OPUS

HUTT RIVER MOUTH

Sediment Input and Aggradation in the lower Hutt River

Prepared for Greater Wellington

Hutt River Mouth

Sediment Input and Aggradation in the lower Hutt River

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Contents

1 Introduction

The development of a sediment budget for the Hutt River is critical to making an assessment of the environmental effects of sediment mining from the river mouth. This report forms part of a series of three reports which investigate different aspects of the sediment budget for the Hutt River. In this particular report, the amount of sediment (gravel, sand and silt) deposited along the river to its mouth is quantified using sediment aggradation analysis of cross-section survey data, and gravel extraction records.

The Hutt River has a catchment of 640km² (Figure 1.1). A number of tributaries contribute water and sediment to the main channel as it flows in a south-westerly direction towards the river mouth in Wellington Harbour. It should be noted that sediment movement down the river is episodic, and predominantly occurs under flood conditions. The rate of sediment transport increases non-linearly with the flow of the river. Sediment transport mainly occurs in two fractions: bedload, where the material rolls, bounces or slides along the bed (i.e., the coarser fractions of sediment including gravel, down to fine sand material); and suspended load, where the material is suspended in the water column (i.e., the finer fractions including fine sand and silt material)[1].

To quantify the volume of bedload and suspended load transported and deposited along the river, the results of a recent Greater Wellington Regional Council (GWRC) gravel bed material analysis (Gardner, 2010) were analysed. This identified a consistently aggrading reach in the lower part of the river below Taita Gorge. The results of the analysis of this reach were then screened to eliminate inconsistencies in the cross-section data between surveys. This included the effects of channel realignment upstream of the Ewen Bridge (1993-1998), and between the Ewen Bridge and the Ava Rail Bridge (2005). The cumulative change in sediment volume was then determined for each inter-survey period. The net aggradational volume for each period was added to the volume of sediment extracted over the same period. This provided an estimate of the total bedload and suspended load deposited.

The net sediment volumes deposited for each inter-survey period are compared in a companion report (Opus, 2010a) with independent estimates of the bedload and suspended load. Those volumes were obtained from sediment transport relationships and the measured Hutt River flow record.

[1] Suspended load also includes a proportion of very fine clay-sized sediment which remains in suspension as it is too fine to be deposited. This is referred to as wash load.

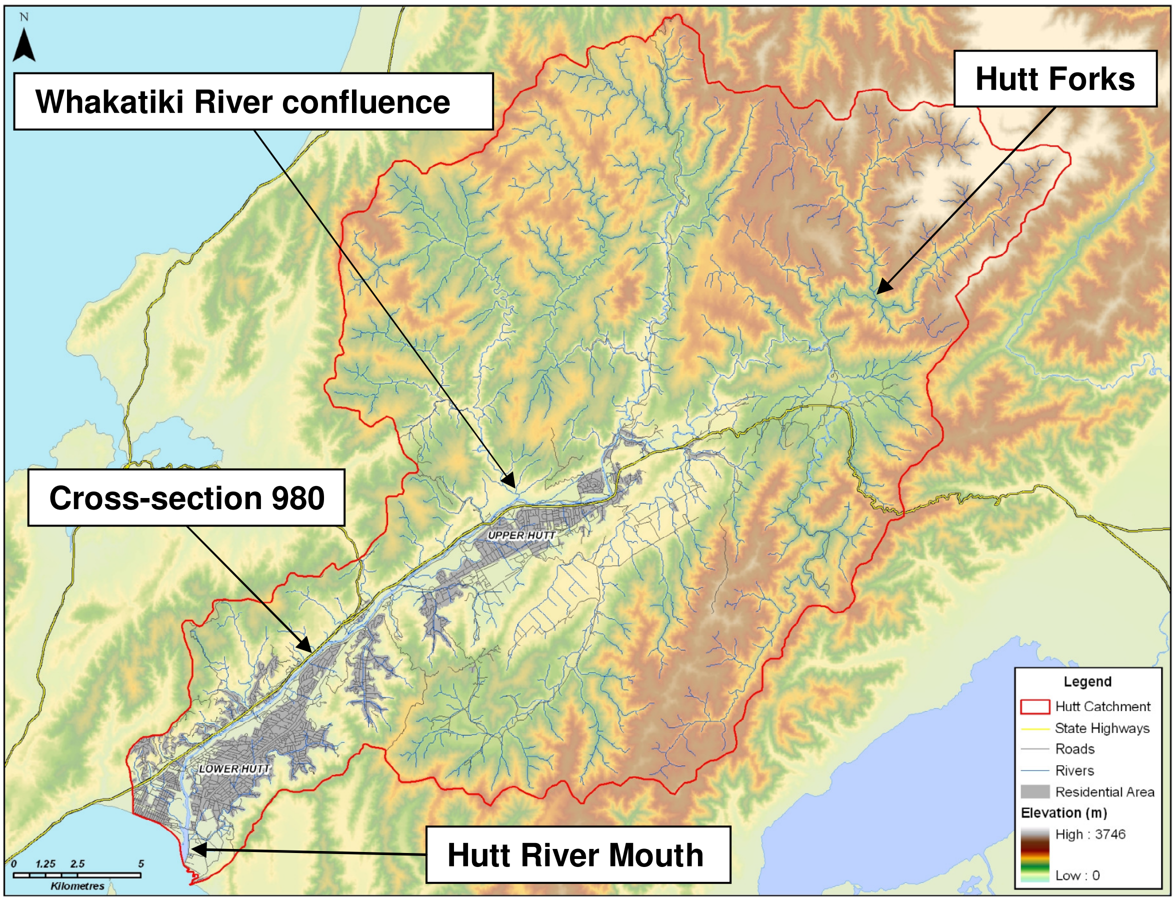

Figure 1.1: Hutt River catchment.

2 Available data

2.1 Cross-section survey data

The Greater Wellington Regional Council (GWRC) regularly surveys cross-sections at 313 locations along the lower 33.5km of the Hutt River. The data from these surveys are used to analyse trends in gravel bed material movement, and bed aggradation and degradation along the river. The results of this analysis are used to guide policy on gravel extraction and general river management.

The last five surveys were carried out in 1987, 1993, 1998, 2004 and 2009. Given the number of river cross-sections to be surveyed, each survey took a number of months to complete. Table 2.1 notes the period of each survey that has been assumed for the analysis in this report, and also the companion report on sediment transport processes in the river (Opus, 2010a).

Table 2.1: Assumed survey dates.

Survey year	Survey period	Assumed survey end date
1987-1989	May-September 1987 (mouth to Silverstream Bridges) October to December 1988 (Silverstream Bridges to Birchville Gorge) August to September 1989 (Birchville Gorge to Hutt Gorge)	1 Sept1987
1993	April-August 1993	1 August 1993
1998	January-April 1998	1 April 1998
2004	December 2003-April 2004	1 April 2004
2009	September 2008-April 2009	1 April 2009

Gardner (2010) used the data from these cross-section surveys to calculate the changes in gravel bed material volumes along the Hutt River. These calculations cover the river upstream of cross-section 30. This cross-section is coincident with the end of Winstone Aggregates Ltd sand mining plant sited on the right bank of the river mouth (refer to aerial photographs in Appendix A). The calculations exclude a 660m long reach between cross-sections 1 and 30 (cross-section 1 is coincident with the end of the Seaview reclamation along the left bank of the Hutt River mouth). Sediment deposition occurs over this reach and is actively mined by Winstones. Bed level changes over this reach are discussed in Opus (2010b).

The changes in bed material volumes calculated by Gardner (2010) do not differentiate between changes in volume caused by bed aggradation, and those caused by bank erosion. However, the latter component is likely to be very minor compared to the former except where significant bank erosion has occurred.

2.2 Gravel extraction data

Over time large quantities of sediment have been extracted from the Hutt River mouth, and at various locations further upstream. GWRC has recorded the quantities of sediment extracted from specific reaches of the Hutt River (refer to gravel extraction volume table in Appendix B). For the purposes of this analysis, it has been assumed that the extraction within each reach is approximately uniform along the length of that reach.

2.3 Characteristics of sediment extracted at the river mouth

Unfortunately no information is available on the composition of the sediment extracted from the river mouth (between the Hutt Estuary Bridge and the end of the Seaview reclamation along the left bank). This is where finer sediment transported by the river is expected to be deposited. However, information is available on the composition of the reject material (Corporate and Environmental Research, 1998). This information can be used to infer details of the composition of the raw sediment extracted from the river mouth.

The Corporate and Environmental Research (CER) report refers to measurements of the reject fraction by Winstones over a four month period in 1998. These averaged approximately:

- 37% pebbles and cobbles (grain size >5mm) plus some sand; and

- 63% silty material (grain size <75µm).

In March 1996, Materials Advisory and Testing Services took two random samples from the reject sediment piles. They determined the following material composition:

- 18% and 21% cobbles and stones (assumed to be grain sizes >19mm);
- 34% and 28% sand and granules (assumed to be grain sizes 75µm to 19mm); and
- 45% and 51% silt (assumed to be grain sizes <75µm).

