22 August 2024

File Ref: OIAPR-1274023063-29560

Tim Costley
Member of Parliament for Ōtaki
By email: Tim.Costley@parliament.govt.nz

Tēnā koe Tim

Request for information 2024-172

I refer to your request for information dated 25 July 2024, which was received by Greater Wellington Regional Council (Greater Wellington) on 25 July 2024. You have requested the following:

"**Concern over Waikanae River Gravel Build Up**

I am writing to share with you concerns that I've heard from our local community.

I have been advised by multiple constituents of concerns around the build-up of gravel in the Waikanae River and Estuary.

As I understand, excess gravel used to be regularly removed by GWRC, but has not been done for some years. Our community are concerned, having witnessed flooding events in Wairoa that were reported as being exacerbated by gravel build-ups.

I would request:
• Information you have on gravel build-ups along the Waikanae River,
• Known dates over the last 20 years when gravel was removed,
• Any future plans to remove gravel.

I'd be grateful for any information you can share with me that I can communicate with our local community"

Greater Wellington's response follows:

Attachment 1 is a 2017 report that covers gravel build up in the Waikanae River (along with management recommendations) as well as **Attachment 2** 2022 Waikanae Channel Capacity Assessment.

Below is a table outlining known dates over the last 20 years when gravel was removed.

Table: Gravel extraction from Waikanae River (2004-2024)

	Waikanane River Reach					
Year	**Pukekawa/El Rancho**	**Greenaway Road to Jim Cooke Park**	**New Highway**	**above Jim Cooke Park**	**Otaihanga Tidal**	**Total per Year**
2004-2005	Locations not recorded					17488
2005-2006	Locations not recorded					10150
2006-2007	5,360	2250			1080	8,690
2007-2008	1,170	1,570				2,740
2008-2009		1690		874		2,564
2009-2010						0
2010-2011	1660			660		2,320
2011-2012						0
2012-2013						0
2013-2014						0
2014-2015						0
2015-2016						0
2016-2017	7821					7,821
2017-2018						0
2018-2019	1216	1140	1042			3,398
2019-2020						0
2020-2021						0
2021-2022						0
2022-2023	476					476
2023-2024						0
Totals (m3)	**17,703**	**6,650**	**1,042**	**1,534**	**1,080**	**55,647**

Regarding future plans to remove gravel, Greater Wellington is currently operating under an existing resource consent to undertake maintenance works in, and around, the Waikanae River. A new resource consent application was lodged approximately 10 years ago which included gravel extraction activities. Through conversations with Te Ātiawa ki Whakarongotai this application was put on hold and since then the operational work has been completed under the existing consent with continuance.

We are aware that the gravel accumulation in the lower reaches of the Waikanae River is impacting on the flood carrying capacity of the river. While this gravel accumulation has a minor (less that 5mm impact) on the flood levels for a flood with a 100-year ARI (or 1% AEP), it is possible that the gravel build-up has a more than minor effect on moderate flows.

To progress this issue, conversations have restarted between Greater Wellington, Kāpiti Coast District Council, the Department of Conservation and Te Ātiawa ki Whakarongotai. There was an onsite meeting on Friday 16 August 2024 to discuss the issue of flood risk, gravel extraction at the estuary, as well as the cutting of the river mouth.

Greater Wellington's preferred approach in the short term is to manage this reduced capacity in smaller flood events through gravel extraction from the riverbed near the Otaihanga Boat Club. In the longer term, a new resource consent is required to cover river management activities, and this needs to be done in a holistic way, working closely with Te Ātiawa ki Whakarongotai.

Following the meeting on Friday 16 August 2024, the next step is to establish whether immediate gravel extraction work can be carried out under the existing consent or whether a new consent is required. Once this is determined, next steps and timeframes can be confirmed.

We would be happy to keep you updated on this situation and can meet in person on-site to help you understand the issue if you would like.

If you have any concerns with the decision(s) referred to in this letter, you have the right to request an investigation and review by the Ombudsman under section 27(3) of the Local Government Official Information and Meetings Act 1987.

Please note that it is our policy to proactively release our responses to official information requests where appropriate. Our response to your request will be published shortly on Greater Wellington's website with your personal information removed.

Nāku iti noa, nā

Lian Butcher
Kaiwhakakahaere Matua Taiao | Group Manager Environment

Copied to:
Nigel Corry, Chief Executive, Greater Wellington Regional Council
Daran Ponter, Chair, Greater Wellington Regional Council
Penny Gaylor, Council Member, Greater Wellington Regional Council

Gravel Management Review & Recommendations

WAIKANAE RIVER

May 2017

Report Prepared by: Laddie Kuta
Gravel Strategy Secondment Engineer

For more information, contact the Greater Wellington Regional Council:

www.gw.govt.nz
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Executive Summary

This report summarises results from the Waikanae River gravel analysis based on the 2014 cross-section survey. The aim of the document is to provide planning recommendations for short and long-term operational management. This includes setting an annual gravel extraction rate to be implemented until the next scheduled monitoring/analysis, which is aligned with the natural behaviour of the river and flood/erosion control goals. The recommendations are based on the analytical results, a workshop and discussions held amongst key Flood Protection officers, and an understanding of the recent operations and practices carried out within the river.

All results and inputs are included in this report for reference, which makes for an extensive document. However, for quick reference the reader need only refer to pages 11-12 of this document for the final recommendations.

Contents

1.0 Purpose

The purpose of this report is to:

1. contrast the latest cross section survey (i.e. October 2014) with historical surveys to realise trends in gravel behaviour throughout the Waikanae River's monitored area;
2. summarise the gravel trends that are occurring within the various monitored reaches;
3. provide an understanding of the current overall gravel balance within the Waikanae River;
4. highlight any significant aggradation or degradation that is occurring within the river;
5. relate gravel trends to recent and historical operations to better understand the effects of river works and gravel extraction;
6. recommend gravel extraction targets that are in-line with the natural behaviour of the river and flood/erosion hazard mitigation; and
7. make note of any knowledge gaps and practices that should be addressed to progress the gravel management strategy for the Greater Wellington Region.

2.0 Background

The monitored area of the Waikanae River extends from the river mouth to a location immediately upstream of the water treatment plant – a distance of almost 7.5km.

As part of the Waikanae River's floodplain management plan[1] a series of 59 cross sections are positioned throughout the monitored area. For the most part these cross sections were originally surveyed as a complete set of sections in 1991 with successive surveys completed in 1995, 1999, 2004, 2010, and most recently in 2014. This report summarises a thorough analysis of all surveys from 1991 onward.

Cross section surveys have been undertaken prior to 1991, as far back as 1957; however, some of the locations of these surveyed sections and the completeness of the cross section set does not align with successive surveys, making comparisons of surveys earlier than 1991 difficult to contrast with the later surveys. Therefore, the 1991 survey is

[1] The current FMP for the Waikanae River referenced is 'The Community's Plan for the Waikanae River and its Environment – reprinted 2013 with addendum'.

considered the first complete survey for estimating natural sediment transport trends throughout the Waikanae River. Furthermore, the 1991 survey is considered a baseline for the floodway and therefore all Mean Bed Levels (MBLs) and volume estimates throughout this report are relative to that point in time.

The monitored area of the Waikanae River is further broken down into the six reaches illustrated below.

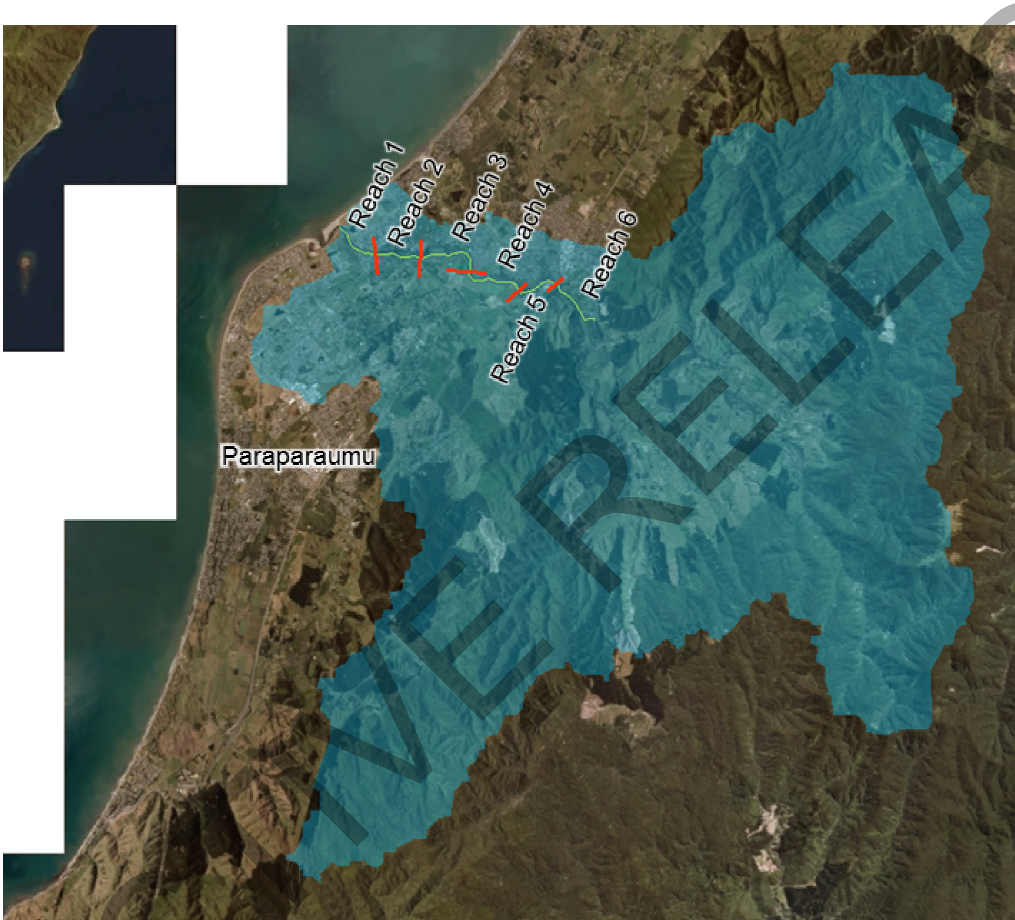


Figure 2.1 – Waikanae River Catchment and Monitored Reaches

Active Channel MBLs and gravel volumes have been estimated using the agreed methods set out in the GWRC document '*Discussion document on methods to determine mean bed levels and gravel volumes*' [2], which recommends a bottom-of-bank method for estimating each survey 'active channel' mean bed levels and an extent-of-channel-movement method for estimating the gravel volumes. All MBL and volume results have been calculated using Hilltop Hydro Version 6.55 software.

An additional criterion for assessing deposition and scour effects within the Waikanae River scheme is the proposed Design Bed Envelope (DBE). This parameter for the Waikanae River, which consists of an

[2] http://ourspace.gw.govt.nz/archive/env/fp/N 03/09/N-03-09-05/N-03-09-05-v9/Discussion document on methods to determine mean bed levels and gravel volumes [1306299].docx

upper and lower limit, was developed based on work by Gary Williams. The standardised development and use of DBEs as a management tool across all managed rivers in the region is still being assessed. The best way forward for this tool in terms of how it will be developed and used in gravel management across the entire region will be detailed further in the Greater Wellington gravel management strategy.

3.0 Summary of Results

A plot of long-sections for each survey's active channel MBLs (Appendix C) reveals an important point-of-inflection immediately downstream of the new expressway bridge, where the general grade of the river drops from approximately 1:275 on the upstream end down to a shallower 1:1500 on the coastal downstream end. Another less extreme grade change occurs upstream of Jim Cooke Park where the grade drops from approximately 1:175 throughout the upstream reaches down to the aforementioned 1:275. These locations of obvious grade change signal zones where changes in the gravel transport behaviour would be expected, and as expected is realised throughout the following results – especially around the downstream grade change.

3.1 Reach 1 – Otaihanga

The active channel MBLs in this reach have varied since 1991, with an overall upward trend between 0.10m and almost 0.5m since 1991. Effects from a gravel island downstream of the boating club are evident in the raised MBLs around *XS 040* and *XS 050*. The effects of cutting the mouth and the shifting nature of the sand tongue at the coast are reflected in the fluctuation of MBLs near *XS 010*.

As expected, the volume trend throughout this reach is reflective of the MBL trends. The volume of gravel in this reach has been building up since 1991, predominantly around the gravel island mentioned above and around a point-bar on the true-right bank across from the boating club. Volumes in these areas have increased by over 5,000m^3 between cross sections.

There have been minor extraction operations throughout this reach since 1991. Results indicate this reach has an overall natural tendency to aggrade at an estimated rate of approximately 1,900m^3/year when this extraction is accounted for.

3.2 Reach 2 – El Rancho

This reach is an aggrading reach of the scheme. Since 1991, localised MBLs have naturally come up by approximately 0.75m downstream of the foot bridge at *XS 090* as well as at the location of new expressway bridge (*XS 150*). Likewise, since 1991 an overall rise in MBLs throughout this reach has been within the range of 0.15m to 0.60m.

The build-up of material downstream of the Otaihanga Domain near *XS 090* is contributed to effects from the downstream point-bar mentioned in Section 3.1. Gravel build-up around El Rancho near *XS 130* and *XS 150* occurs in a section of the river where the active channel is most confined throughout the whole of the scheme. Widening of this section was suggested in the design by Gary Williams, but has not been completed. Widening the active channel at this location will have an effect on frequent flood conveyance; however, from a depositional point of view this location is still downstream of the first point-of-inflection and therefore will continue to naturally deposit gravels over time. Results also show that gravel has been building up downstream of the new expressway bridge prior to any of its construction; further exemplifying the deposition in this area is an effect of low bed-grade rather than recent channel changes related to the construction of the bridge.

The section-to-section volume increases for this reach have been between 800m^3 and 3,200m^3 since 1991. Overall this reach is naturally aggrading at a rate of approximately 1,500m^3/year.

3.3 Reach 3 – Kauri/Puriri

The MBLs within this reach reveal the effects of gravel extraction that occurred throughout the 2000s, as this reach has been the main focus of extraction operations.

Localised MBLs near the Equestrian & Vaulting Club have increased by almost 0.4m since 1991. Some localised areas indicate MBLs are lower than they were in 1991 even though this is an aggrading reach. This is due in part to the extraction efforts that have gone on within this reach but also a reflection of the transition in grade regime moving upstream of the first point-of-inflection. The point-bar on the true-left bank across from the Equestrian & Vaulting Club is a good location for future gravel extraction operations; however, it should be noted that operations at this location will not arrest gravel accumulations further downstream.

Section-to-section volume changes range from near equal to the 1991 volumes to localised increases of more than 3,000m^3; due in part to the targeted extraction zones. Overall, the natural trend in this reach is to deposit gravel at a rate of 1,900m^3/year.

