	-14297	-4636	-18584	12	-21	-6	-15
	4	4	1.528	2267	-6795	-3882	-8410	-3	-4	-9	-16
	5	5	2.011	-617	-2334	-1860	-4811	1	-5	1	-3
Diagonal dr.	6	6	2.497	3086	-1893	-868	325	12	-2	-5	5
	7	7	3.017	952	-39	-2053	-1140	-9	3	-3	-9
	8	8	3.500	-3511	-4839	1887	-6463	-6	-23	11	-18
	9	9	4.023	-2265	-5613	4311	-3567	-2	1	6	5
	10	10	4.506	-1930	8267	-4871	1466	-6	33	-26	1
	11	11	5.029	-3807	8045	-4643	-405	-9	-3	8	-4
Bell Rd B	12	12	5.507	3439	-283	15843	18999	24	1	58	83
Bell Rd A	13	13	6.018	6700	5668	42262	54630	3	21	107	131
Kopuaroa \	14	14	6.500	2122	15079	40038	57239	6	42	58	106
Kopuaroa /	15	15	7.000	23302	15253	18462	57017	87	20	15	122
	16	16	7.250	14573	4060	5571	24204	29	13	30	72
Raparapahoe	17	17	7.500	12565	1673	5113	19351	71	0	11	82
	18	18	8.000	17852	692	8001	26545	1	2	21	24
Waiari just d/s	19	19	8.503	-883	5928	13246	18291	-4	22	32	50
	20	20	9.000	-117	5229	12181	17293	3	0	17	20
	21	21	9.500	2931	399	6764	10094	9	1	10	20
	22	22	10.000	1705	2213	5012	8930	-2	7	10	15
	23	23	10.550	-149	2446	5154	7451	1	1	9	11
	24	24	11.000	2063	343	5094	7500	9	-1	14	22
	25	25	11.511	2861	3403	-1629	4635	4	13	-20	-3
Te Matai	26	26	12.000	2265	3019	-3073	2211	6	-1	8	13
		Total		**85753**	**39377**	**162638**	**287768**	**226**	**84**	**364**	**674**

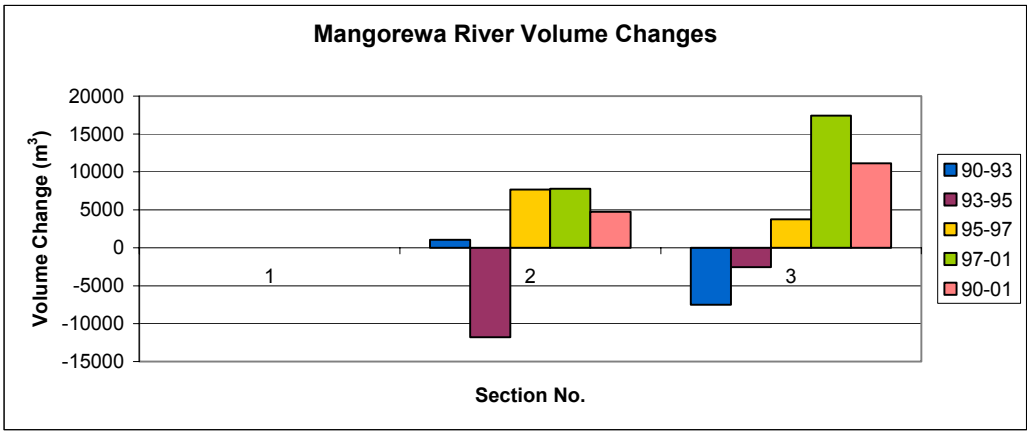


Kaituna River above Te Matai Changes from 1990 to Oct 2001									
		Volume Change (m^3)				Area Change (m^2)			
Section number	Distance (km)	1990 to Oct 93	Oct 93 to Jun 97	Jun 97 to Oct 01	1990 to Oct 01	1990 to Oct 93	Oct 93 to Jun 97	Jun 97 to Oct 01	1990 to Oct 01
37	12.82					-9	0	7	-2
38	13.76	-12608	-19051	1699	-29960	-17	-40	-4	-61
39	14.21	-6689	-2722	-3856	-13267	-14	27	-14	-1
40	14.65	-3710	1683	-6526	-8553	-6	-18	-21	-45
41	15.16	5161	-14672	-6299	-15810	26	-39	-4	-17
42	15.67	3847	-9665	1283	-4535	-5	-15	11	-9
43	16.09	-1830	-4593	-643	-7066	-4	-9	-14	-27
44	16.65	-9552	-1282	-8844	-19678	-25	5	-14	-34
45	17.185	-6063	1409	-3604	-8258	-6	2	-5	-9
46	17.94	-2277	2769	3583	4075	1	4	13	18
47	18.365	-1399	802	2629	2032	-8	0	1	-7
48	19.155	-4547	-860	-637	-6044	-3	-2	-3	-8
49	19.99	-5962	-2776	3307	-5431	-11	-6	12	-5
51	21.685	-8205	-4219	4245	-8179	-3	-2	-4	-9
52	22.15	-516	-2049	-632	-3197	0	-8	1	-7
53	22.77	-1861	-2162	896	-3127	-6	1	2	-3
	Total	**-56211**	**-57388**	**-13399**	**-126998**	**-90**	**-100**	**-36**	**-226**



Mangorewa River Volume Changes;
Surveyed Sept 90, Oct 93, Nov 95, Jun 97, Oct 01

Section number	Ricoda number	Distance (km)	Area Change (m^2)					Volume Change (m^3)				
			90-93	93-95	95-97	97-01	90-01	90-93	93-95	95-97	97-01	90-01
1	1	0	8	-18	11	-5	-4	0	0	0	0	0
2	2	1.152	-6	-3	3	18	12	1040	-11783	7694	7795	4746
3	3	2.34	-6	-2	3	12	7	-7492	-2544	3767	17400	11131
		Total	**-4**	**-23**	**17**	**25**	**15**	**-6452**	**-14327**	**11461**	**25195**	**15877**



Tarawera River - Volume changes
Surveys 1993, (1996), 1998, 2000

River Section	Ricoda XS No	Distance (km)	Volume Change (m^3) Feb 93 to Feb 98	Feb 98 Oct 00	Feb 93 to Oct 00	Area Change (m^2) Feb 93 to Feb 98	Feb 98 Oct 00	Feb 93 to Oct 00
1b	18	0.51	0	0	0	4	12	16
2	2	0.71	391	2808	3199	0	17	17
3	3	2.24	-226	12494	12268	-1	0	-1
4	4	3.12	-204	-731	-935	0	-2	-2
5	5	4.32	-1793	-10793	-12586	-2	-17	-19
6	6	5.05	-3617	-10223	-13840	-7	-11	-18
7	7	6.50	-12572	-20054	-32626	-10	-16	-26
8	8	7.56	-10062	-14248	-24310	-9	-11	-20
9	9	9.00	-13653	-10470	-24123	-10	-4	-14
10	10	10.14	-10078	-7513	-17591	-7	-9	-16
11	11	11.22	-9384	-7412	-16796	-10	-5	-15
12	12	12.50	-7772	-5917	-13689	-2	-5	-7
13	13	13.30	-5013	-2856	-7869	-10	-3	-13
14	14	14.48	-7801	-5714	-13515	-2	-8	-10
15	15	15.68	1471	-5440	-3969	5	-2	3
16	16	17.00	1198	-1062	136	-4	0	-4
17	17	17.85	-4189	0	-4189	-7	0	-7
		Total	**-83304**	**-87131**	**-170435**	**-72**	**-64**	**-136**