There appeared to be some variability between the two sources of grain size measurements. However, the Winstones measurements over a period of time were considered by CER to be most representative of the average composition of sediment in the reject stockpile.

The total volume of reject material stockpiled between July 1993 and January 1998 was approximately 64,400m^3. The total volume of material extracted from the river mouth over the period 1 August 1993 to March 1998 was approximately 220,200m^3 (Gardner, 2010). If the small differences between these two periods are ignored, then it is possible to infer an estimated composition of the raw sediment deposited in the sediment mining zone and the river mouth (Table 2.2).

Table 2.2: Estimated size fractions of raw sediment material deposited in the Hutt River mouth mining zone.

Size	Volume (m^3)	Fraction (%)
Pebbles and cobbles (grain size 5mm and above)	23,800	11
Sand (grain size 75 microns to 5mm)	155,800	71
Silt (grain size 75 microns and smaller)	40,600	18
Total	220,200	100

Table 2.2 shows that the bulk of sediment deposited at the river mouth is sand-sized.

3 Definition of aggradation reach

To assess the sediment balance of the river, it is first necessary to define a control volume within which the bed of the river is showing a continual aggrading trend (Figure 3.1). The sediment balance is then given by the equation:

Sediment input volume = volume of sediment aggradation + volume of mined sediment

In this report the volume of sediment aggradation is estimated from the river cross-section data analysis (Gardner, 2010). The volume of mined sediment has been obtained from sediment extraction records. In applying the above equation, the assumption is that the wash load fraction (clay material in suspension) is transported right through the control volume and is not deposited. It is possibly even flushed right out of the harbour.

The sediment input volume in the above equation has been independently estimated from sediment transport rating relationships using the flow record from Taita Gorge (Opus, 2010a).

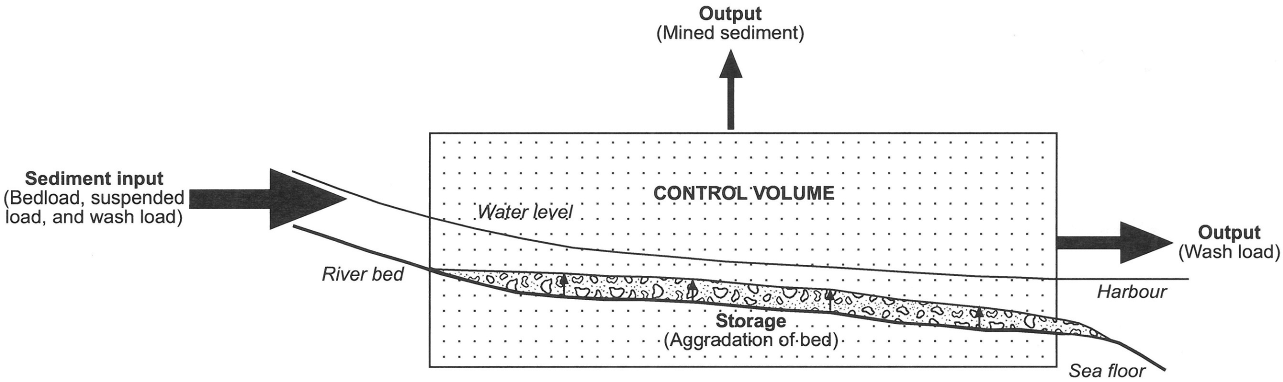

Figure 3.1: Control volume for sediment balance in the lower reaches of the Hutt River.

The Hutt River mouth forms the downstream boundary of the control volume shown in Figure 3.1. The upstream boundary needs to be at a location such that the change in sediment volume over time is close to zero. Furthermore, the upstream boundary needs to be at a location downstream of the Whakatiki River. This is the last major tributary entering the Hutt River contributing significant volumes of flow and sediment.

Figure 3.2 shows the change in sediment volume over time along the Hutt River downstream of the Silverstream Bridges. It can be seen that there has been a general degradational trend over time between the Silverstream Bridges and just downstream of Taita Rocks. There has been a general aggradational trend from just downstream of Taita Rocks to the river mouth. Cross-section 980 has changed only very slightly over time. This location therefore marks the transition from upstream degradation to downstream aggradation of the river bed. Cross-section 980 (located 10.09km upstream of cross-section 30 at the river mouth) has consequently been chosen as the upstream boundary of the volume control shown in Figure 3.1 (refer to aerial photographs in Appendix A for location of cross-section 980).

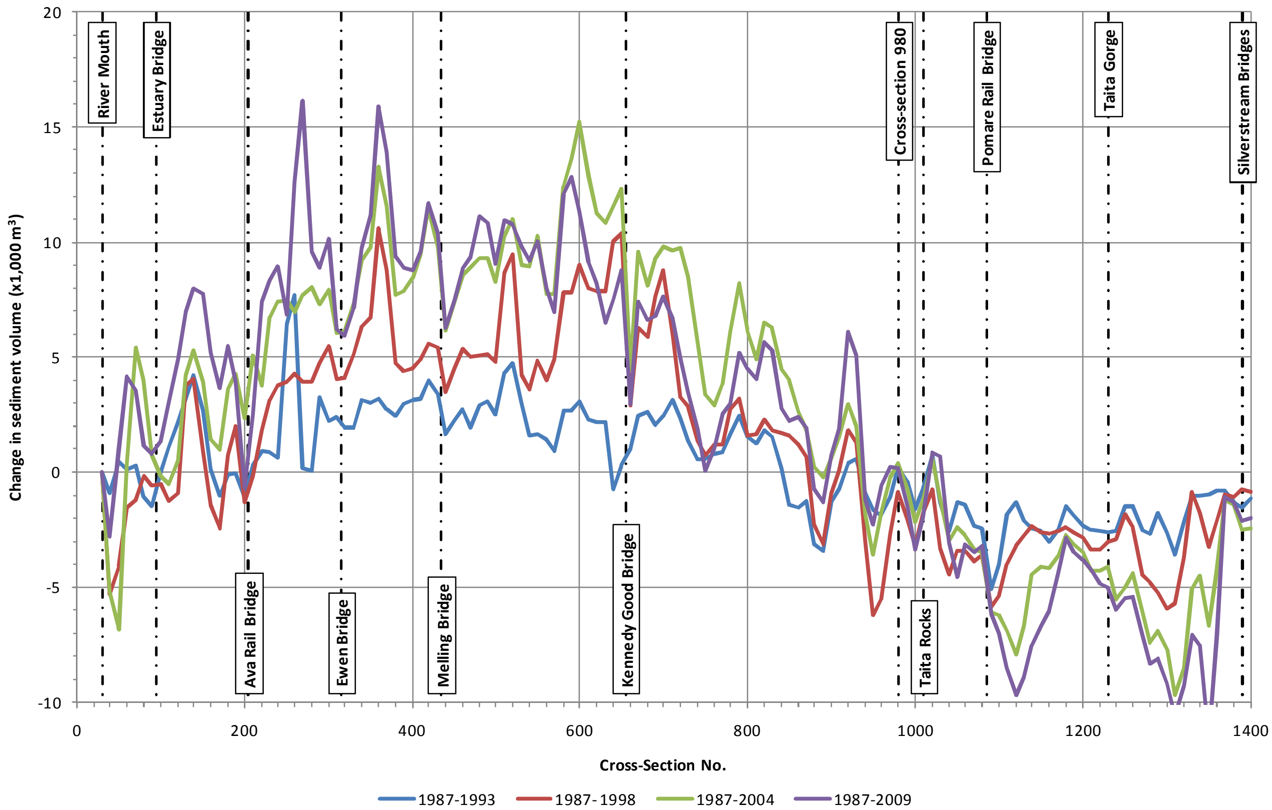

Figure 3.2: Change in sediment volume over time along Hutt River between the Silverstream Bridges and the river mouth.

4 Sediment balance

4.1 Introduction

As outlined in Section 3, the sediment balance of the selected control volume in Figure 3.1 consists of three items:

1. Volume of sediment aggradation of river bed;
2. Volume of extracted (mined) sediment; and
3. Sediment input volume (from natural sediment transport processes).

The first item can be determined from the changes in gravel volume reported by Gardner (2010). The second item is obtained from sediment extraction records provided by GWRC. The third item is the sum of the first two.

4.2 Sediment aggradation of the river bed

From the data shown in Figure 3.2, it is possible to derive a cumulative sediment change curve[2] for each inter-survey period. Plotting the raw data in this manner highlighted problems with a number of data points. These indicated excessive and unrealistic sediment volume changes over time. These were traced to:

- Cross-sections not being surveyed (cross-section 620 in both the 1987 and 1993 surveys);
- The change in cross-sectional area used to calculate the sediment volume change being affected by significant bank erosion (cross-section 830 and 840 in the 2004 and 2009 surveys); and
- The effects of channel realignment (in the Ewen Floodway project which affected cross-sections 320-340 in the 1993-1998 inter-survey period; and the Ava to Ewen realignment project in 2005 which affected cross-sections 230 and 240 in the 2004-2009 inter-survey period)

After adjusting the raw data to eliminate the effects of these influences, cumulative sediment volume change curves were produced for each inter-survey period (Figure 4.1).