3.4 Reach 4 – Jim Cooke Park

The effect of the steeper overall bed-grade and resulting change in sediment transport becomes apparent in this reach. MBLs have increased since 1991 near Jim Cooke Park where the meander takes a large sweeping bend towards the north. MBLs have increased around this location due to natural point-bar dynamics by almost 0.5m; however, upstream of this bend the MBLs have decreased by the same extent (i.e. -0.5m) below the 1991 levels. MBLs begin to increase at the upstream extent of this reach as a result of the grade control structure and its effects on raising bed levels.

Section-to-section volume changes in this reach vary with some minor localised build-up, but mostly the section-to-section volumes have reduced since 1991 by approximately 2,500m^3. Overall, this reach appears to be slightly losing gravel at a natural rate of approximately 300m^3/year.

3.5 Reach 5 – Below State Highway 1

The MBLs at the downstream extent of this reach are affected by the grade control structure and as such have increased since 1991 by more than 0.25m. Traveling upstream through this reach, the localised effects of the grade control structure disappear and the overall transport dynamics from the steeper bed-grade and erodible bed are reflected in the MBLs, which have decreased since 1991 by upwards of 1.0m.

Section-to-section volume changes vary since 1991 with localised decreases and increases of approximately -3,900m^3 and 2,800m^3, respectively. Overall, the natural gravel trend can be considered balanced with a slight tendency towards scour and losses of less than 200m^3/year.

3.6 Reach 6 – Above State Highway 1

The effect of the steep bed-grade and transportable material is reflected in the degradation of the bed throughout this reach in both the MBLs and estimated gravel volumes.

Localised MBLs have decreased since 1991 by more than 0.75m. The effects of the water treatment plant's instream structure, located at the upstream end of this reach, are reflected in the MBLs where localised build-up of gravel between 0.35m and 0.75m has occurred since 1991.

Section to section gravel volumes have generally decreased throughout this reach with a maximum section-to-section loss of just over 6,400m^3 since 1991. Overall, this reach is losing gravel at a rate of approximately 1,200m^3/year.

4.0 Gravel Balance

When trying to understand the gravel balance for the monitored area of the Waikanae River it is important to note that the gravel-input rate coming in from the high country upstream from the water treatment plant is an unknown. However, with the knowledge that negligible volumes of gravel leave the system through the mouth and by comparing surveys over time we can understand the average annual dynamics of gravel-transport occurring within each reach. Furthermore, summing these natural trend results for all reaches over the monitored time provides an indication of whether the monitored area as a whole is building-up or losing gravel.

4.1 Present-day Volume Balance

The monitored scheme extent of the Waikanae River appears to be accumulating gravel at a rate of approximately 3,700m^3 per annum. This 3,700m^3 per annum is a minimum rate of gravel scouring out of the bed and banks and coming into the system from high country sources upstream of the water treatment plant. Earlier studies carried out on the Waikanae River and the Ruamahanga River catchment suggest the volume of gravel contributed from the upper catchments is relatively low compared to the contribution from bed and bank erosion.

In addition to the measured data, there are a number of locations within the river that show obvious visual signs of gravel build-up over the years. One of these locations is near the Otaihanga Boating Club. An island of gravel tends to build up downstream of the boating club as illustrated in Figure 4.1.

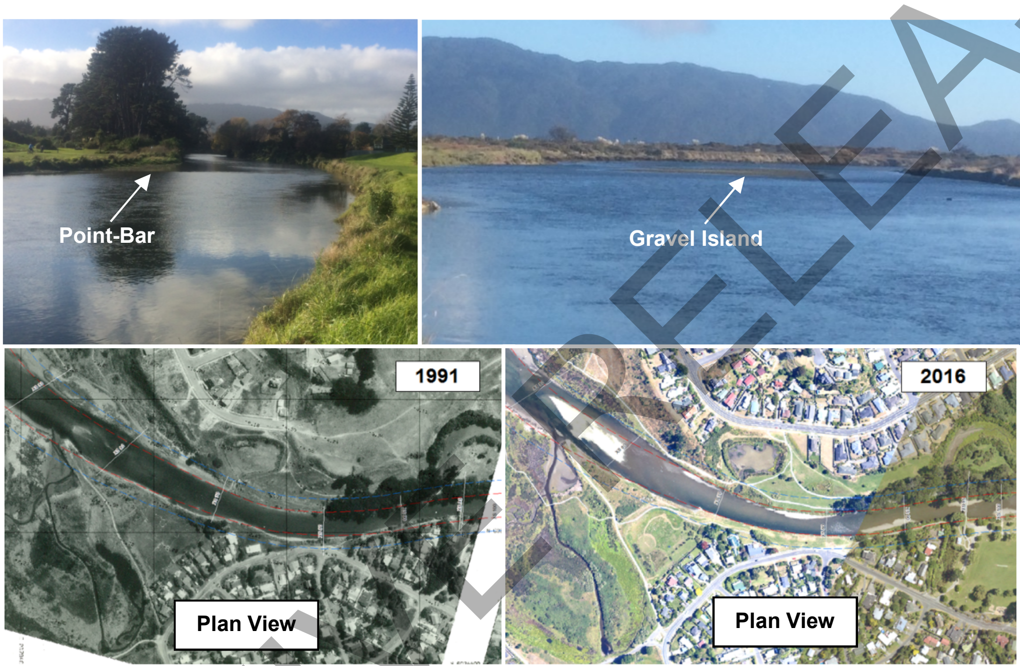


Figure 4.1 – Field Observation near Otaihanga Boating Club

The make-up of the gravel island's substratum is unknown and could potentially be an irregular geologic lens that prevents scour and induces build-up at this location. Further investigation would need to be carried out to determine this.

A point-bar on the true-right bank across from the boating club is also an area of aggradation and is also illustrated in the plan view over time in Figure 4.1.

Another location of observed gravel build-up is downstream of the new expressway bridge. This location is the most confined active-channel section of the entire scheme. It is also still downstream of the first point-of-inflection in the overall bed-grade. The combination of the confinement effects and the predominant shallow bed-grade effect makes this location susceptible to build up with gravel over time. Channel widening was designed throughout this reach by Gary Williams and has to date been partially completed.

It also should be noted that gravel was building up in this location prior to any changes made for the construction of the new expressway bridge – further exemplifying the import role the shallow bed-grade plays in gravel build-up in this location.

Figure 4.2 – Field Observation near New Expressway Bridge

In terms of operations, the true-left bank across from the equestrian and vaulting club has been subject to the greatest amount of extraction over the years. The inside of the long sweeping bend behaves in typical point-bar fashion with regard to gravel build-up and progress. Field observations in 2015, prior to an extraction operation, revealed the extent of gravel accumulation that occurs on the inside of this bend (Figure 4.3).

Figure 4.3 – Field Observation near Equestrian & Vaulting Club

It is believed the degrading bed in the upper reaches is a natural process but also related to the change in the floodway's meander and transport characteristics that occurred over time as the floodway evolved. At this time, it is not clear to what extent this is a natural process and to what extent it is a result of the river management regime.

The scour in the upstream reaches is not currently causing any significant issues; however, it is a trend that must be monitored and kept in mind moving forward as it could eventually lead to bank failures, additional gravels supplied to the lower reaches, and potential loss of hard river management works due to scour in the degrading reaches.

In attempt to sustainably balance gravel budgets throughout a managed floodway, gravel extraction should be avoided as a flood control measure in any reach that is known to be degrading. In relation to this approach on the Waikanae River, gravel should only be extracted from locations downstream of Jim Cooke Park. Works within the active channel, alternative to extraction, will need to be planned long-term in the degrading reaches in order to hold the design line, balance gravel budgets, and mitigate further incidents of bank erosion.

Table 4.1 – Gravel Balance and Estimated Sustainable Allocation for the Waikanae River

Mass Balance for All Reaches					
Reach			Trending Annual Rate (m^3/yr)	Surplus/Deficit since 1998 (m^3)	Surplus Volume only since 1998 (m^3)
1	Otaihanga Reach	XS10-XS80	1,941	29,140	29,140
2	El Rancho Reach	XS80-XS150	1,535	15,529	15,529
3	Kauri/Puriri Reach	XS150-XS260	1,888	13,603	13,603
4	Jim Cooke Park Reach	XS260-XS350	-305	-6,751	N/A
5	Below SH1 Reach	XS350-XS420	-179	-5,087	N/A
6	Above SH1 Reach	XS420-XS550	-1,192	-29,647	N/A
Balance for Entire Study Reach			**3,689**	**16,787**	**58,273**

Value 1 - Trending Downstream Aggradation Total (m^3/yr)	5,364	*i.e. this is the sum of the trending annual rates, or yearly build-up, downstream of Jim Cooke Park.*
Value 2 - Overall Gravel build-up since 1991 (m^3)	58,273	*i.e. this is the sum of the surplus gravels that have built up in the aggrading reaches downstream of Jim Cooke Park since 1991.*
Estimated Sustainable Extraction Rate	**5,300**	(i.e. Value 1 above rounded down to the nearest $100m^3$)

Since 1991 the loss of material from the upper reaches has contributed to a surplus of gravel in the lower reaches. A volume approaching $60,000m^3$ above the 1991 levels currently sits in surplus in the reaches downstream of Jim Cooke Park. This surplus volume is additional to the natural aggradation occurring on an annual basis. A graduated illustration of where this surplus gravel is located throughout the floodway is provided in Appendix I.

All estimated reach trends have been summed in Table-4.1 and the result indicates the entire floodway is building up material at a rate of approximately 3,700m^3/year, as mentioned earlier. However, annual trends for the aggrading reaches downstream of Jim Cooke Park have been summed up to arrive at a sustainable extraction rate of 5,300m^3/year as this extent of extraction will have negligible effects on the degradation happening in the upper reaches. This sustainable extraction rate is a minimum estimate as there is, as mentioned earlier, a large volume of gravel since 1991 sitting in storage downstream of Jim Cooke Park.

4.2 Previous Study Comparison

Cross section surveys and bed level analysis have been carried out prior to 1991; however, their completeness varies in-terms of cross section alignments and extraction accounting. Attempts have been made in these previous studies to assimilate data extents and understand the balance of gravel transport throughout the Waikanae River.

Results presented in Table 4.2 include results from both the *Waikanae River – RIVER CHARACTERISTICS AND SEDIMENTATION*[3] as well as results from this current study, which have been summed and estimated in a manner that best aligns with the previous data extents.

Table 4.2 – Comparing Previous Balance Results with Current Results

Lower Waikanae Historical and Current Transport Balance Results (Lower Waikanae includes results between Cross Sections 70 to 190)				
Period	Extraction (m^3)	Channel Change (m^3)	Net Supply	
			Total (m^3)	Average Annual (m^3/year)
1957 - 1975	129,600	-	129,600	7,000
1975 - 1983	57,600	19,100	76,700	9,500
1983 - 1987	28,800	- 13,600	15,200	4,000
1987 - 1991	28,800	9,900	38,700	9,500
1991 - 1995	7,200	336	7,536	2,000
1995 - 1999	-	8,243	8,243	2,000
1999 - 2004	14,107	10,629	24,737	5,000
2004 - 2010	23,954	- 978	22,976	4,000
2010 - 2014	1,621	10,612	12,233	3,000

Upper Waikanae Historical and Current Transport Balance Results (Upper Waikanae includes results between Cross Sections 190 to 380)				
Period	Extraction (m^3)	Channel Change (m^3)	Net Supply	
			Total (m^3)	Average Annual (m^3/year)
1957 - 1975	50,400	77,400	127,800	7,000
1975 - 1983	22,400	500	22,900	3,000
1983 - 1987	11,200	28,300	39,500	10,000
1987 - 1991	11,200	2,600	13,800	3,500
1991 - 1995	2,800	2,183	4,983	1,000
1995 - 1999	-	- 7,111	- 7,111	- 2,000
1999 - 2004	3,911	7,533	11,444	2,500
2004 - 2010	11,262	- 11,886	- 624	-
2010 - 2014	330	14,128	14,458	3,500

Note: - an extraction rate of 10,000m^3/year was used up to 1991 in accordance with information provided in the report 'Waikanae River - RIVER CHARACTERISTICS AND SEDIMENTATION - May 1992', due to the lack of accurate extraction accounting prior to 1991.
- the 10,000m^3/year has been divided between the two reaches based on a weighting of extraction operations post 1991.
- a rounding function to the nearest 500m^3 was applied to the results for Average Annual Net Supply.

In accordance with the previous study, two reaches of the Waikanae River floodway are examined in Table 4.2: the Lower Waikanae between *XS 070* and *XS 190* and, the Upper Waikanae between *XS 190* and *XS 380*.

[3] OurSpace edoc# 1399683.

Examining the lower reach results, the average annual supply ranges between 2,000m^3/year and 5,000m^3/year after 1991; whereas, the average annual supply ranges between 4,000m^3/year and 9,500m^3/year before 1991. The results after 1991 somewhat reflects the detailed results presented in this study; however, the results prior to 1991 vary widely – most likely due to data integrity and lack of accurate extraction accounting.

The upper reach results vary widely both prior to 1991 and after 1991. This is believed to be related to several factors that include data integrity, extraction accounting, high degradation and scour in this reach, and the instream works that have been built throughout this reach over time.

Contrasting results prior to 1991 with the results after 1991 confirms the necessity for accurate accounting in these highly dynamic environments and also provides further confidence in the forecasts and recommendations provided in Section 5 of this report.

5.0 Recommendations

The following recommendations are made from the 2017 Waikanae River gravel analysis:

6.1 Short-term/Immediate Recommendations

1. A sustainable gravel extraction equivalent to 5,300m^3/year should be considered for the Waikanae River scheme;

2. Since 1991 an additional 60,000m^3 of gravel sits in storage within the active channel downstream of Jim Cooke Park and should be managed as part of a go-forward operations program or during the planning of major works;

3. Gravel extraction for ongoing commercial purposes should not occur upstream of the equestrian and vaulting club;

4. Weighting for gravel extraction locations should be based on natural deposition trends and locations of surplus gravel within the floodway since 1991;

5. Based on the previous recommendation, an extraction operation plan with various options that aligns with other users and stakeholders in the river environment should be developed to address ongoing aggradation and the excess gravel stored in the system;

6. Informed in-stream works (i.e. results guided) alternative to extraction should be planned for in degrading reaches of the Waikanae River;

7. A geologic investigation should be carried out to determine the substratum make-up of the island downstream of the boating club;

8. An operations program should be developed based on the results presented in this analysis;

6.2 Long-term Recommendations

1. Although the results herein are confidently based on six complete surveys, the forecasts and recommendations provided in this document are based on trends in a natural system that are not static; therefore, recommended extraction rates for each reach should be adjusted if necessary after each future survey/analysis;

2. Further hydraulic modelling should be carried out to assess long-term flood-effects of aggrading reaches of the Waikanae River;

3. The Design Bed Envelope should be monitored and potentially revised as new data becomes available and a region wide approach becomes accepted;

4. High scour zones near instream structures should be monitored closely and managed in terms of long-term hazards;

5. A DTM survey combined with a below-water-surface and below-vegetation survey at cross sections together with a thalweg survey between cross sections should be considered as a progressive gravel bed monitoring method for the Waikanae River; and

6. The analysis template created and used for this analysis combined with the onsite workshop and team leader workshop proved to be an effective exercise. Therefore; the process used for the 2017 Waikanae River Gravel Analysis should be adopted as part of the gravel strategy for the Greater Wellington Region.

Appendix A – Reach by Reach Cross Section Alignments

Waikanae River Reach 1 – Otaihanga Reach (*XS 010 to XS 080*)

Waikanae River Reach 2 – El Ranch Reach (*XS 090 to XS 150*)

Waikanae River Reach 3 – Kauri/Puriri Reach (*XS 155 to XS 260*)

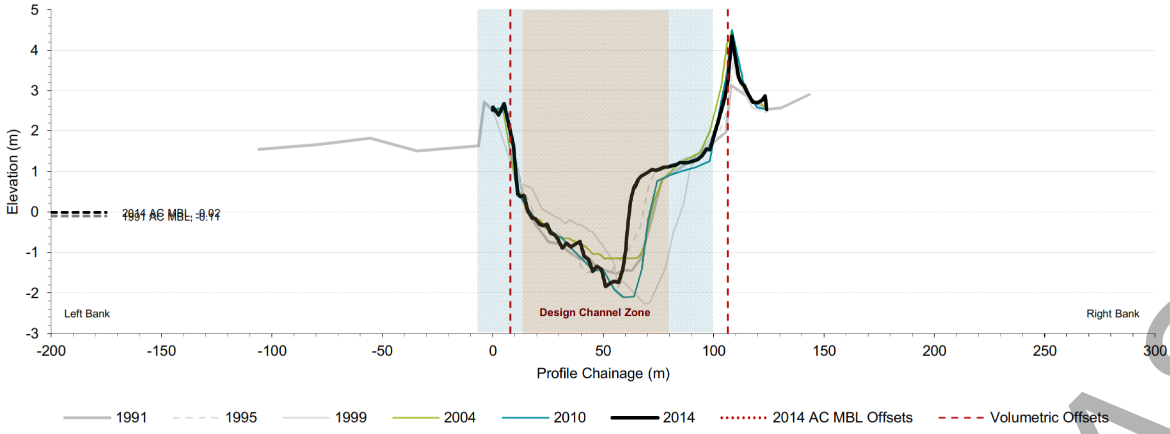
Waikanae River Reach 4 – Jim Cooke Park Reach (*XS 270 to XS 350*)

Waikanae River Reach 5 – Below SH1 Reach (*XS 360 to XS 420*)

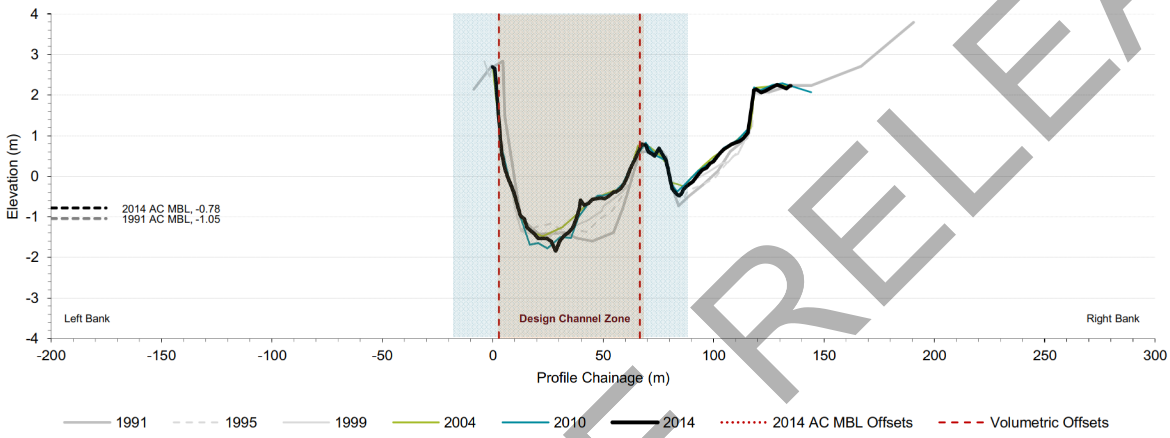
Waikanae River Reach 6 – Above SH1 Reach (*Road XS to XS 550*)