The curves start at cross-section 980 (distance 0km) and terminate at cross-section 30 (distance 10.09km). This downstream limit is co-incident with the tip of the right bank point on which Winstone's sand mining plant is located. A positive slope with increasing downstream distance on these curves is indicative of aggradation of the bed while a negative slope is indicative of degradation.

Figure 4.1 shows that in general the bed over this section of the Hutt River has been aggrading over time. In the 2004-2009 inter-survey period there has been a degradational trend over the reach between 1km and 4km downstream of cross-section 980 (upstream and downstream of the Kennedy-Good Bridge). Further downstream the aggradation trend is re-established. The largest net increase in sediment aggradation occurred over the 1998-2004 inter-survey period. This is likely related to the number of significant flood events over that period.

Appendix C provides a tabulation of the cumulative sediment volumes downstream of cross-section 980 as follows:

- Raw data, as supplied by GWRC;
- Data corrected for the effects of missing cross-section information, and large scale bank erosion; and
- Data with the effects of river realignment eliminated.

[2] A cumulative sediment change curve is obtained by summing the change in sediment volume over distance downstream. This type of curve highlights any inconsistencies in values of sediment volume change.

Table 4.1 summarises the net aggradation volumes between cross-section 980 (just downstream of Taita Rock) and cross-section 30 (at the river mouth). These net aggradation volumes exclude any sediment deposited between the tip of Winstone's sand mining plant (cross-section 30) and the end of the Seaview reclamation (cross-section 1). This area is included within permitted sand mining zone (refer to aerial photographs in Appendix A). Analysis of bed level changes over this reach is presented in Opus (2010b).

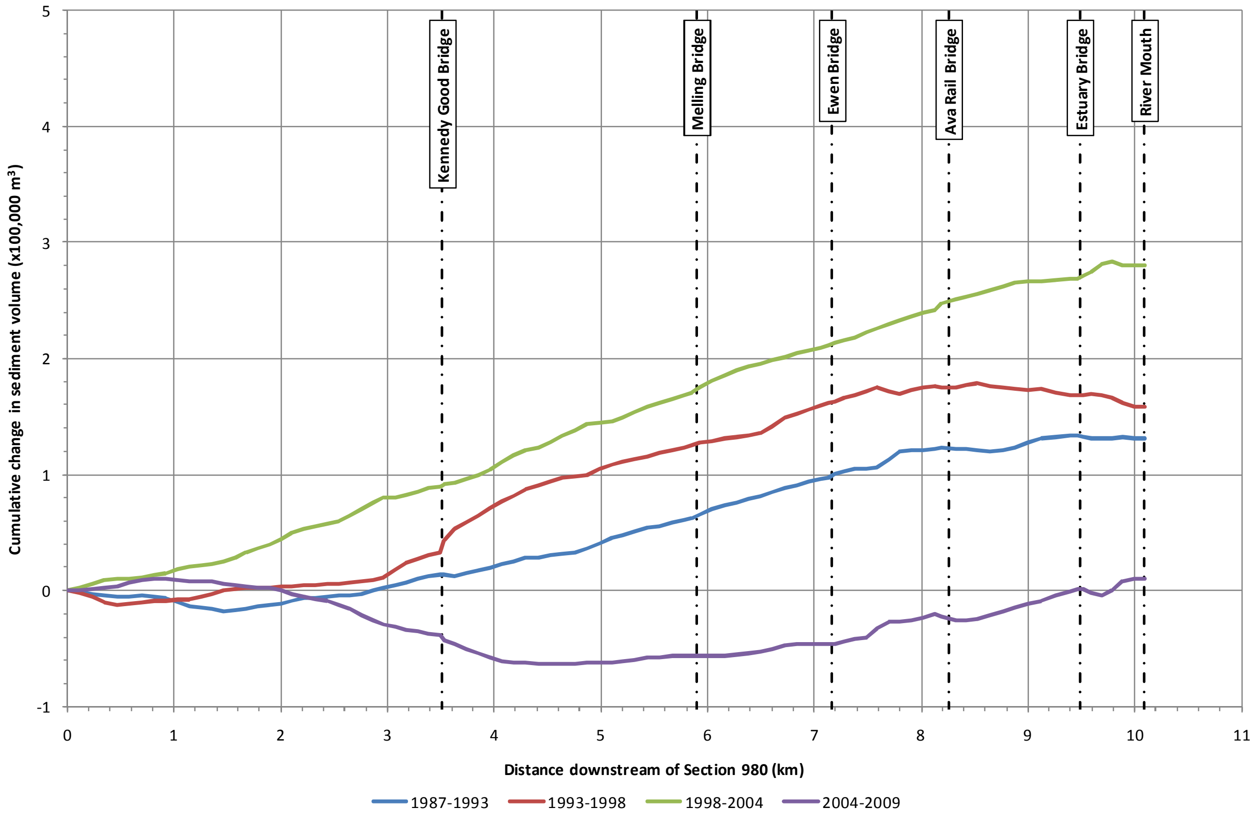

Figure 4.1: Cumulative change in sediment volume in Hutt River downstream of cross-section 980 for each inter-survey period from 1987-2009.

Table 4.1: Net sediment aggradational volumes downstream of cross-section 980.

Inter-survey period	Build-up (m^3)
1 Sep 1987- 31 Jul1993	131,300
1 Aug 1993 – 31 Mar 1998	156,600
1 Apr 1998 – 31 Mar 2004	282,000
1 Apr 2004 – 31 Mar 2009	9,800
Total (1 Sep 1987-31 Mar 2009)	579,700

4.3 Sediment extraction

Data obtained from GWRC (refer Table 4.2 and Figure 4.2) show that between 1987 and 2009 sediment was extracted at the river mouth and upstream of cross-section 210 (situated at the Ava Rail Bridge). The annualised sediment extraction returns have been adjusted to match the periods between cross-section surveys.

It should be noted that the sediment material extracted upstream of cross-section 210 is predominantly gravel. That extracted at the river mouth is predominantly sand and silt.

The extraction volumes for the river mouth include sediment material extracted between Winstone's sand mining plant and the end of the Seaview reclamation.

The data in Table 4.2 and Figure 4.2 show that extraction volumes at the river mouth have been relatively constant. However, the extraction volumes upstream of the river mouth have varied both in amount and in location. Between 1992 and 2000 the extraction of gravel material from the river upstream of the mouth was suspended to allow the river to recover. In the 2004-2009 inter-survey period the extraction volume upstream of the river mouth increased significantly.

Table 4.2: Sediment extraction volumes from the Hutt River between 1987 and 2009.

<table>
<tr><th rowspan="2">Inter-survey Period</th><th colspan="7">Extraction Volumes in Reaches (m^3)</th></tr>
<tr><th>River Mouth</th><th>90-210</th><th>210-320</th><th>320-660</th><th>660-800</th><th>800-980</th><th>Total</th></tr>
<tr><td>1 Sep 1987- 31 Jul1993</td><td>279,255</td><td></td><td colspan="2">32,331</td><td colspan="2">27,955</td><td>342,298</td></tr>
<tr><td>1 Aug 1993 – 31 Mar 1998</td><td>220,205</td><td></td><td></td><td></td><td></td><td></td><td>220,205</td></tr>
<tr><td>1 Apr 1998 – 31 Mar 2004</td><td>263,213</td><td></td><td colspan="3">46,656</td><td></td><td>309,869</td></tr>
<tr><td>1 Apr 2004 – 31 Mar 2009</td><td>220,132</td><td></td><td colspan="3">226,042</td><td></td><td>446,174</td></tr>
<tr><td>1 Sep 1987-31 Mar 2009</td><td>982,805</td><td></td><td colspan="4">332,983</td><td>1,318,546</td></tr>
</table>