Appendix B – Historical Cross Section Profiles

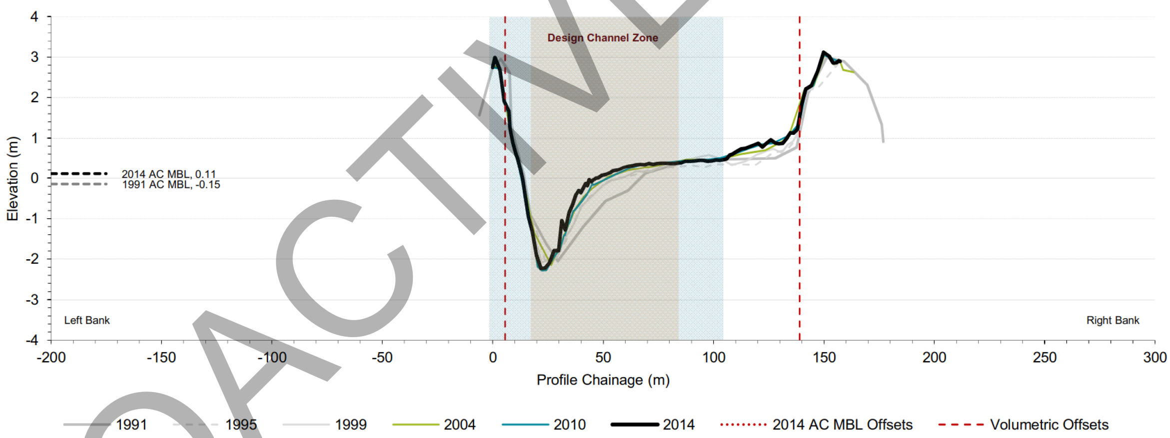
Waikanae River - Cross Section 10



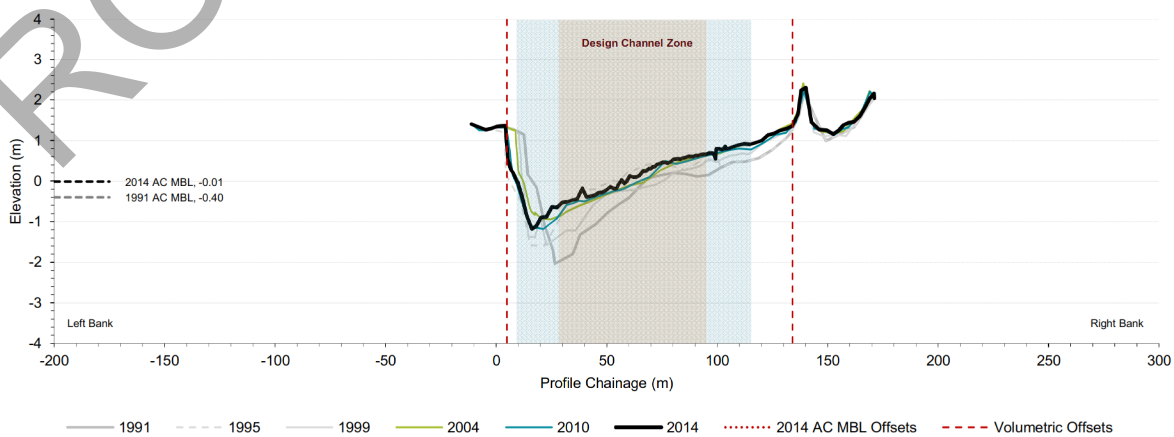
Waikanae River - Cross Section 20

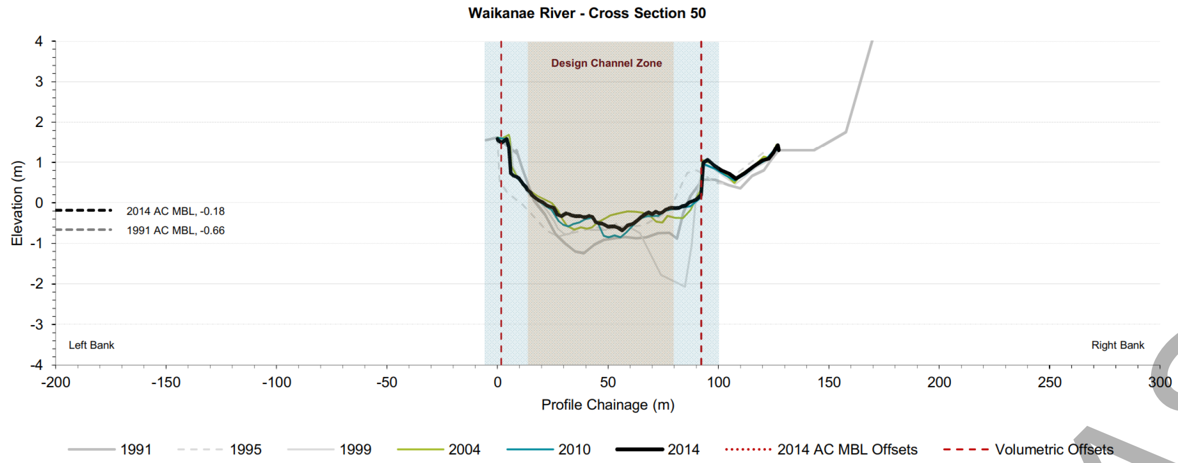


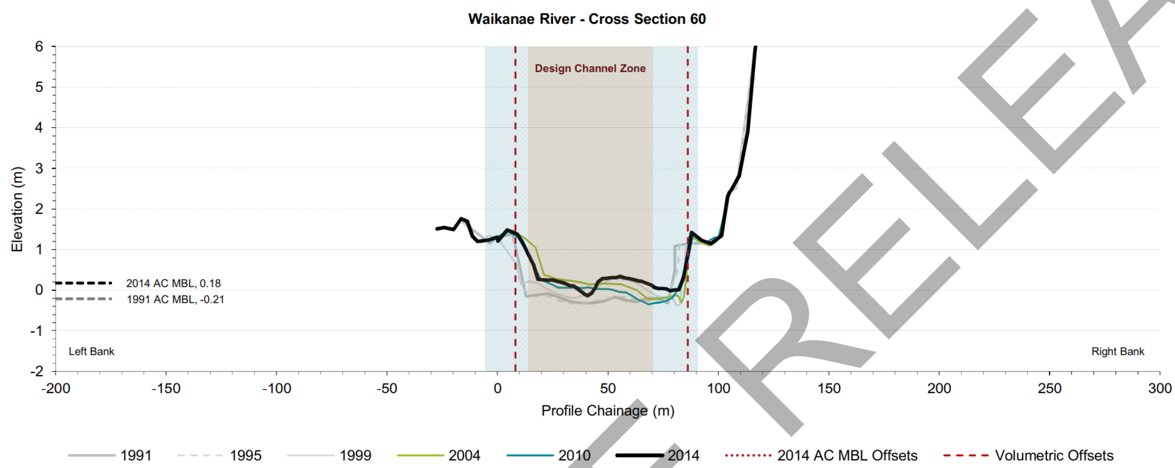
Waikanae River - Cross Section 30

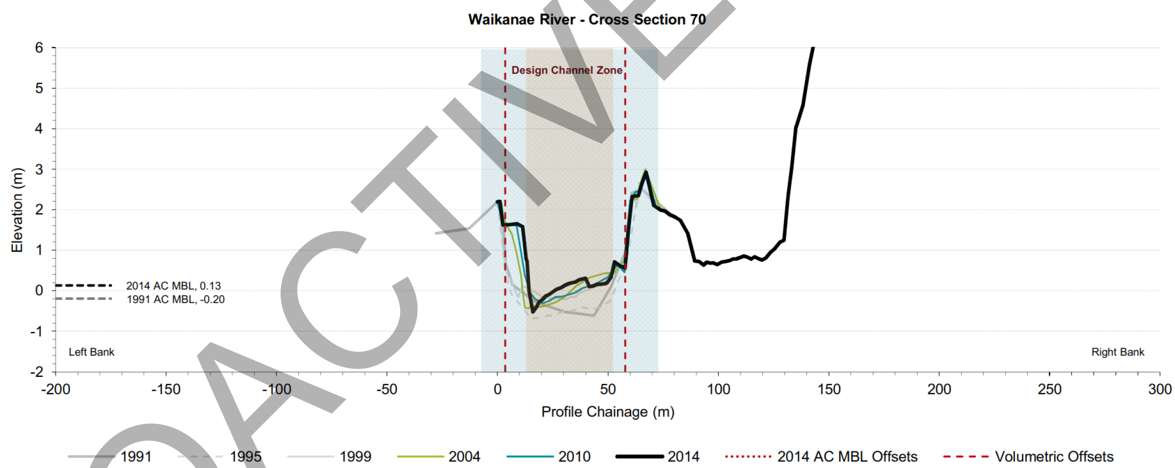


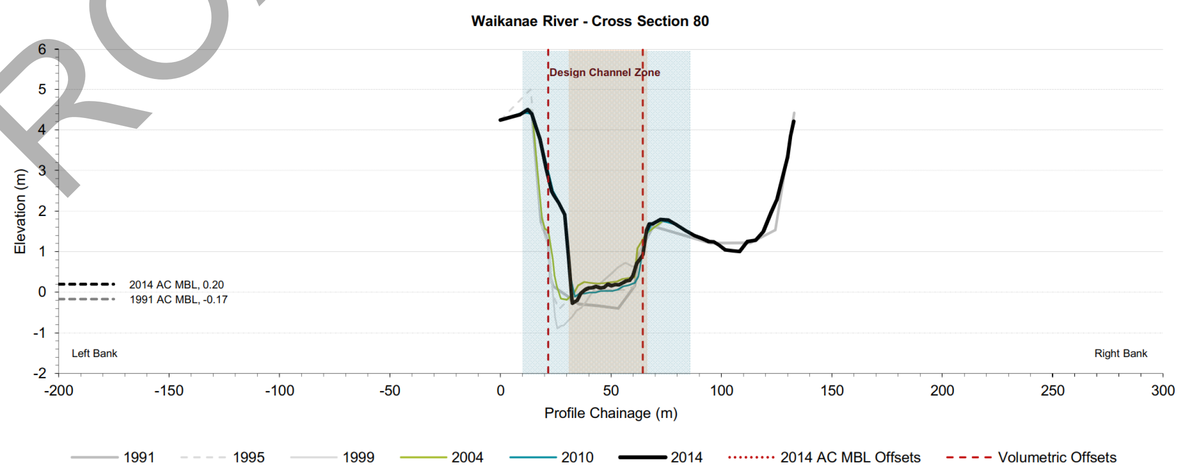
Waikanae River - Cross Section 40

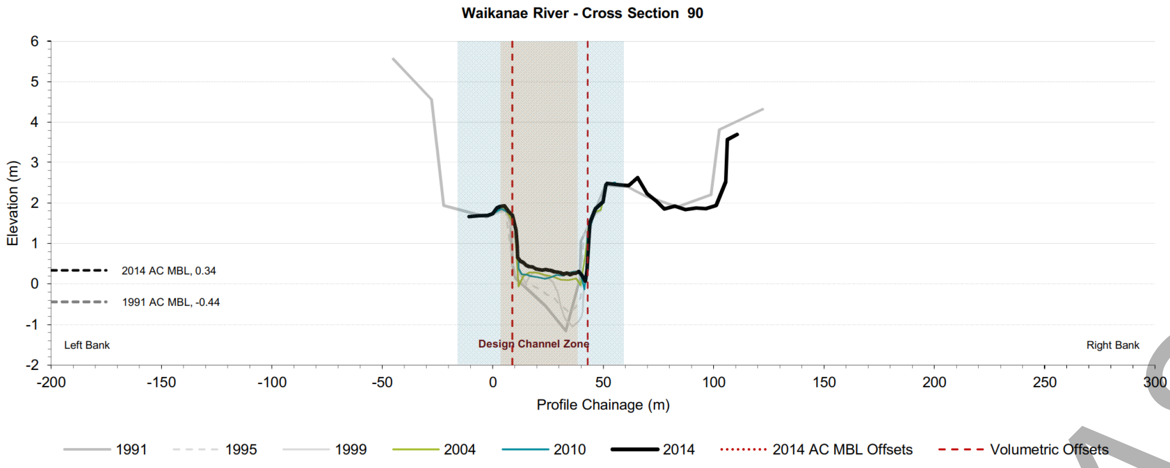


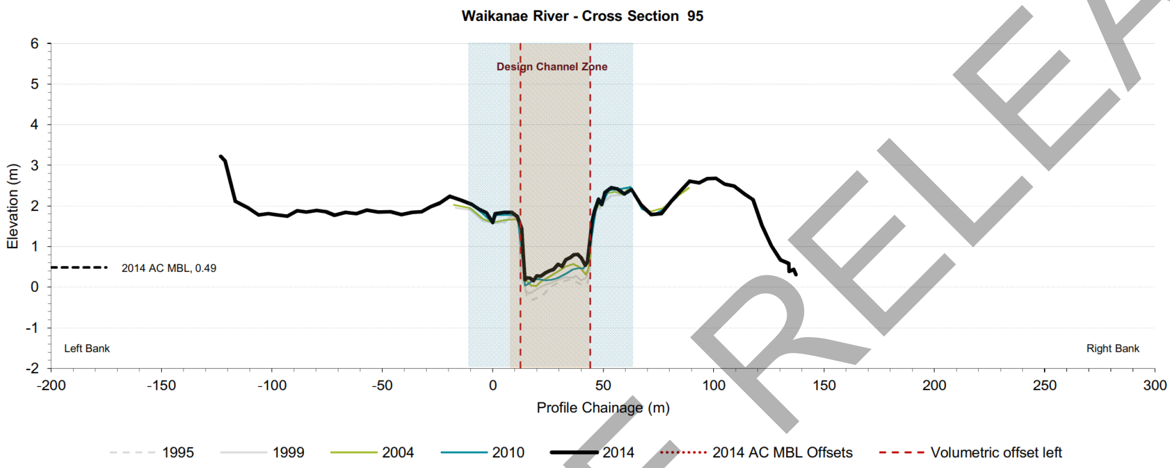

Waikanae River - Cross Section 50
Design Channel Zone
2014 AC MBL, -0.18
1991 AC MBL, -0.66
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

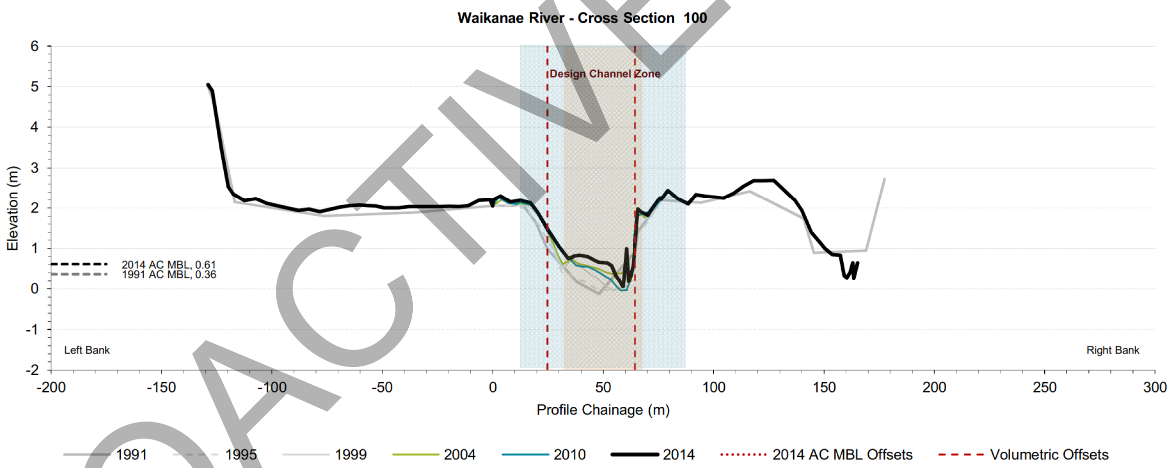

Waikanae River - Cross Section 60
Design Channel Zone
2014 AC MBL, 0.18
1991 AC MBL, -0.21
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

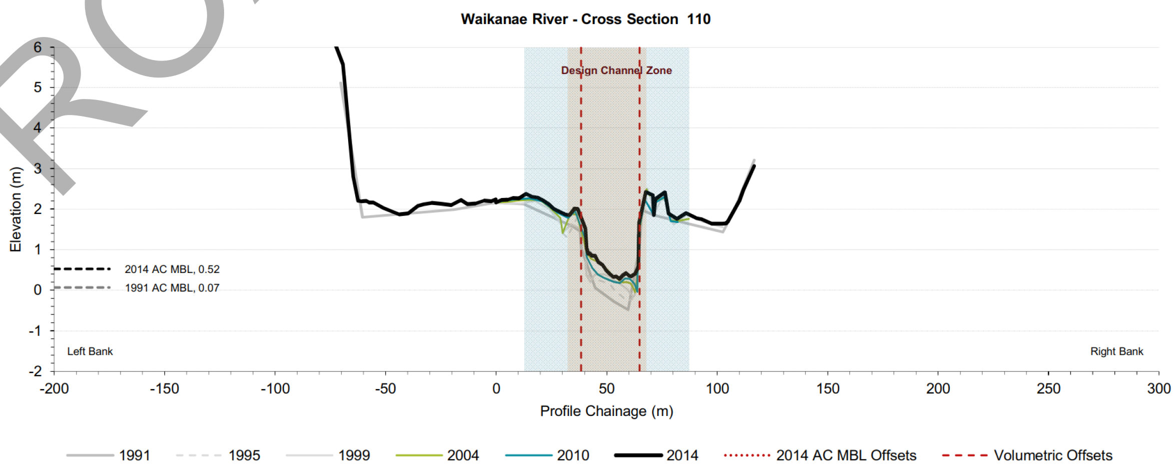

Waikanae River - Cross Section 70
Design Channel Zone
2014 AC MBL, 0.13
1991 AC MBL, -0.20
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 80
Design Channel Zone
2014 AC MBL, 0.20
1991 AC MBL, -0.17
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 90
Elevation (m)
Profile Chainage (m)
2014 AC MBL, 0.34
1991 AC MBL, -0.44
Design Channel Zone
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

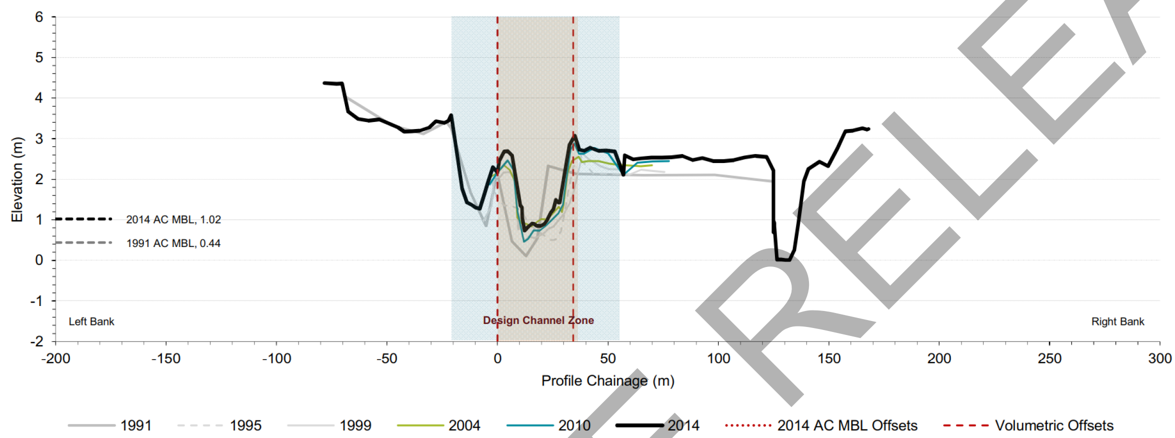

Waikanae River - Cross Section 95
Elevation (m)
Profile Chainage (m)
2014 AC MBL, 0.49
Design Channel Zone
Left Bank
Right Bank
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric offset left


Waikanae River - Cross Section 100
Elevation (m)
Profile Chainage (m)
2014 AC MBL, 0.61
1991 AC MBL, 0.36
Design Channel Zone
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

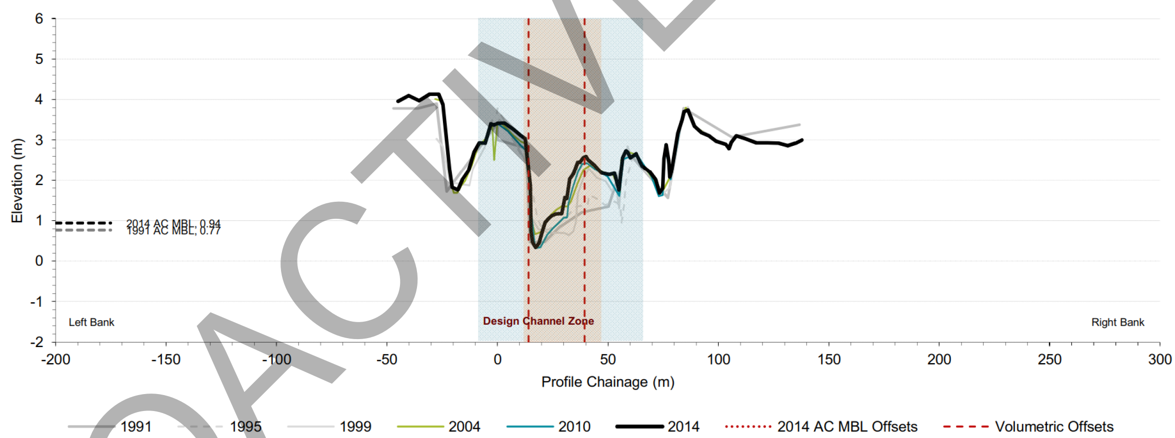

Waikanae River - Cross Section 110
Elevation (m)
Profile Chainage (m)
2014 AC MBL, 0.52
1991 AC MBL, 0.07
Design Channel Zone
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

Waikanae River - Cross Section 120

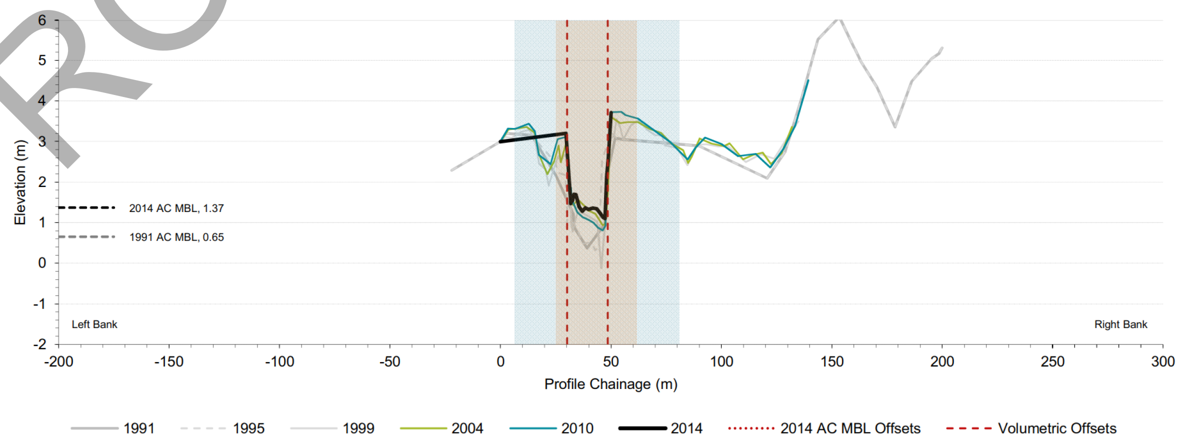
Waikanae River - Cross Section 130

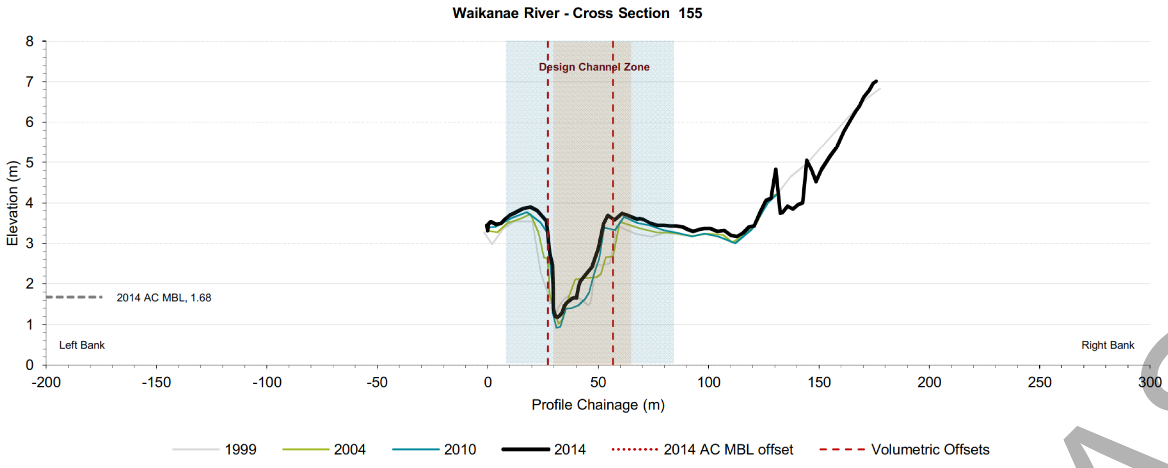


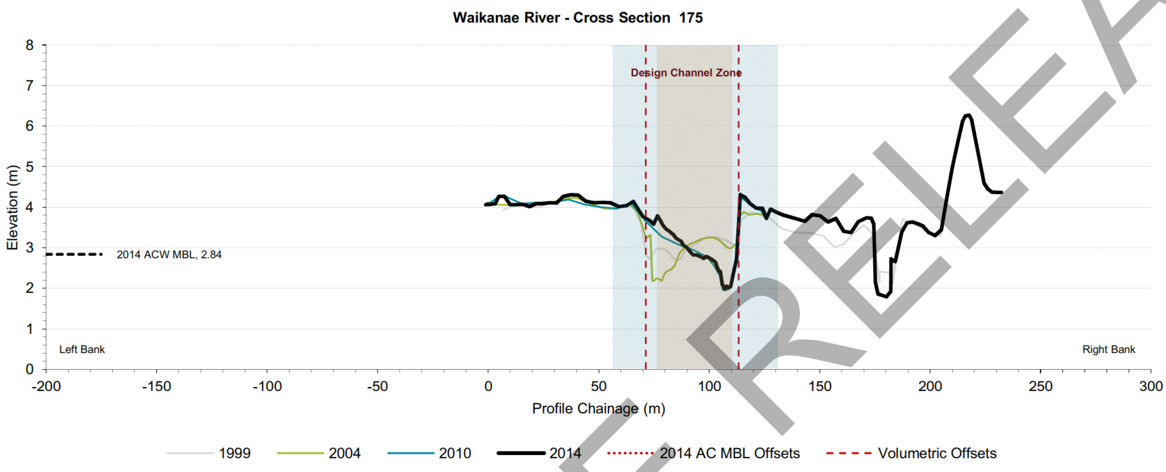
Waikanae River - Cross Section 140

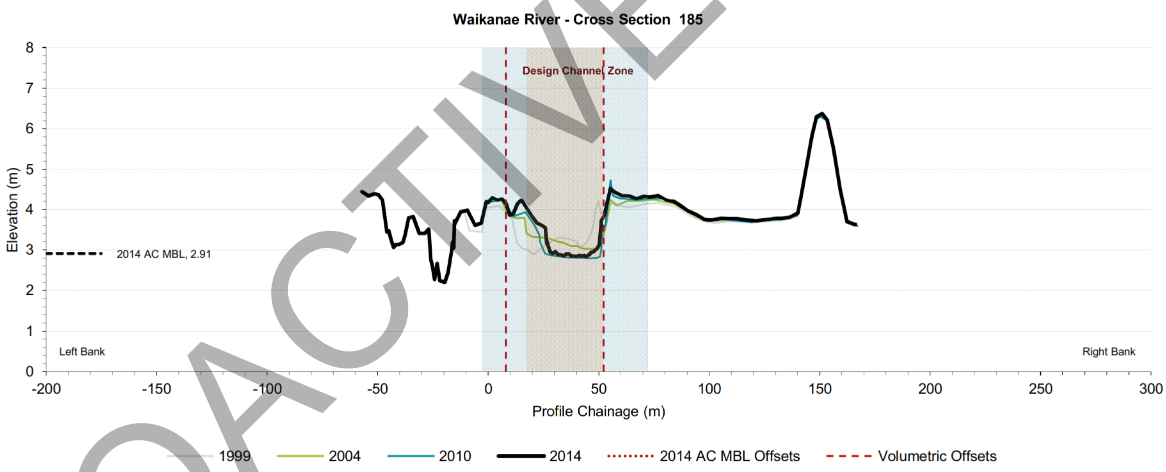


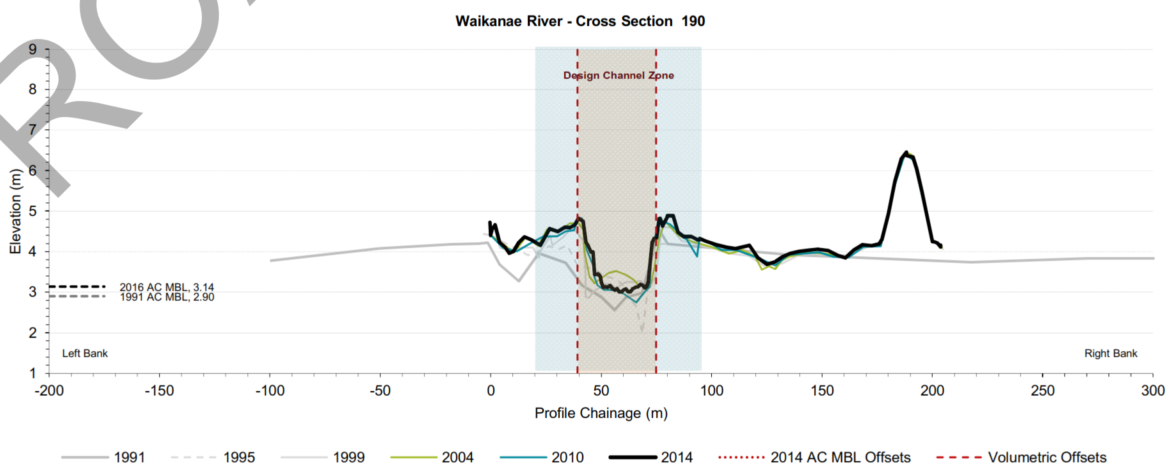
Waikanae River - Cross Section 150



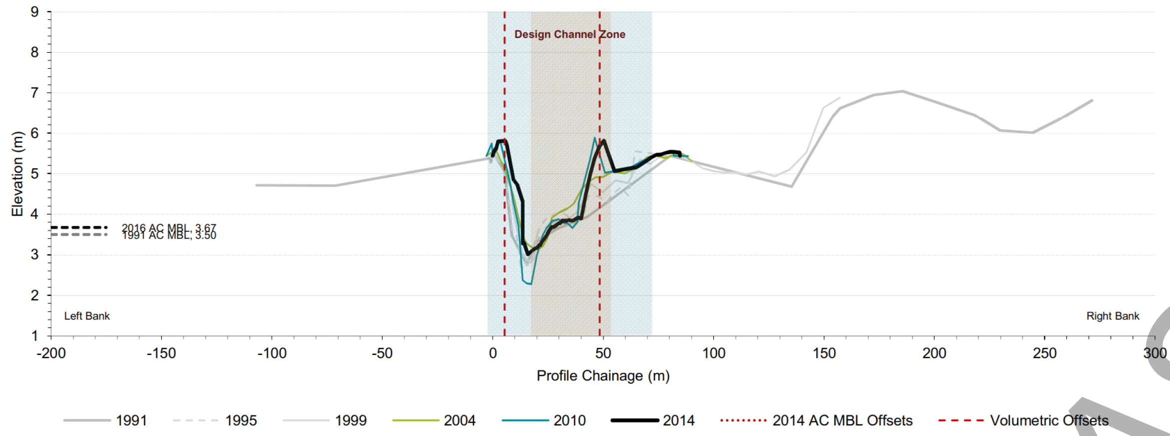

Waikanae River - Cross Section 155
Design Channel Zone
2014 AC MBL, 1.68
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1999
2004
2010
2014
2014 AC MBL offset
Volumetric Offsets


Waikanae River - Cross Section 175
Design Channel Zone
2014 ACW MBL, 2.84
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

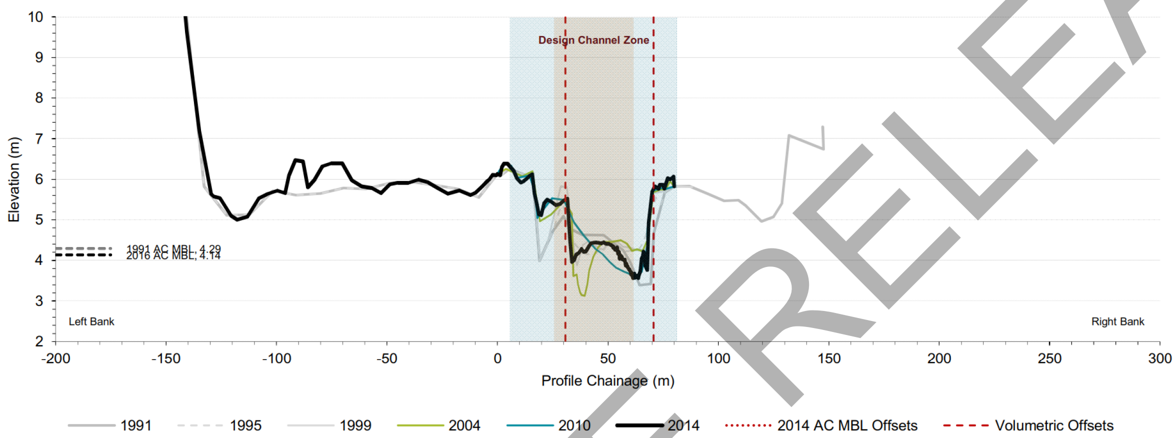

Waikanae River - Cross Section 185
Design Channel Zone
2014 AC MBL, 2.91
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 190
Design Channel Zone
2016 AC MBL, 3.14
1991 AC MBL, 2.90
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