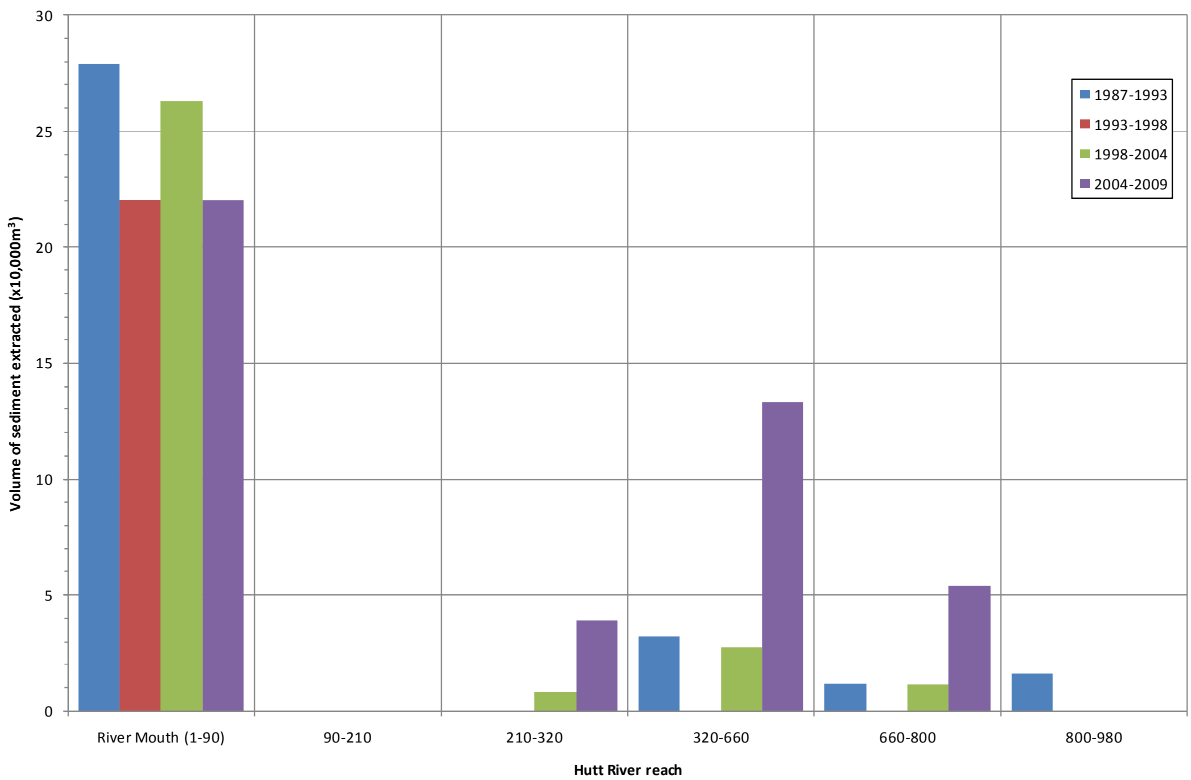

Figure 4.2: Sediment extraction volumes from Hutt River between 1987 and 2009.

4.4 Sediment input from upstream

The sediment input from upstream into the selected control volume is the sum of the net aggradation volume over the reach, together with the extraction volume from within the reach. The results are summarised in Table 4.3 and in Figure 4.3.

Table 4.3: Sediment balance for selected control volume.

Component	Sediment volume (m³)				
	1987-1993	1993-1998	1998-2004	2004-2009	1987-2009
Net aggradation	131,307	156,645	281,955	9,766	579,673
Extraction - River - Mouth	 60,286 279,255	 0 220,205	 46,656 263,213	 226,042 220,132	 332,983 982,805
Input	470,848	376,850	591,824	455,940	1,895,462

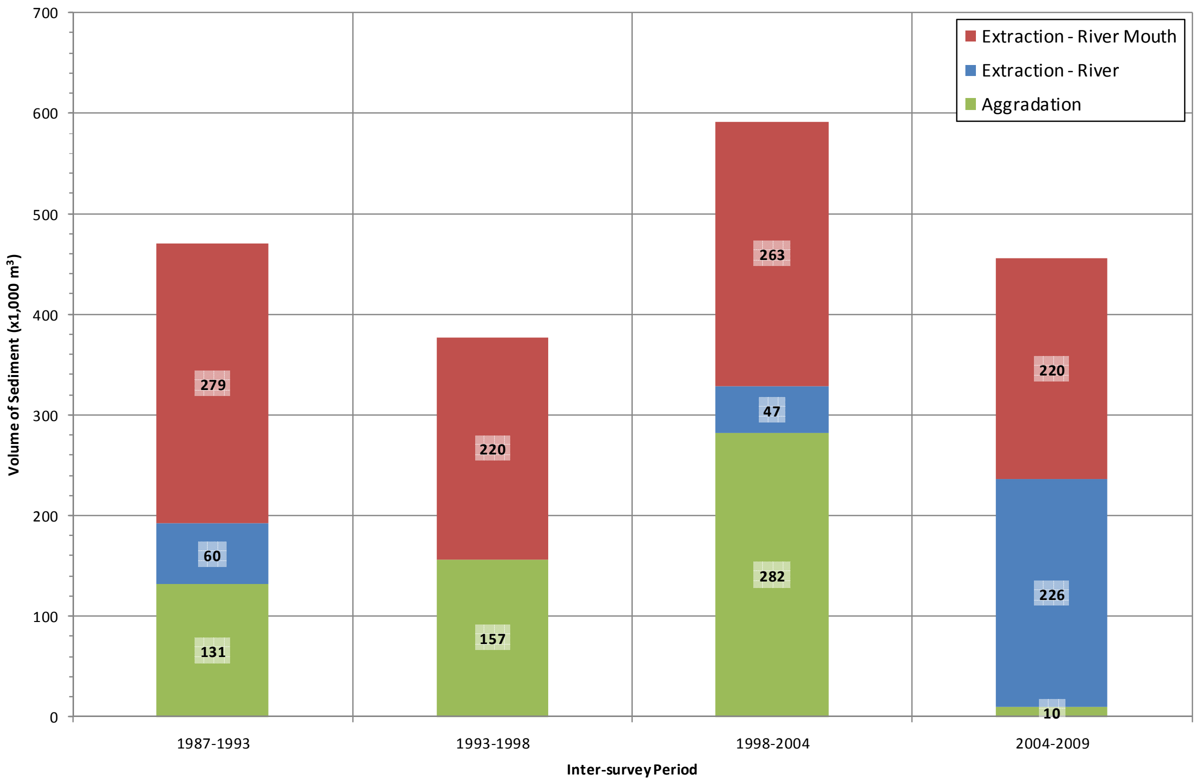

Figure 4.3: Sediment balance for selected control volume.

As the inter-survey periods are of differing lengths, it is more consistent to look at the data in terms of average annual volume over each period. These values are summarised in Table 4.4 and Figure 4.4.

Table 4.4: Average annual sediment balance for control volume.

Component	Sediment volume (m^3/year)				
	1987-1993	1993-1998	1998-2004	2004-2009	1987-2009
Net aggradation	22,204	33,596	47,003	1,955	26,862
Extraction - River - Mouth	 10,194 47,221	 0 47,228	 7,778 43,879	 45,239 44,056	 15,430 45,543
Input	79,619	80,825	98,660	91,250	87,835

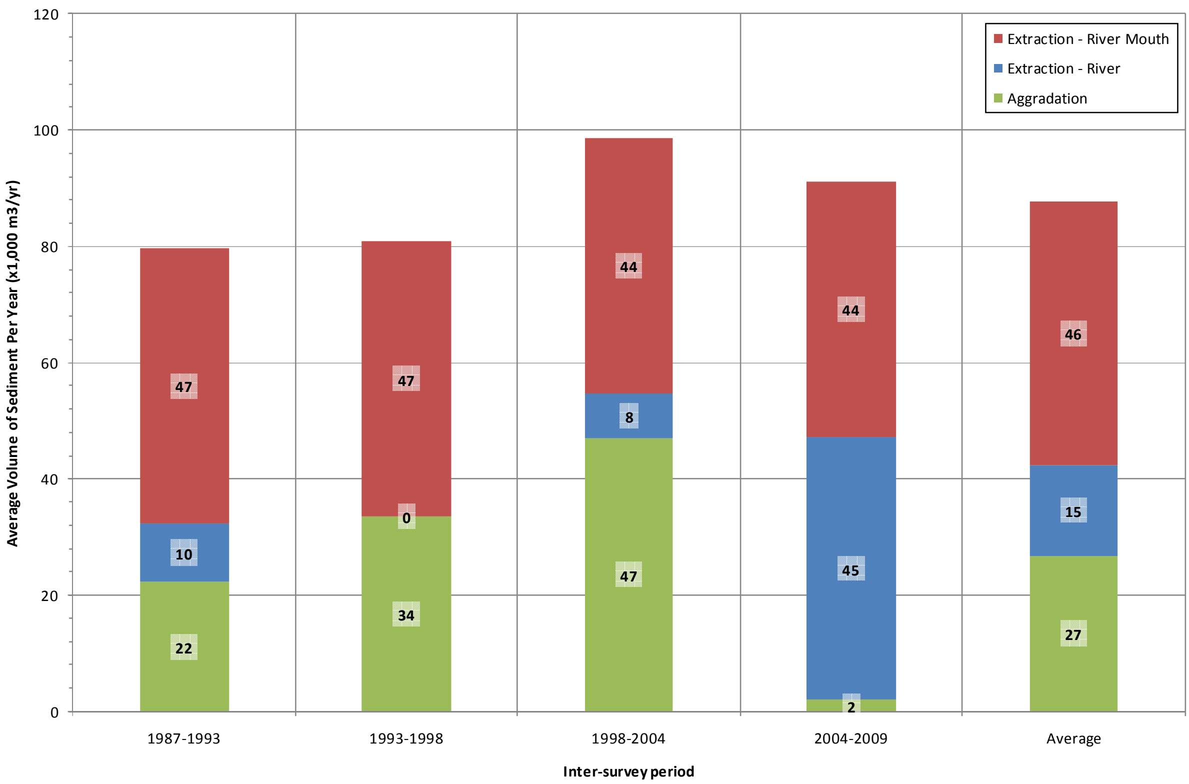

Figure 4.4: Average annual sediment input into control volume.