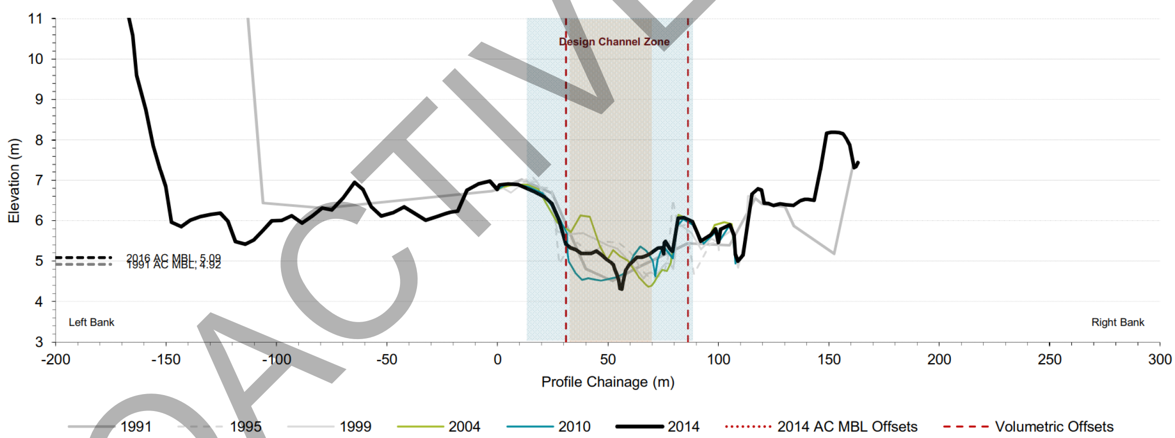
Waikanae River - Cross Section 200



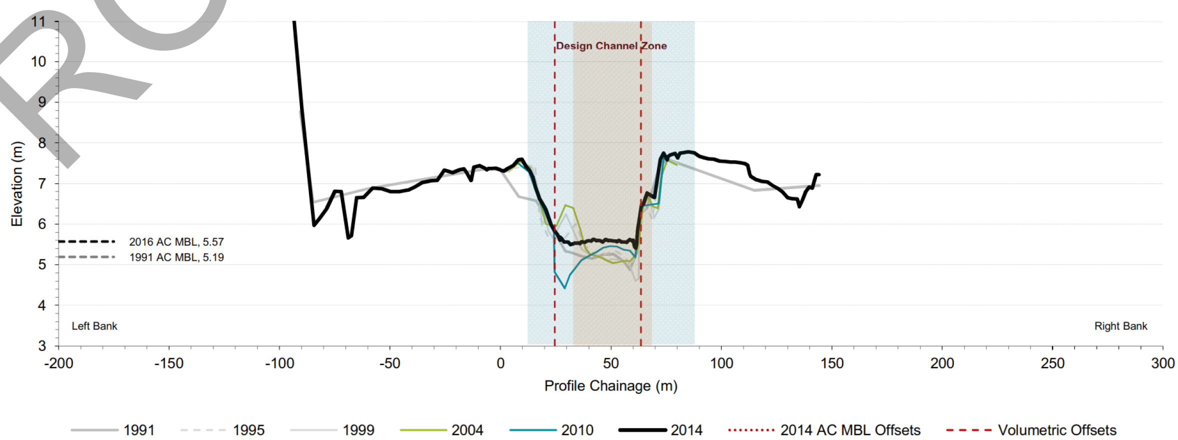
Waikanae River - Cross Section 210



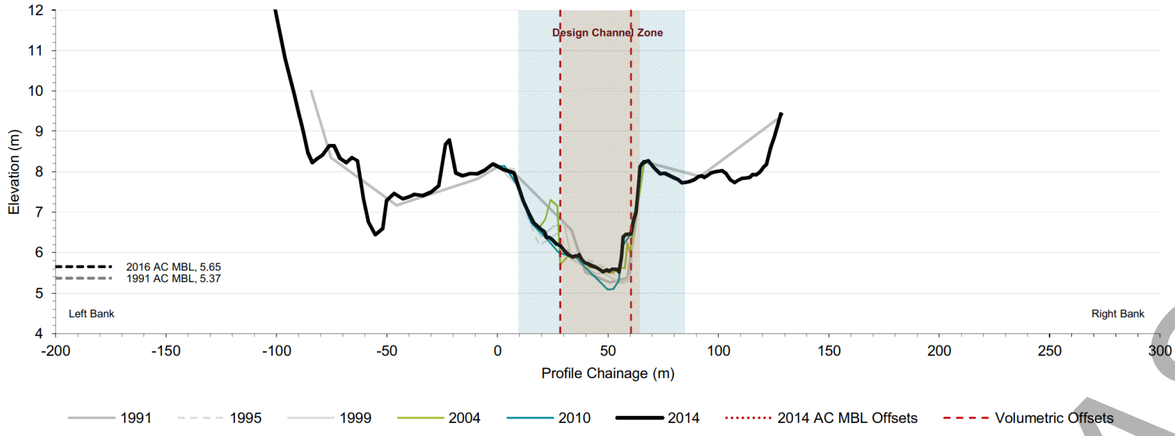
Waikanae River - Cross Section 220



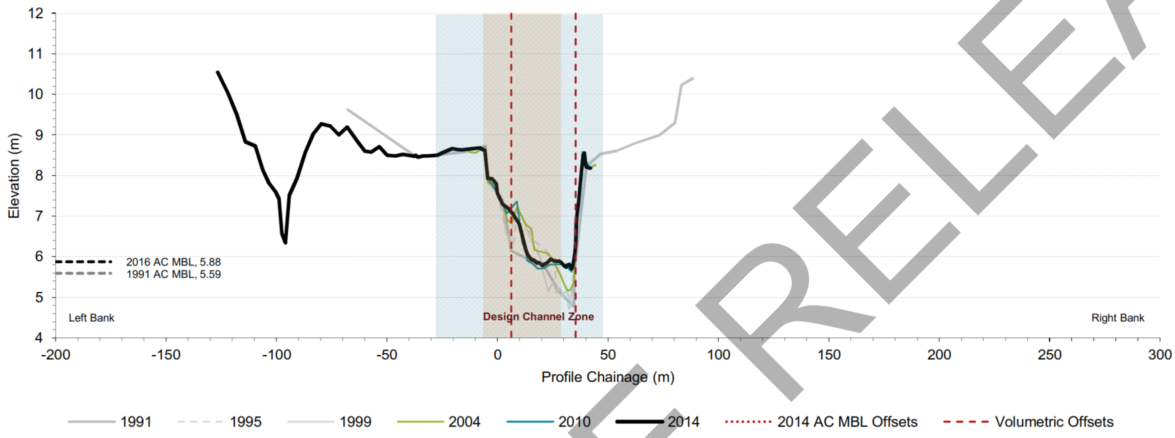
Waikanae River - Cross Section 230



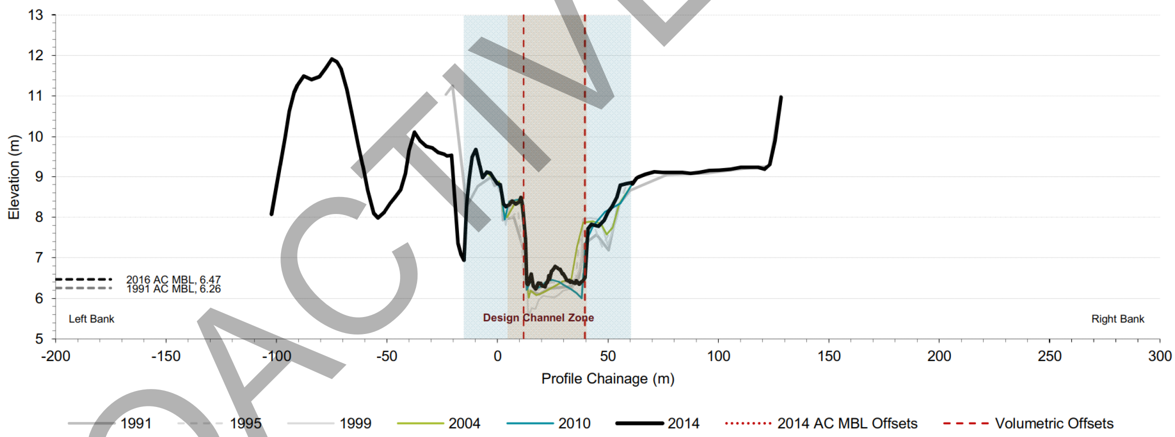
Waikanae River - Cross Section 240



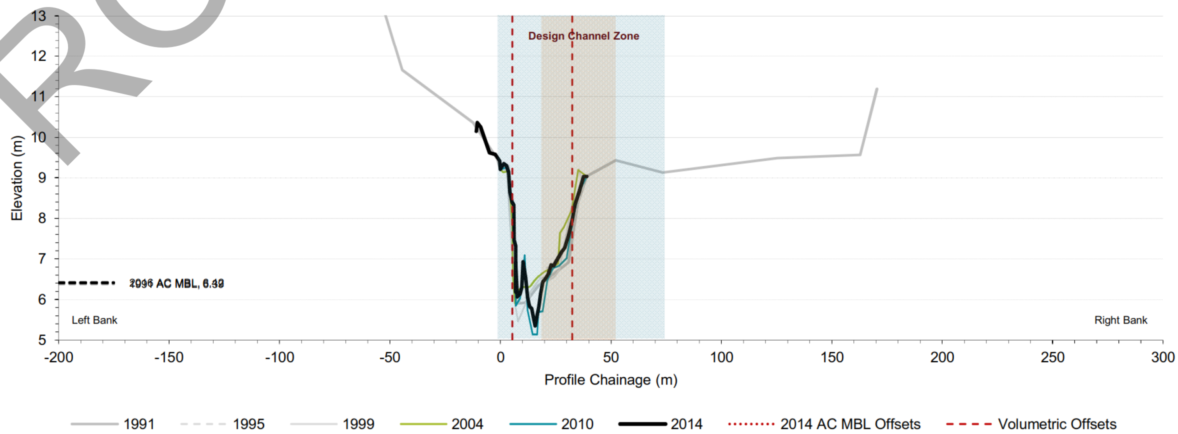
Waikanae River - Cross Section 250

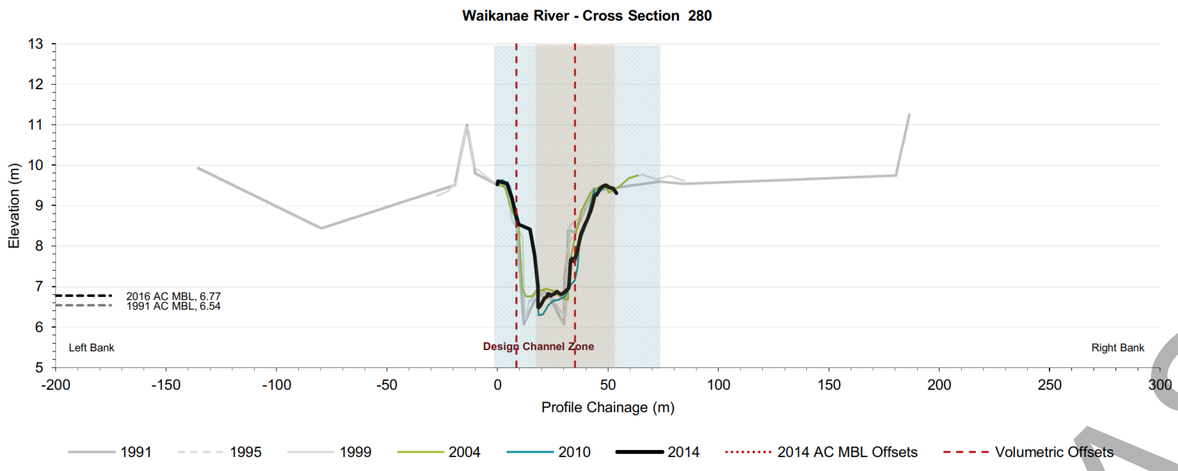


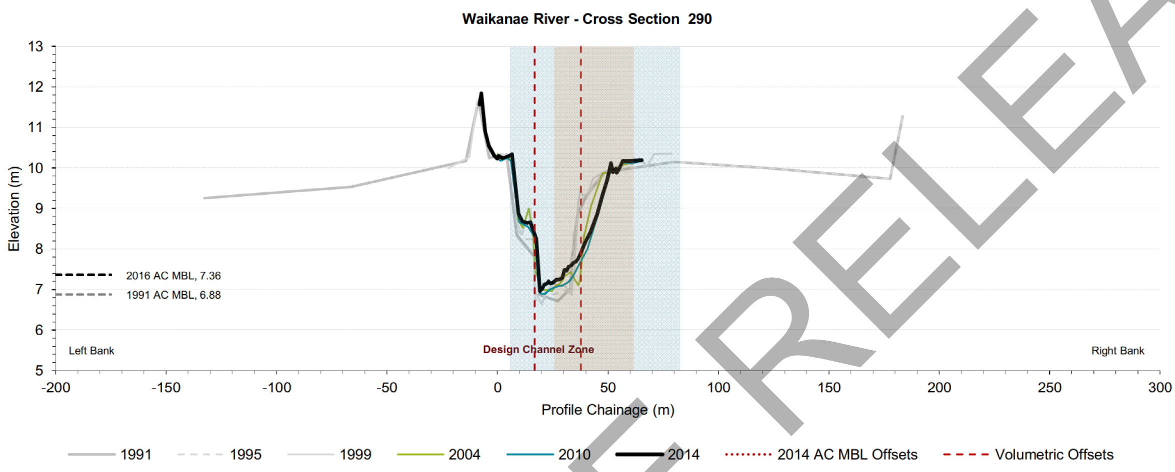
Waikanae River - Cross Section 260

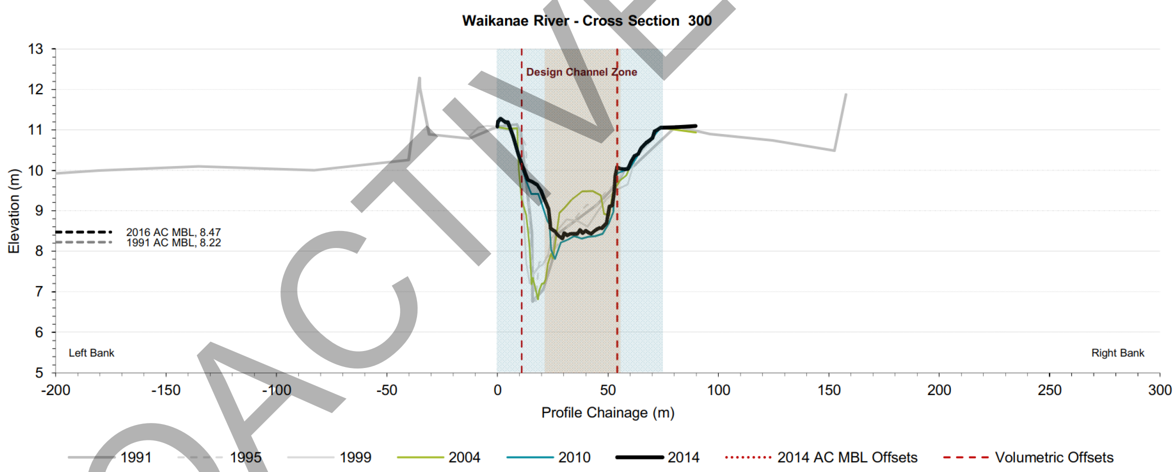


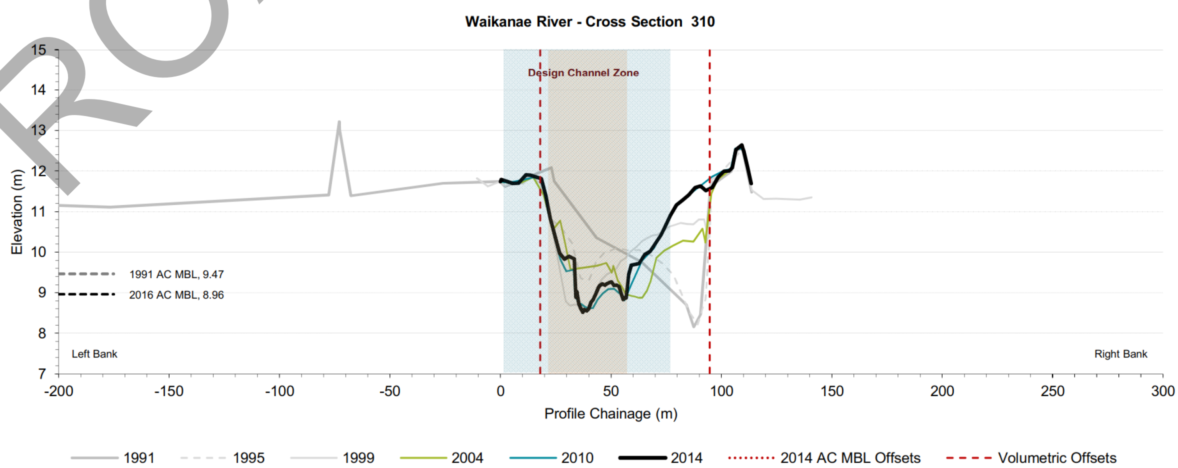
Waikanae River - Cross Section 270



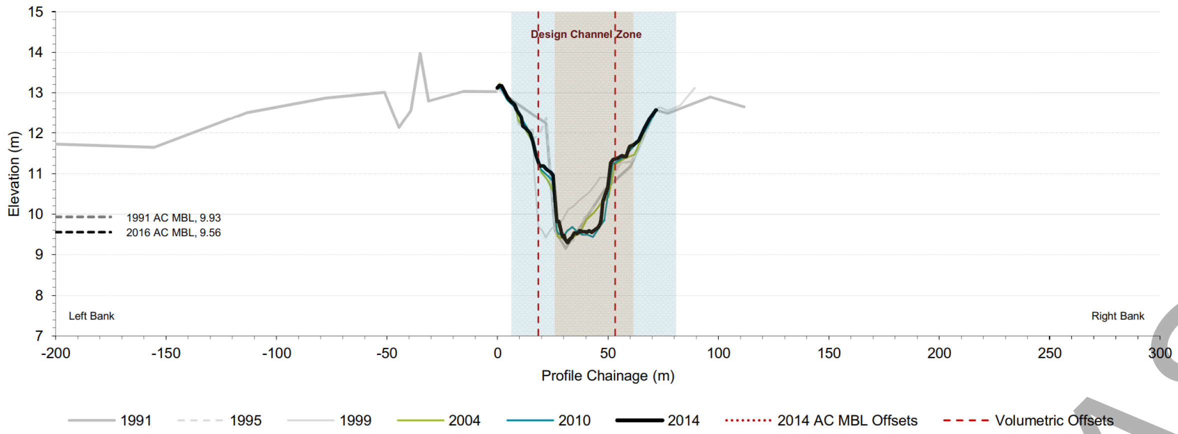

Waikanae River - Cross Section 280
Elevation (m)
Profile Chainage (m)
2016 AC MBL, 6.77
1991 AC MBL, 6.54
Left Bank
Design Channel Zone
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 290
Elevation (m)
Profile Chainage (m)
2016 AC MBL, 7.36
1991 AC MBL, 6.88
Left Bank
Design Channel Zone
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

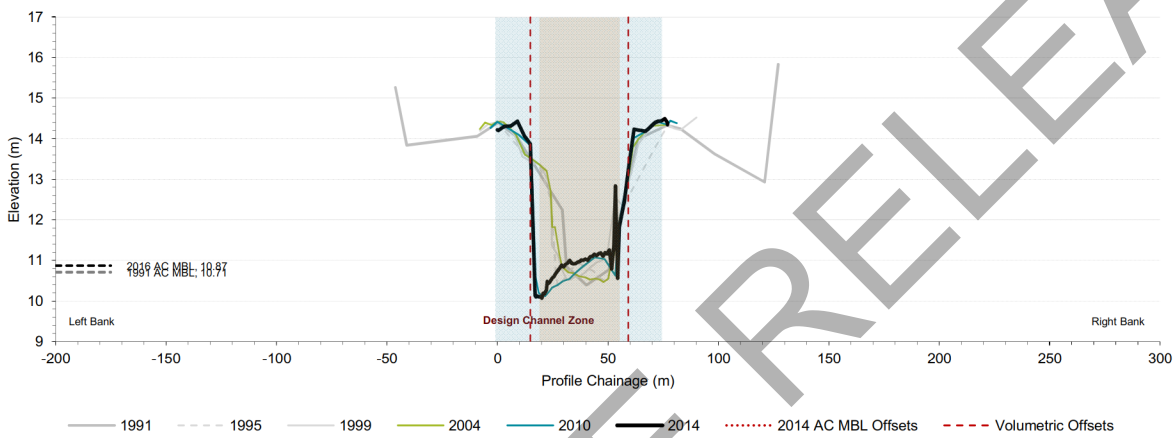

Waikanae River - Cross Section 300
Elevation (m)
Profile Chainage (m)
Design Channel Zone
2016 AC MBL, 8.47
1991 AC MBL, 8.22
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 310
Elevation (m)
Profile Chainage (m)
Design Channel Zone
1991 AC MBL, 9.47
2016 AC MBL, 8.96
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

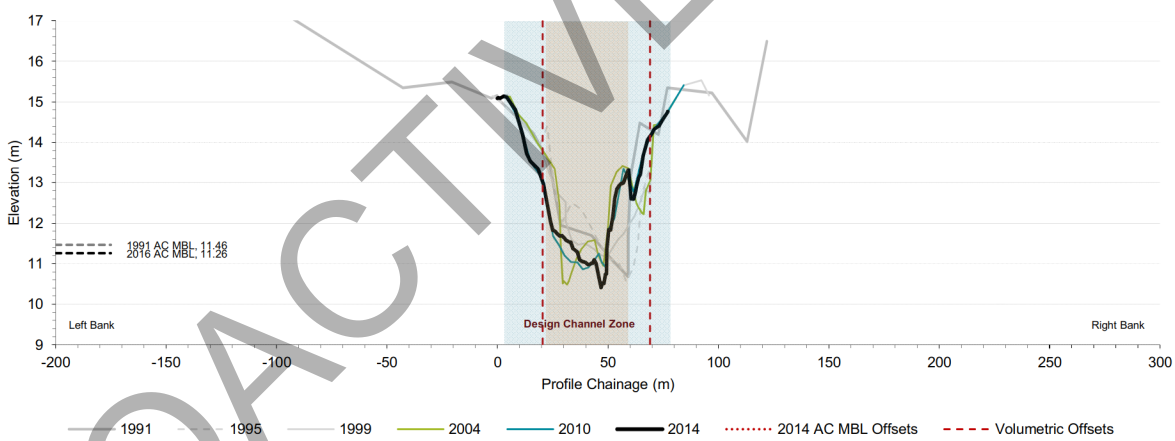
Waikanae River - Cross Section 320



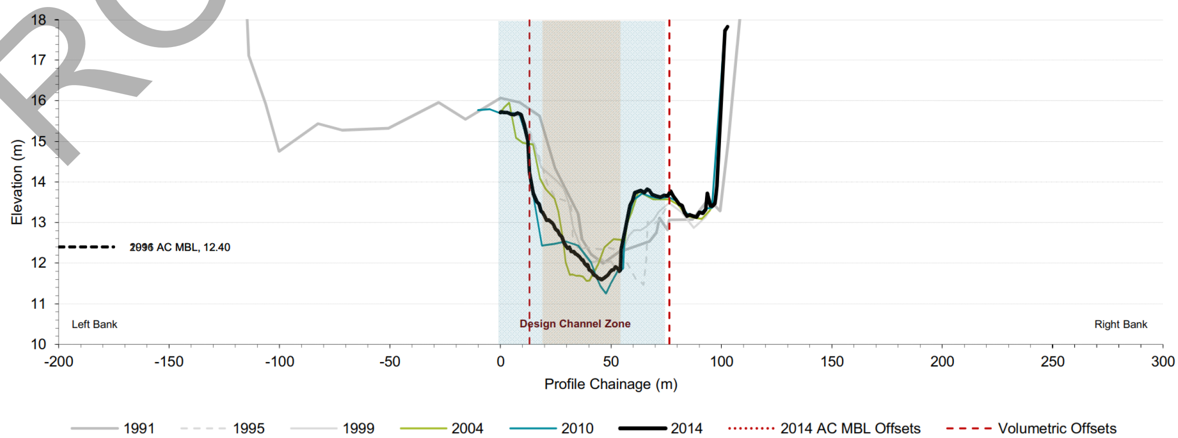
Waikanae River - Cross Section 330

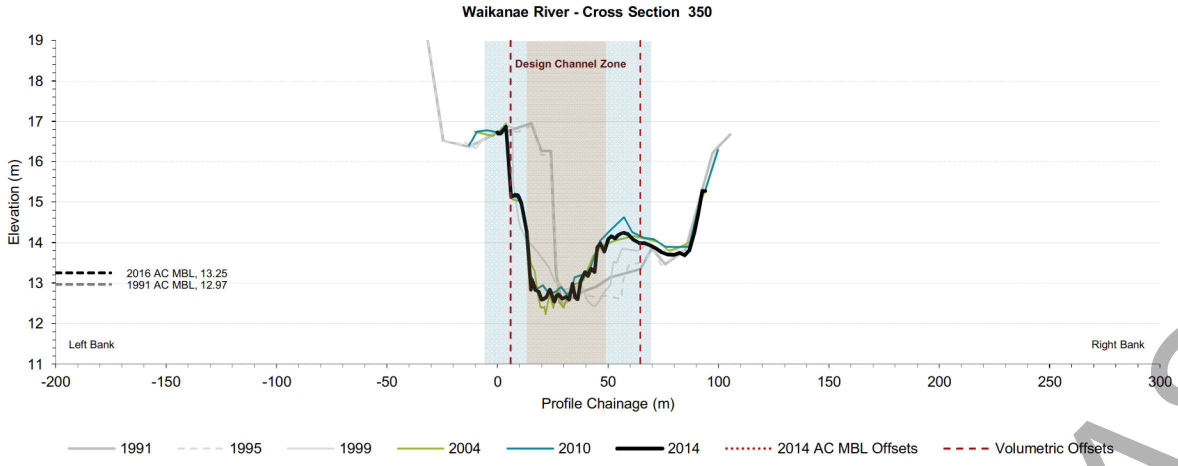


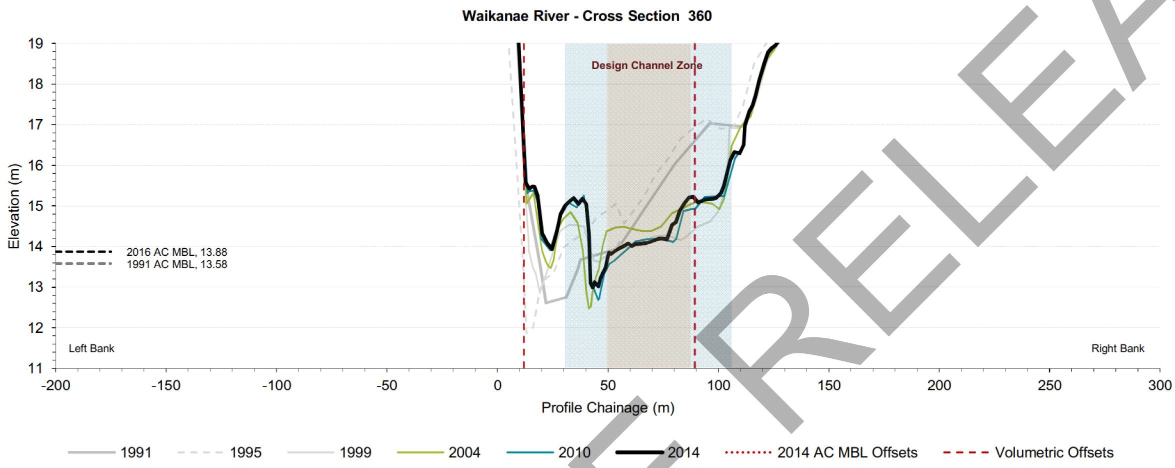
Waikanae River - Cross Section 340

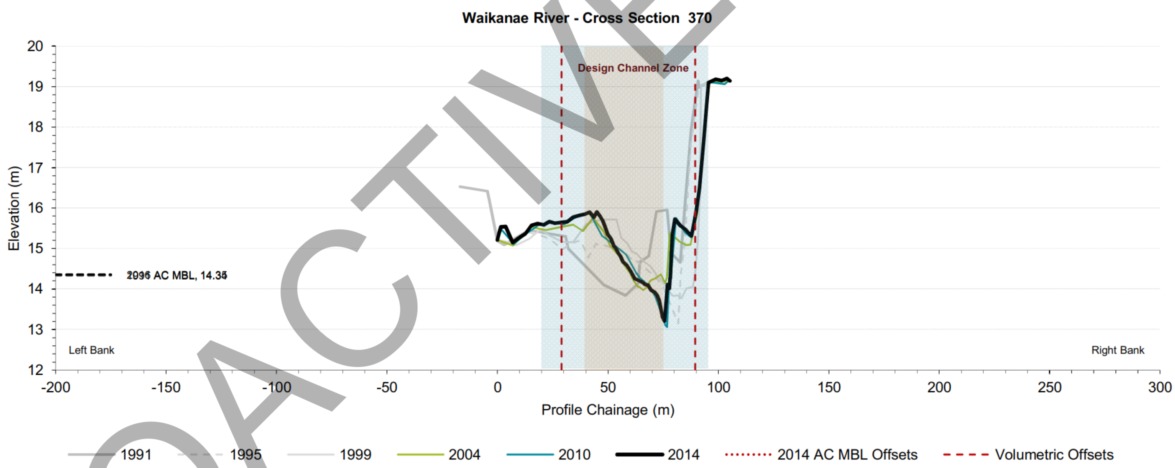


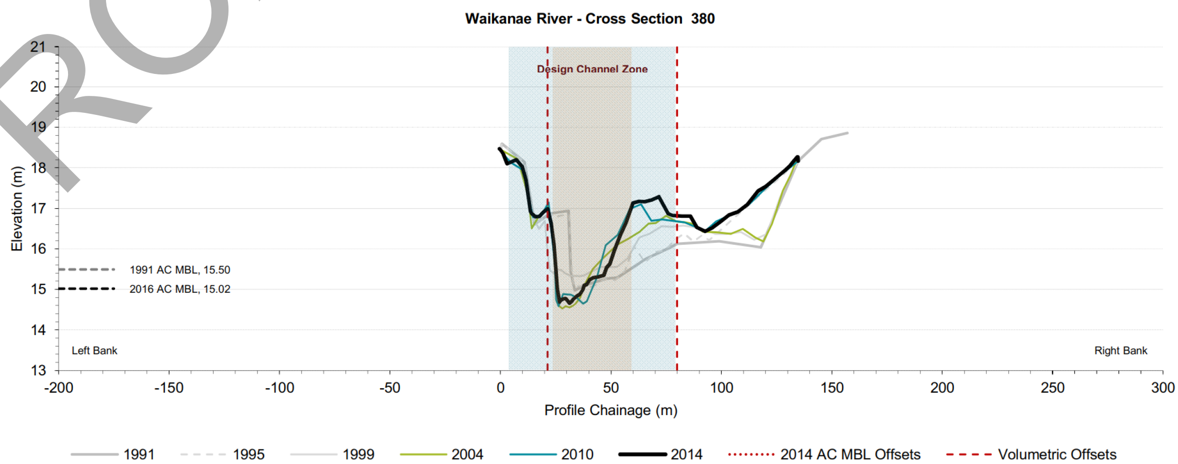
Waikanae River - Cross Section 345



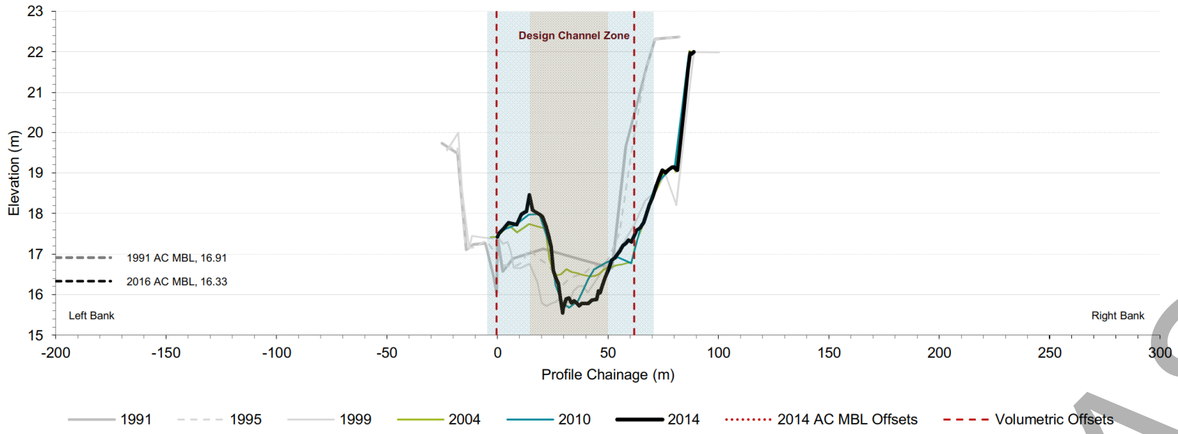

Waikanae River - Cross Section 350
Design Channel Zone
2016 AC MBL, 13.25
1991 AC MBL, 12.97
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 360
Design Channel Zone
2016 AC MBL, 13.88
1991 AC MBL, 13.58
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