Table 4.4 and Figure 4.4 show that the annual input of sediment from upstream was relatively constant over the first two inter-survey periods i.e., between 1987 and 1998. The input of sediment was highest over the 1998-2004 inter-survey period. The annual sediment input to the control volume reflects the amount of flood activity. Opus (2010a) evaluates the sediment input (suspended load and bedload) using sediment transport rating relationships, and compares this to the sediment input volumes evaluated in this report. The results of Opus (2010a) are consistent with the current findings.

The average annual sediment input over the period 1987-2009 is estimated to be approximately 87,800m^3/year. This is likely to be a slight under-estimate as it excludes any allowance for sediment aggradation in the 660m long reach between cross-sections 1 and 30 (from the top of Winstone's sand mining plant to the Seaview reclamation).

5 Conclusion

Summation of the net aggradation and sediment extraction volumes in the lower Hutt River yields an average annual sediment input between 1987 and 2009 of approximately 87,800m³/year. This result is less than, but consistent with, the volume presented in Opus (2010a). The conservative nature of the current estimate is for the reasons outlined in Opus (2010a) i.e., wash load contribution, and material deposited beyond the river mouth.

6 References

Corporate and Environmental Research Ltd (1998). *Options report, reuse and disposal of by-products, Hutt River mouth dredgings*. Report prepared for Greater Wellington Regional Council, July 1998.

Gardner, M (2010), *Hutt River floodplain management plan – Hutt River Gravel Analysis 1987 -2009*, Greater Wellington Regional Council Report, Reference N/03/09/05, June 2010.

Hutt City Council (1998). *Hutt estuary bridge scour protection, Contract No. AD 16-2746, Contract Documents*. December 1998.

Opus, 2010a: *Hutt River Mouth: Fluvial sediment transport.* Report prepared for Greater Wellington Regional Council by Opus International Consultants Ltd. Reference 350861.00, September 2010.

Opus, 2010b: *Hutt River Mouth: Coastal sediment transport processes and beach dynamics.* Report prepared for Greater Wellington Regional Council by Opus International Consultants Ltd. Reference 350861.00, September 2010.

Appendix A – Aerial photographs showing cross-sections along Hutt River between Taita Rocks and river mouth

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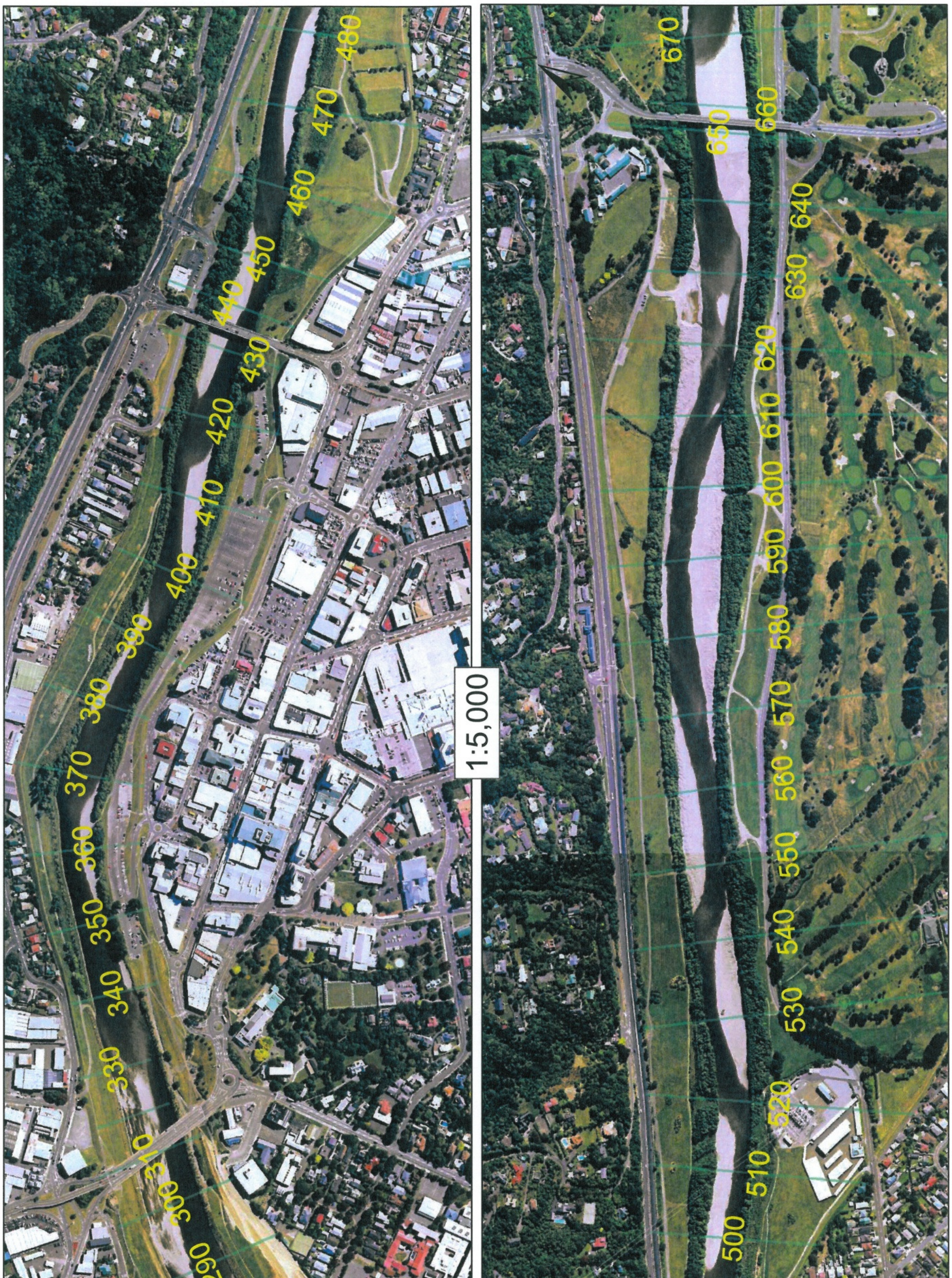
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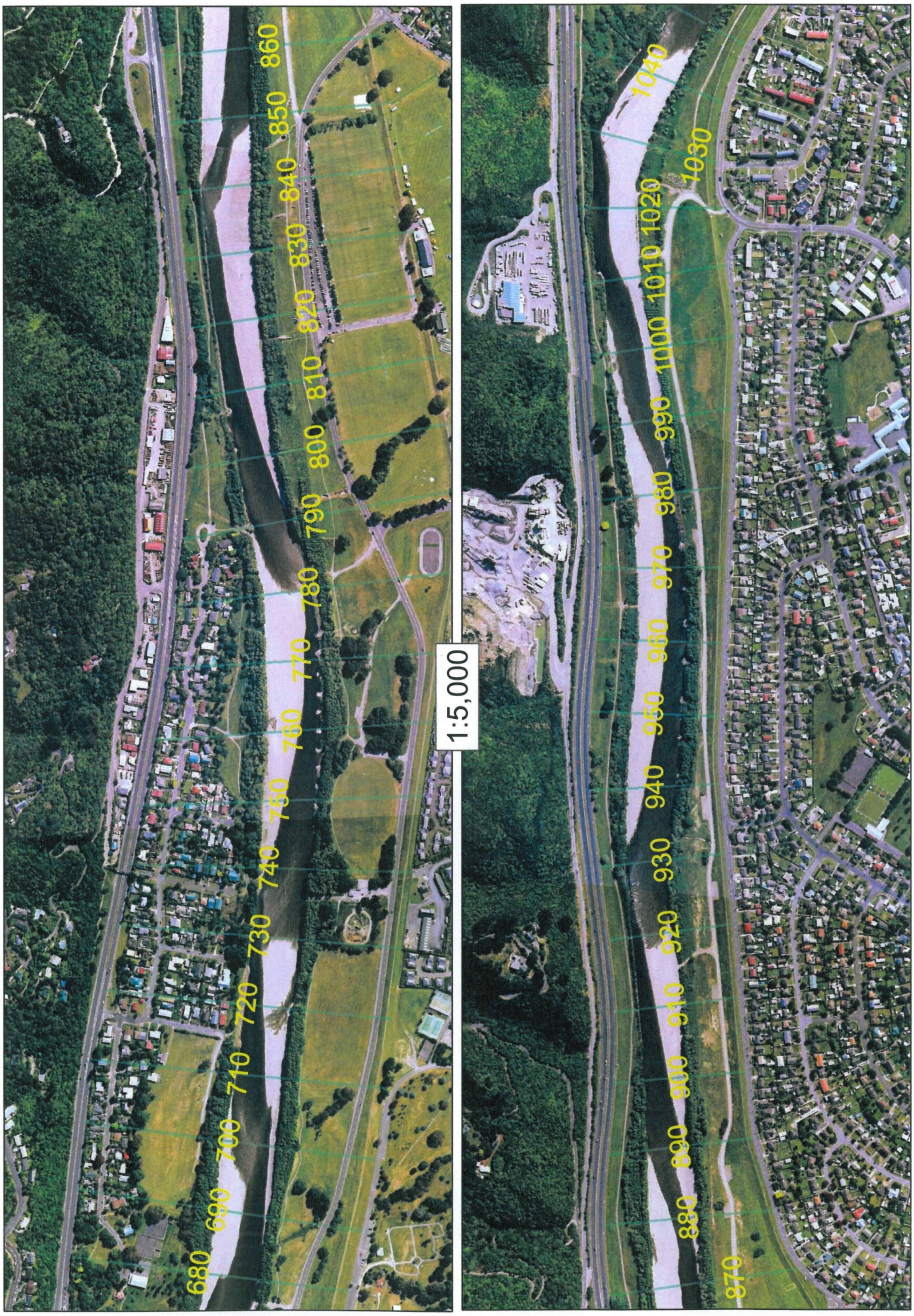
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Appendix B – Sediment extraction volumes from the Hutt River

<table>
<tr><th rowspan="2">Year</th><th colspan="6">Extraction Volumes in Reaches (m^3)</th></tr>
<tr><th>River Mouth</th><th>210-320</th><th>320-660</th><th>660-800</th><th>800-1010</th><th>Total</th></tr>
<tr><td>1987</td><td>37,000</td><td colspan="2">15,122</td><td colspan="2"></td><td>52,122</td></tr>
<tr><td>1988</td><td>46,000</td><td colspan="2">10,631</td><td colspan="2"></td><td>56,631</td></tr>
<tr><td>1989</td><td>51,000</td><td colspan="2">16,659</td><td colspan="2"></td><td>67,659</td></tr>
<tr><td>1990</td><td>54,000</td><td colspan="2">13.84</td><td colspan="2">24,328</td><td>78,342</td></tr>
<tr><td>1991</td><td>61,000</td><td></td><td></td><td colspan="2">6,384</td><td>67,384</td></tr>
<tr><td>1992</td><td>27,000</td><td></td><td></td><td></td><td></td><td>27,000</td></tr>
<tr><td>1993</td><td>48,000</td><td></td><td></td><td></td><td></td><td>48,000</td></tr>
<tr><td>1994</td><td>48,000</td><td></td><td></td><td></td><td></td><td>48,000</td></tr>
<tr><td>1995</td><td>51,968</td><td></td><td></td><td></td><td></td><td>51,968</td></tr>
<tr><td>1996</td><td>37,688</td><td></td><td></td><td></td><td></td><td>37,688</td></tr>
<tr><td>1997</td><td>48,069</td><td></td><td></td><td></td><td></td><td>48,069</td></tr>
<tr><td>1998</td><td>58,387</td><td></td><td></td><td></td><td></td><td>58,387</td></tr>
<tr><td>1999</td><td>41,966</td><td></td><td></td><td></td><td></td><td>41,966</td></tr>
<tr><td>2000</td><td>45,374</td><td></td><td></td><td></td><td></td><td>45,374</td></tr>
<tr><td>2001</td><td>41,664</td><td colspan="3">13,186</td><td></td><td>54,850</td></tr>
<tr><td>2002</td><td>39,816</td><td colspan="3">15,823</td><td></td><td>55,639</td></tr>
<tr><td>2003</td><td>39,102</td><td colspan="3">16,462</td><td></td><td>55,564</td></tr>
<tr><td>2004</td><td>45,486</td><td colspan="3">4,752</td><td></td><td>50,238</td></tr>
<tr><td>2005</td><td>51,240</td><td colspan="3">58,545</td><td></td><td>109,785</td></tr>
<tr><td>2006</td><td>44,734</td><td colspan="3">37,642</td><td></td><td>82,376</td></tr>
<tr><td>2007</td><td>39,445</td><td colspan="3">59,604</td><td></td><td>99,049</td></tr>
<tr><td>2008</td><td>41,650</td><td colspan="3">63,171</td><td></td><td>104,821</td></tr>
<tr><td>2009</td><td>36,064</td><td colspan="3">14,207</td><td></td><td>50,271</td></tr>
</table>

(Source: GWRC records)

Appendix C – Sediment aggradation volumes from cross-section 980 to river mouth

Changes in gravel volumes (m^3)

Raw data

Cross Section	1987-1993	1993-1998	1998-2004	2004-2009
980	170.0	-1021.9	1262.2	-252.4
970	-1081.6	-1579.1	2456.6	405.8
960	-1906.2	-3596.7	3712.0	1136.0
950	-1646.9	-4547.7	2576.5	1359.4
940	-906.5	-2119.3	1229.3	606.8
930	559.8	729.9	699.1	3065.5
920	371.0	1471.3	1120.9	3124.3
910	-725.3	760.7	1488.3	386.5
900	-1283.9	378.3	1521.3	136.0
890	-3418.0	290.2	2899.5	-1104.2
880	-3162.8	861.7	2520.2	-942.5
870	-1271.4	1929.7	1154.2	105.2
860	-1514.3	2713.0	1403.7	-188.6
850	-1452.4	3045.1	2406.5	-1787.9
840	189.3	1497.3	2826.5	-1703.0
830	1516.8	294.0	4458.5	-961.8
820	1841.6	425.0	4248.8	-896.2
810	1247.5	392.4	3261.1	-837.8
800	1561.6	61.9	4524.0	-1641.1
790	2478.2	733.8	4998.6	-3022.2
780	1669.5	1068.0	3349.6	-3140.3
770	848.0	363.6	2626.1	-1354.9
760	816.4	381.1	1707.5	-1854.8
750	563.5	204.8	2584.3	-3277.9
740	581.9	806.6	4267.2	-3747.6
730	1388.4	1442.7	5671.9	-5033.9
720	2318.7	917.2	6504.6	-4777.2
710	3132.8	2882.9	3594.8	-2948.2
700	2470.1	6306.8	1051.0	-2180.8
690	2061.8	5594.0	1611.4	-2472.2
680	2630.6	3260.6	2194.8	-1499.1
670	2431.5	3834.4	3329.6	-2208.0
660	1003.0	1882.5	1554.5	-1475.4
650	299.1	10085.0	1918.0	-3502.3
640	-745.1	10802.1	1523.8	-4041.4
630	4309.2	11461.8	2924.3	-4292.5
620			3390.5	-3060.3
610	2280.6	5677.7	4954.6	-3787.7
600	3055.0	5959.2	6206.9	-3896.1
590	5335.3	10334.8	5796.1	-818.6
580			4597.0	-322.0
570	920.2	3959.4	2896.1	-798.6
560	1415.8	2596.0	3756.2	194.3
550	1642.5	3208.5	5426.9	-267.0
540	1609.8	1976.3	5348.3	270.0
530	2957.5	1280.3	4792.4	770.4
520	4732.9	4725.4	1567.4	-226.7
510	4319.0	4323.7	1611.7	708.3
500	2526.1	2249.7	3464.2	849.8
490	3067.5	2078.3	4146.0	1547.8
480	2909.8	2164.2	4233.7	1817.8
470	1966.2	3071.4	3871.4	464.8
460	2711.4	2676.5	3143.3	317.4
450	2300.7	2229.5	2854.8	59.2
440	1653.7	1832.6	2674.5	86.0
430	3394.6	1997.5	4425.7	548.6
420	4018.6	1543.2	5918.9	189.5
410	3190.4	1734.1	4553.7	96.2
400	3158.5	1359.0	3927.5	365.1
390	2943.0	1429.7	3479.6	1067.6
380	2471.6	2276.4	2965.5	1626.3

Adjusted for gaps

Mike11 Chainage (m)	Distance	1987-1993	1993-1998	1998-2004	2004-2009
39705	0	170.0	-1021.9	1262.2	-252.4
39821	116	-1081.6	-1579.1	2456.6	405.8
39937	232	-1906.2	-3596.7	3712.0	1136.0
40053	348	-1646.9	-4547.7	2576.5	1359.4
40171	466	-906.5	-2119.3	1229.3	606.8
40287	582	559.8	729.9	699.1	3065.5
40402	697	371.0	1471.3	1120.9	3124.3
40516	811	-725.3	760.7	1488.3	386.5
40629	924	-1283.9	378.3	1521.3	136.0
40740	1035	-3418.0	290.2	2899.5	-1104.2
40853	1148	-3162.8	861.7	2520.2	-942.5
40958	1253	-1271.4	1929.7	1154.2	105.2
41064	1359	-1514.3	2713.0	1403.7	-188.6
41171	1466	-1452.4	3045.1	2406.5	-1787.9
41279	1574	189.3	1497.3	2826.5	-1703.0
41383	1678	1516.8	294.0	4458.5	-961.8
41490	1785	1841.6	425.0	4248.8	-896.2
41598	1893	1247.5	392.4	3261.1	-837.8
41705	2000	1561.6	61.9	4524.0	-1641.1
41811	2106	2478.2	733.8	4998.6	-3022.2
41921	2216	1669.5	1068.0	3349.6	-3140.3
42029	2324	848.0	363.6	2626.1	-1354.9
42139	2434	816.4	381.1	1707.5	-1854.8
42246	2541	563.5	204.8	2584.3	-3277.9
42352	2647	581.9	806.6	4267.2	-3747.6
42460	2755	1388.4	1442.7	5671.9	-5033.9
42568	2863	2318.7	917.2	6504.6	-4777.2
42676	2971	3132.8	2882.9	3594.8	-2948.2
42783	3078	2470.1	6306.8	1051.0	-2180.8
42885	3180	2061.8	5594.0	1611.4	-2472.2
42987	3282	2630.6	3260.6	2194.8	-1499.1
43086	3381	2431.5	3834.4	3329.6	-2208.0
43193	3488	1003.0	1882.5	1554.5	-1475.4
43233	3528	299.1	10085.0	1918.0	-3502.3
43337	3632	-745.1	10802.1	1523.8	-4041.4
43446	3741	2154.6	5730.9	2924.3	-4292.5
43555	3850	2154.6	5730.9	3390.5	-3060.3
43664	3959	2280.6	5677.7	4954.6	-3787.7
43771	4066	3055.0	5959.2	6206.9	-3896.1
43883	4178	2667.7	5167.4	5796.1	-818.6
43999	4294	2667.7	5167.4	4597.0	-322.0
44115	4410	920.2	3959.4	2896.1	-798.6
44229	4524	1415.8	2596.0	3756.2	194.3
44342	4637	1642.5	3208.5	5426.9	-267.0
44462	4757	1609.8	1976.3	5348.3	270.0
44577	4872	2957.5	1280.3	4792.4	770.4
44701	4996	4732.9	4725.4	1567.4	-226.7
44808	5103	4319.0	4323.7	1611.7	708.3
44908	5203	2526.1	2249.7	3464.2	849.8
45016	5311	3067.5	2078.3	4146.0	1547.8
45138	5433	2909.8	2164.2	4233.7	1817.8
45253	5548	1966.2	3071.4	3871.4	464.8
45373	5668	2711.4	2676.5	3143.3	317.4
45485	5780	2300.7	2229.5	2854.8	59.2
45565	5860	1653.7	1832.6	2674.5	86.0
45633	5928	3394.6	1997.5	4425.7	548.6
45741	6036	4018.6	1543.2	5918.9	189.5
45862	6157	3190.4	1734.1	4553.7	96.2
45978	6273	3158.5	1359.0	3927.5	365.1
46091	6386	2943.0	1429.7	3479.6	1067.6
46202	6497	2471.6	2276.4	2965.5	1626.3

Adjusted for realignments in 1993-98 and 2004-09

Distance	1987-1993	1993-1998	1998-2004	2004-2009
0	170.0	-1021.9	1262.2	-252.4
116	-1081.6	-1579.1	2456.6	405.8
232	-1906.2	-3596.7	3712.0	1136.0
348	-1646.9	-4547.7	2576.5	1359.4
466	-906.5	-2119.3	1229.3	606.8
582	559.8	729.9	699.1	3065.5
697	371.0	1471.3	1120.9	3124.3
811	-725.3	760.7	1488.3	386.5
924	-1283.9	378.3	1521.3	136.0
1035	-3418.0	290.2	2899.5	-1104.2
1148	-3162.8	861.7	2520.2	-942.5
1253	-1271.4	1929.7	1154.2	105.2
1359	-1514.3	2713.0	1403.7	-188.6
1466	-1452.4	3045.1	2406.5	-1787.9
1574	189.3	1497.3	2826.5	-1703.0
1678	1516.8	294.0	4458.5	-961.8
1785	1841.6	425.0	4248.8	-896.2
1893	1247.5	392.4	3261.1	-837.8
2000	1561.6	61.9	4524.0	-1641.1
2106	2478.2	733.8	4998.6	-3022.2
2216	1669.5	1068.0	3349.6	-3140.3
2324	848.0	363.6	2626.1	-1354.9
2434	816.4	381.1	1707.5	-1854.8
2541	563.5	204.8	2584.3	-3277.9
2647	581.9	806.6	4267.2	-3747.6
2755	1388.4	1442.7	5671.9	-5033.9
2863	2318.7	917.2	6504.6	-4777.2
2971	3132.8	2882.9	3594.8	-2948.2
3078	2470.1	6306.8	1051.0	-2180.8
3180	2061.8	5594.0	1611.4	-2472.2
3282	2630.6	3260.6	2194.8	-1499.1
3381	2431.5	3834.4	3329.6	-2208.0
3488	1003.0	1882.5	1554.5	-1475.4
3528	299.1	10085.0	1918.0	-3502.3
3632	-745.1	10802.1	1523.8	-4041.4
3741	2154.6	5730.9	2924.3	-4292.5
3850	2154.6	5730.9	3390.5	-3060.3
3959	2280.6	5677.7	4954.6	-3787.7
4066	3055.0	5959.2	6206.9	-3896.1
4178	2667.7	5167.4	5796.1	-818.6
4294	2667.7	5167.4	4597.0	-322.0
4410	920.2	3959.4	2896.1	-798.6
4524	1415.8	2596.0	3756.2	194.3
4637	1642.5	3208.5	5426.9	-267.0
4757	1609.8	1976.3	5348.3	270.0
4872	2957.5	1280.3	4792.4	770.4
4996	4732.9	4725.4	1567.4	-226.7
5103	4319.0	4323.7	1611.7	708.3
5203	2526.1	2249.7	3464.2	849.8
5311	3067.5	2078.3	4146.0	1547.8
5433	2909.8	2164.2	4233.7	1817.8
5548	1966.2	3071.4	3871.4	464.8
5668	2711.4	2676.5	3143.3	317.4
5780	2300.7	2229.5	2854.8	59.2
5860	1653.7	1832.6	2674.5	86.0
5928	3394.6	1997.5	4425.7	548.6
6036	4018.6	1543.2	5918.9	189.5
6157	3190.4	1734.1	4553.7	96.2
6273	3158.5	1359.0	3927.5	365.1
6386	2943.0	1429.7	3479.6	1067.6
6497	2471.6	2276.4	2965.5	1626.3

Cumulative over distance from xs 980

Distance	1987-1993	1993-1998	1998-2004	2004-2009
0	0.0	0.0	0.0	0.0
116	-1081.6	-1579.1	2456.6	405.8
232	-2987.8	-5175.8	6168.6	1541.8
348	-4634.7	-9723.5	8745.1	2901.2
466	-5541.2	-11842.8	9974.4	3508.0
582	-4981.4	-11112.9	10673.5	6573.5
697	-4610.4	-9641.6	11794.4	9697.8
811	-5335.7	-8880.9	13282.7	10084.3
924	-6619.6	-8502.6	14804.0	10220.3
1035	-10037.6	-8212.4	17703.5	9116.1
1148	-13200.4	-7350.7	20223.7	8173.6
1253	-14471.8	-5421.0	21377.9	8278.8
1359	-15986.1	-2708.0	22781.6	8090.2
1466	-17438.5	337.1	25188.1	6302.3
1574	-17249.2	1834.4	28014.6	4599.3
1678	-15732.4	2128.4	32473.1	3637.5
1785	-13890.8	2553.4	36721.9	2741.3
1893	-12643.3	2945.8	39983.0	1903.5
2000	-11081.7	3007.7	44507.0	262.4
2106	-8603.5	3741.5	49505.6	-2759.8
2216	-6934.0	4809.5	52855.2	-5900.1
2324	-6086.0	5173.1	55481.3	-7255.0
2434	-5269.6	5554.2	57188.8	-9109.8
2541	-4706.1	5759.0	59773.1	-12387.7
2647	-4124.2	6565.6	64040.3	-16135.3
2755	-2735.8	8008.3	69712.2	-21169.2
2863	-417.1	8925.5	76216.8	-25946.4
2971	2715.7	11808.4	79811.6	-28894.6
3078	5185.8	18115.2	80862.6	-31075.4
3180	7247.6	23709.2	82474.0	-33547.6
3282	9878.2	26969.8	84668.8	-35046.7
3381	12309.7	30804.2	87998.4	-37254.7
3488	13312.7	32686.7	89552.9	-38730.1
3528	13611.8	42771.7	91470.9	-42232.4
3632	12866.7	53573.8	92994.7	-46273.8
3741	15021.3	59304.7	95919.0	-50566.3
3850	17175.9	65035.6	99309.5	-53626.6
3959	19456.5	70713.3	104264.1	-57414.3
4066	22511.5	76672.5	110471.0	-61310.4
4178	25179.2	81839.9	116267.1	-62129.0
4294	27846.8	87007.3	120864.1	-62451.0
4410	28767.0	90966.7	123760.2	-63249.6
4524	30182.8	93562.7	127516.4	-63055.3
4637	31825.3	96771.2	132943.3	-63322.3
4757	33435.1	98747.5	138291.6	-63052.3
4872	36392.6	100027.8	143084.0	-62281.9
4996	41125.5	104753.2	144651.4	-62508.6
5103	45444.5	109076.9	146263.1	-61800.3
5203	47970.6	111326.6	149727.3	-60950.5
5311	51038.1	113404.9	153873.3	-59402.7
5433	53947.9	115569.1	158107.0	-57584.9
5548	55914.1	118640.5	161978.4	-57120.1
5668	58625.5	121317.0	165121.7	-56802.7
5780	60926.2	123546.5	167976.5	-56743.5
5860	62579.9	125379.1	170651.0	-56657.5
5928	65974.5	127376.6	175076.7	-56108.9
6036	69993.1	128919.8	180995.6	-55919.4
6157	73183.5	130653.9	185549.3	-55823.2
6273	76342.0	132012.9	189476.8	-55458.1
6386	79285.0	133442.6	192956.4	-54390.5
6497	81756.6	135719.0	195921.9	-52764.2

370	2748.6	6009.0	2793.7	2388.5		46314	**6609**	2748.6	6009.0	2793.7	2388.5		**6609**	2748.6	6009.0	2793.7	2388.5		**6609**	84505.2	141728.0	198715.6	-50375.7
360	3200.4	7412.5	2660.4	2657.1		46426	**6721**	3200.4	7412.5	2660.4	2657.1		**6721**	3200.4	7412.5	2660.4	2657.1		**6721**	87705.6	149140.5	201376.0	-47718.6
350	3031.9	3709.9	3046.5	1404.3		46540	**6835**	3031.9	3709.9	3046.5	1404.3		**6835**	3031.9	3709.9	3046.5	1404.3		**6835**	90737.5	152850.4	204422.5	-46314.3
340	3161.1	26549.1	2825.6	610.8		46650	**6945**	3161.1	26549.1	2825.6	610.8		**6945**	3161.1	3177.9	2825.6	610.8		**6945**	93898.6	156028.3	207248.1	-45703.5
330	1928.7	37828.0	2264.2	-235.3		46760	**7055**	1928.7	37828.0	2264.2	-235.3		**7055**	1928.7	3177.9	2264.2	-235.3		**7055**	95827.3	159206.2	209512.3	-45938.8
320	1924.6	18077.4	2024.7	-165.0		46835	**7130**	1924.6	18077.4	2024.7	-165.0		**7130**	1924.6	2166.8	2024.7	-165.0		**7130**	97751.9	161373.0	211537.0	-46103.8
310	2371.0	1666.1	2004.1	176.6		46901	**7196**	2371.0	1666.1	2004.1	176.6		**7196**	2371.0	1666.1	2004.1	176.6		**7196**	100122.9	163039.1	213541.1	-45927.2
300	2236.0	3257.1	2431.4	2253.4		46981	**7276**	2236.0	3257.1	2431.4	2253.4		**7276**	2236.0	3257.1	2431.4	2253.4		**7276**	102358.9	166296.2	215972.5	-43673.8
290	3238.4	1514.0	2528.9	1606.4		47085	**7380**	3238.4	1514.0	2528.9	1606.4		**7380**	3238.4	1514.0	2528.9	1606.4		**7380**	105597.3	167810.2	218501.4	-42067.4
280	64.8	3872.8	4077.2	1576.6		47191	**7486**	64.8	3872.8	4077.2	1576.6		**7486**	64.8	3872.8	4077.2	1576.6		**7486**	105662.1	171683.0	222578.6	-40490.8
270	162.0	3799.1	3743.2	8406.4		47295	**7590**	162.0	3799.1	3743.2	8406.4		**7590**	162.0	3799.1	3743.2	8406.4		**7590**	105824.1	175482.1	226321.8	-32084.4
260	7705.6	-3400.9	2663.5	5641.8		47399	**7694**	7705.6	-3400.9	2663.5	5641.8		**7694**	7705.6	-3400.9	2663.5	5641.8		**7694**	113529.7	172081.2	228985.3	-26442.6
250	6459.5	-2532.3	3533.6	-601.1		47501	**7796**	6459.5	-2532.3	3533.6	-601.1		**7796**	6459.5	-2532.3	3533.6	-601.1		**7796**	119989.2	169548.9	232518.9	-27043.7
240	627.2	3162.8	3619.7	21076.8		47612	**7907**	627.2	3162.8	3619.7	21076.8		**7907**	627.2	3162.8	3619.7	1541.8		**7907**	120616.4	172711.7	236138.6	-25501.9
230	830.0	2331.1	3568.6	23198.1		47726	**8021**	830.0	2331.1	3568.6	23198.1		**8021**	830.0	2331.1	3568.6	1583.5		**8021**	121446.4	175042.8	239707.2	-23918.5
220	910.8	888.4	1957.3	3637.6		47834	**8129**	910.8	888.4	1957.3	3637.6		**8129**	910.8	888.4	1957.3	3637.6		**8129**	122357.2	175931.2	241664.5	-20280.9
210	292.9	-479.2	5247.1	-2566.4		47899	**8194**	292.9	-479.2	5247.1	-2566.4		**8194**	292.9	-479.2	5247.1	-2566.4		**8194**	122650.1	175452.0	246911.6	-22847.3
200	-1080.2	-222.1	3631.7	-3000.5		48030	**8325**	-1080.2	-222.1	3631.7	-3000.5		**8325**	-1080.2	-222.1	3631.7	-3000.5		**8325**	121569.9	175229.9	250543.3	-25847.8
190	-48.9	2027.5	2293.0	-333.1		48124	**8419**	-48.9	2027.5	2293.0	-333.1		**8419**	-48.9	2027.5	2293.0	-333.1		**8419**	121521.0	177257.4	252836.3	-26180.9
180	-106.8	864.7	2849.4	1868.9		48229	**8524**	-106.8	864.7	2849.4	1868.9		**8524**	-106.8	864.7	2849.4	1868.9		**8524**	121414.2	178122.1	255685.7	-24312.0
170	-1040.6	-1411.5	3446.4	2673.7		48348	**8643**	-1040.6	-1411.5	3446.4	2673.7		**8643**	-1040.6	-1411.5	3446.4	2673.7		**8643**	120373.6	176710.6	259132.1	-21638.3
160	108.5	-1507.1	2823.9	3755.0		48468	**8763**	108.5	-1507.1	2823.9	3755.0		**8763**	108.5	-1507.1	2823.9	3755.0		**8763**	120482.1	175203.5	261956.0	-17883.3
150	2667.4	-1752.9	3033.9	3798.4		48586	**8881**	2667.4	-1752.9	3033.9	3798.4		**8881**	2667.4	-1752.9	3033.9	3798.4		**8881**	123149.5	173450.6	264989.9	-14084.9
140	4226.3	-196.7	1270.9	2668.9		48706	**9001**	4226.3	-196.7	1270.9	2668.9		**9001**	4226.3	-196.7	1270.9	2668.9		**9001**	127375.8	173253.9	266260.8	-11416.0
130	3192.4	570.7	477.3	2723.7		48827	**9122**	3192.4	570.7	477.3	2723.7		**9122**	3192.4	570.7	477.3	2723.7		**9122**	130568.2	173824.6	266738.1	-8692.2
120	2175.1	-3062.5	1411.6	4361.7		48964	**9259**	2175.1	-3062.5	1411.6	4361.7		**9259**	2175.1	-3062.5	1411.6	4361.7		**9259**	132743.3	170762.1	268149.7	-4330.5
110	1075.7	-2340.9	744.5	3482.6		49094	**9389**	1075.7	-2340.9	744.5	3482.6		**9389**	1075.7	-2340.9	744.5	3482.6		**9389**	133819.0	168421.2	268894.2	-847.9
100	19.8	-542.0	336.0	1562.1		49174	**9469**	19.8	-542.0	336.0	1562.1		**9469**	19.8	-542.0	336.0	1562.1		**9469**	133838.8	167879.2	269230.2	714.2
90	-1509.8	921.2	1326.5	57.7		49219	**9514**	-1509.8	921.2	1326.5	57.7		**9514**	-1509.8	921.2	1326.5	57.7		**9514**	132329.0	168800.4	270556.7	771.9
80	-1089.4	902.4	4176.1	-2871.8		49301	**9596**	-1089.4	902.4	4176.1	-2871.8		**9596**	-1089.4	902.4	4176.1	-2871.8		**9596**	131239.6	169702.8	274732.8	-2099.9
70	261.5	-1469.6	6609.1	-1858.9		49397	**9692**	261.5	-1469.6	6609.1	-1858.9		**9692**	261.5	-1469.6	6609.1	-1858.9		**9692**	131501.1	168233.2	281341.9	-3958.8
60	116.8	-1650.1	1940.2	3756.4		49497	**9792**	116.8	-1650.1	1940.2	3756.4		**9792**	116.8	-1650.1	1940.2	3756.4		**9792**	131617.9	166583.1	283282.1	-202.4
50	443.4	-4537.7	-2726.0	7831.4		49595	**9890**	443.4	-4537.7	-2726.0	7831.4		**9890**	443.4	-4537.7	-2726.0	7831.4		**9890**	132061.3	162045.4	280556.1	7629.0
40	-924.6	-4378.5	137.0	2389.5		49705	**10000**	-924.6	-4378.5	137.0	2389.5		**10000**	-924.6	-4378.5	137.0	2389.5		**10000**	131136.7	157666.9	280693.1	10018.5
30	0.0	0.0	0.0	0.0		49795	**10090**	0.0	0.0	0.0	0.0		**10090**	0.0	0.0	0.0	0.0		**10090**	131136.7	157666.9	280693.1	10018.5

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