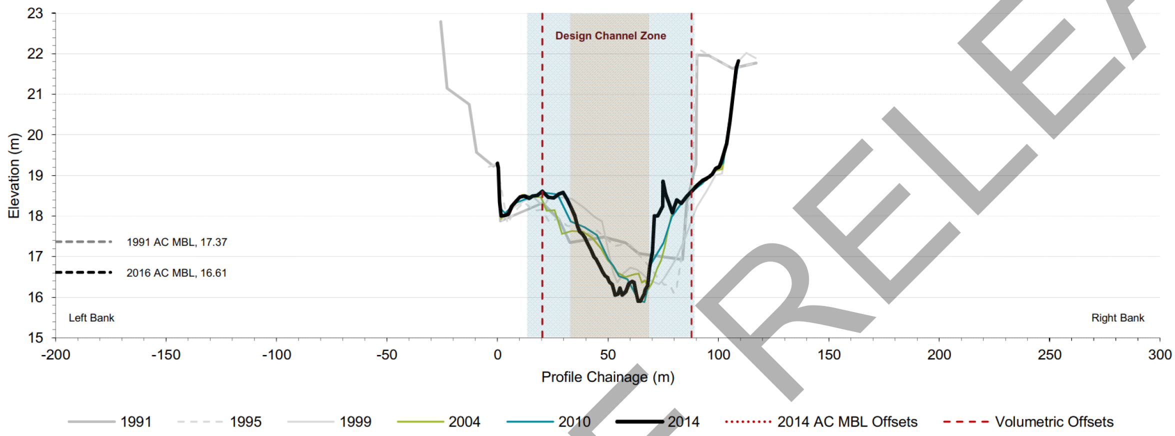

Waikanae River - Cross Section 370
Design Channel Zone
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 380
Design Channel Zone
1991 AC MBL, 15.50
2016 AC MBL, 15.02
Left Bank
Right Bank
Elevation (m)
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

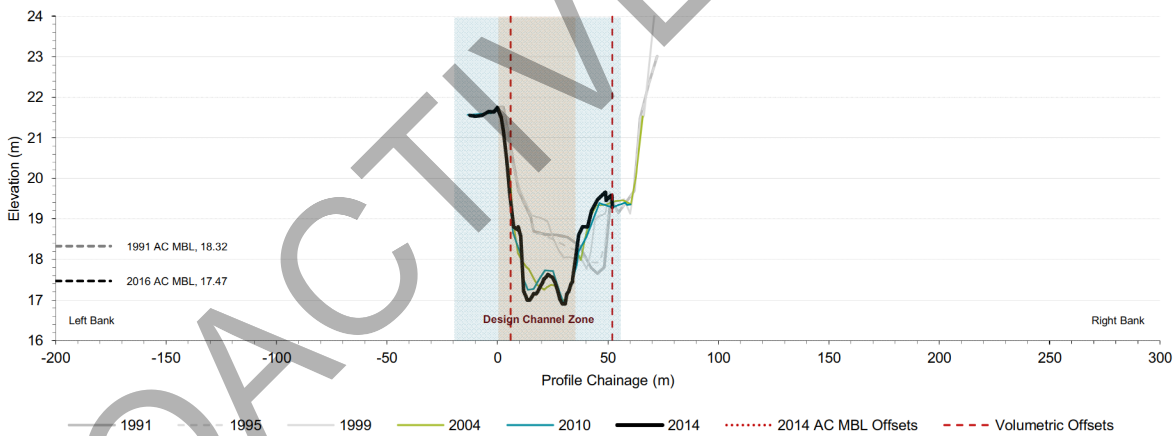
Waikanae River - Cross Section 390



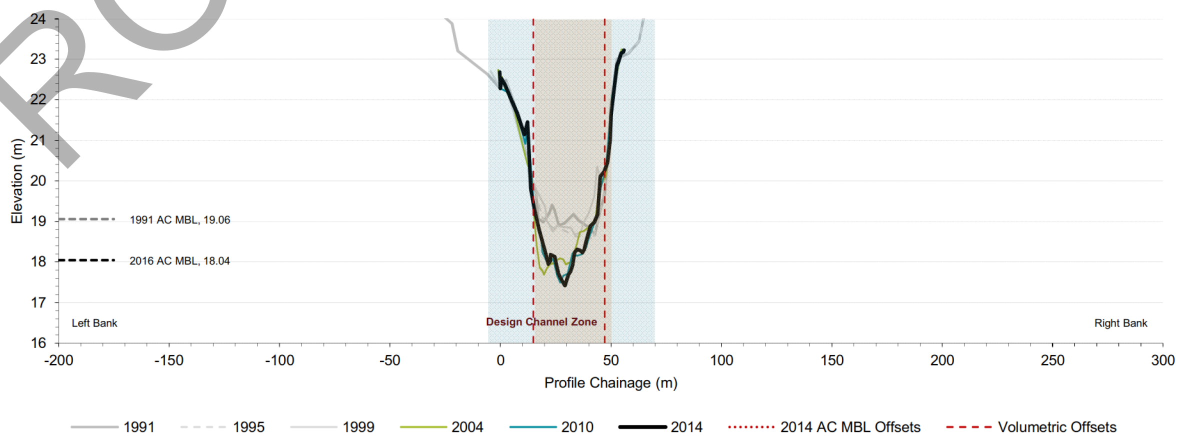
Waikanae River - Cross Section 400



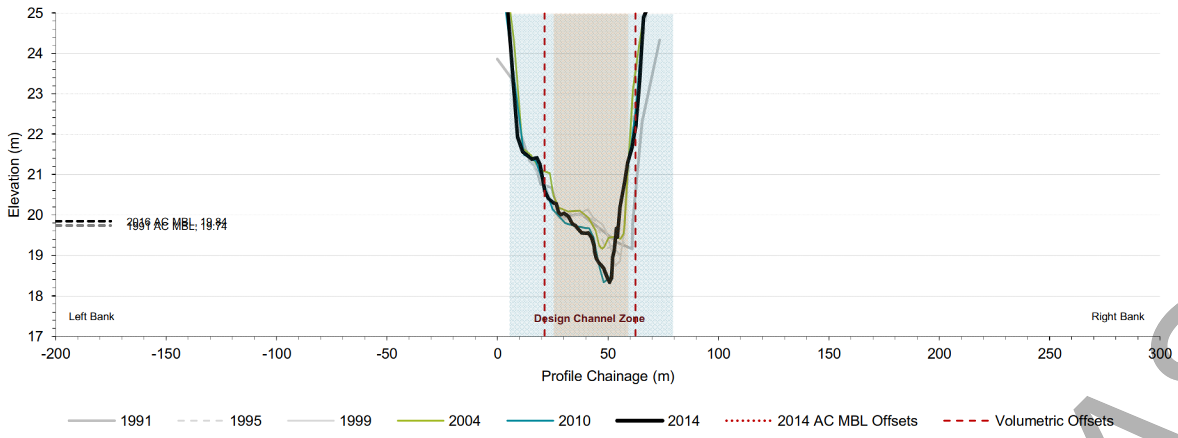
Waikanae River - Cross Section 410



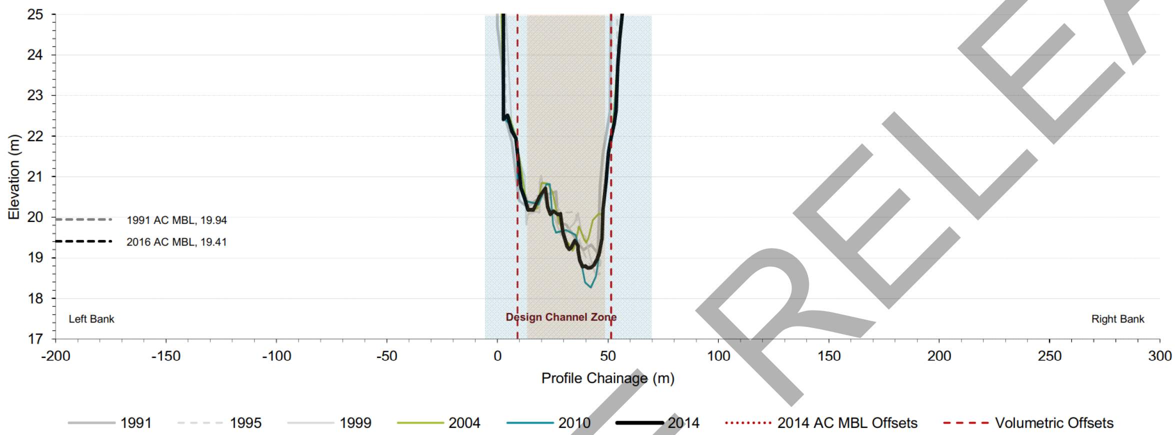
Waikanae River - Cross Section 420



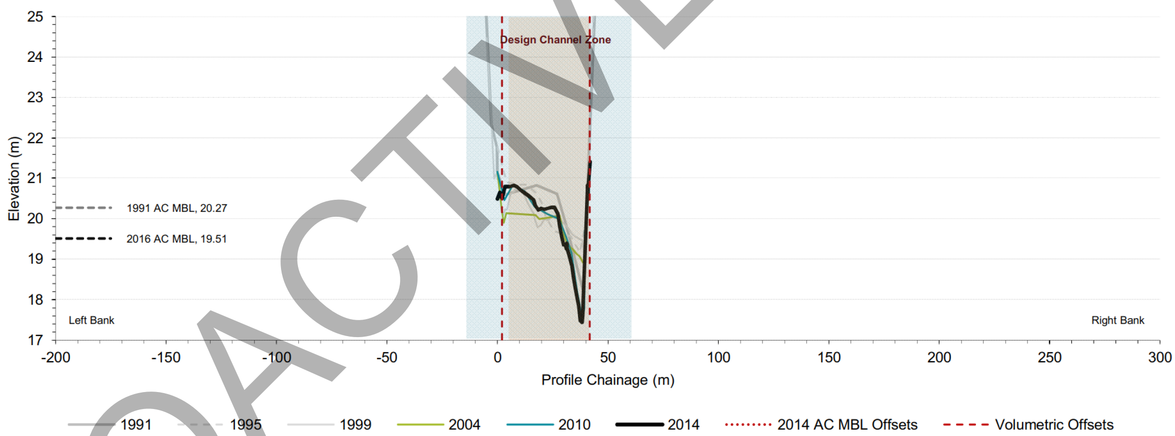
Waikanae River - Cross Section ROAD



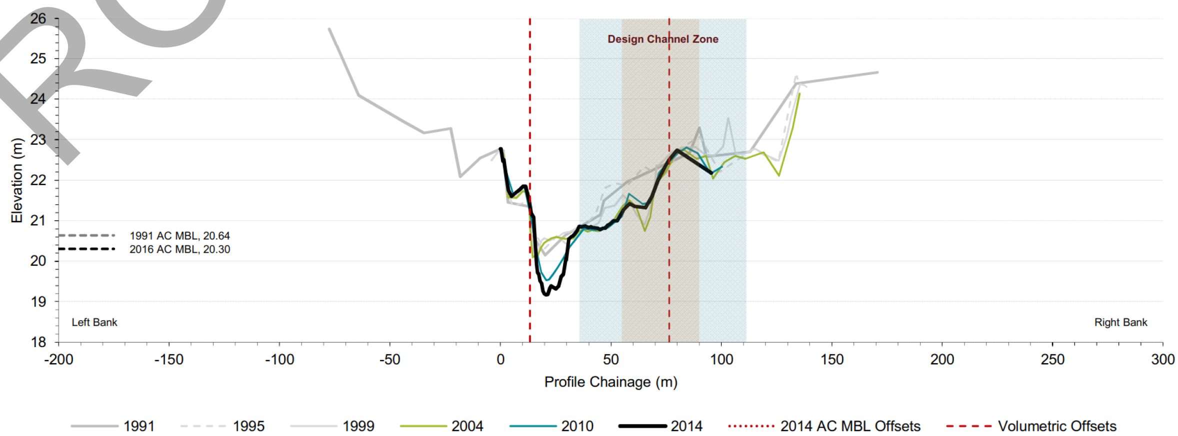
Waikanae River - Cross Section RAIL

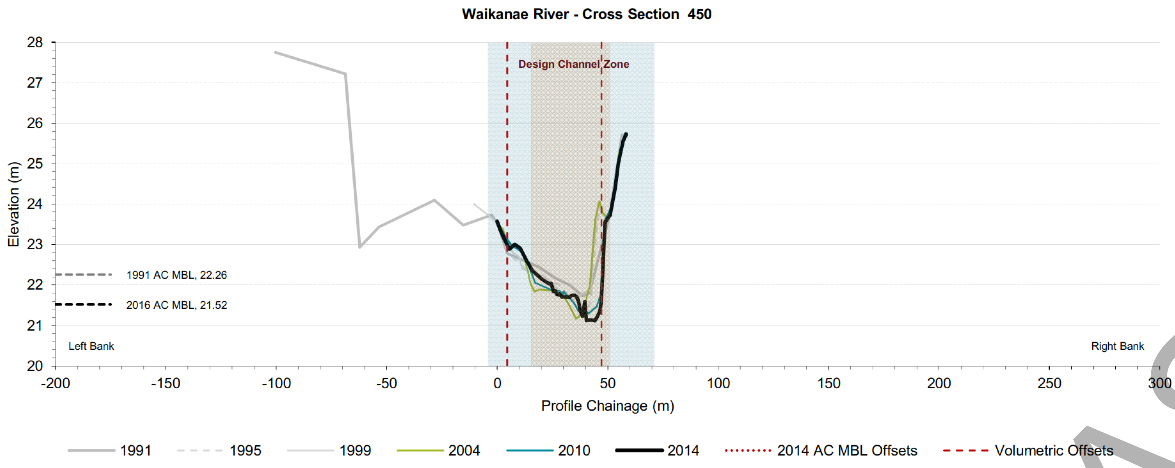


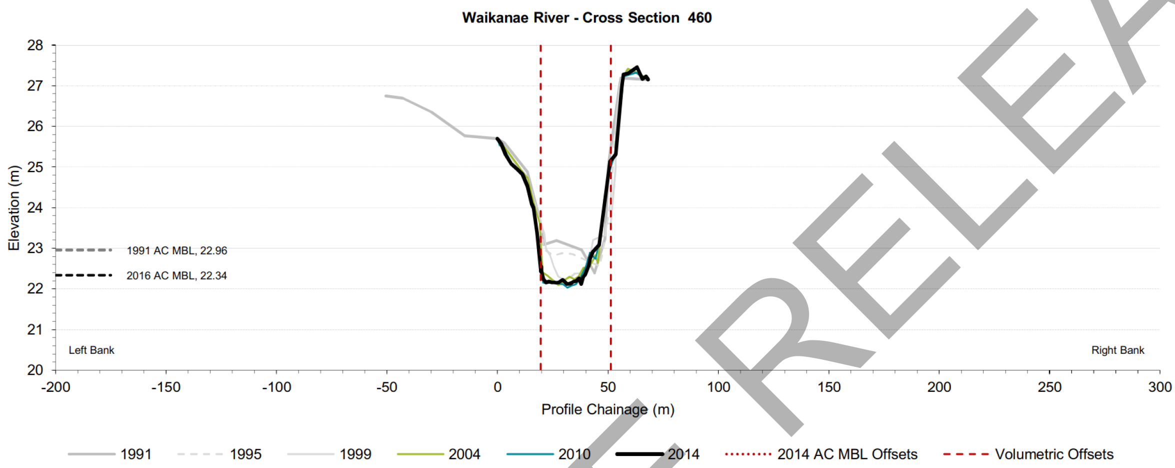
Waikanae River - Cross Section 430

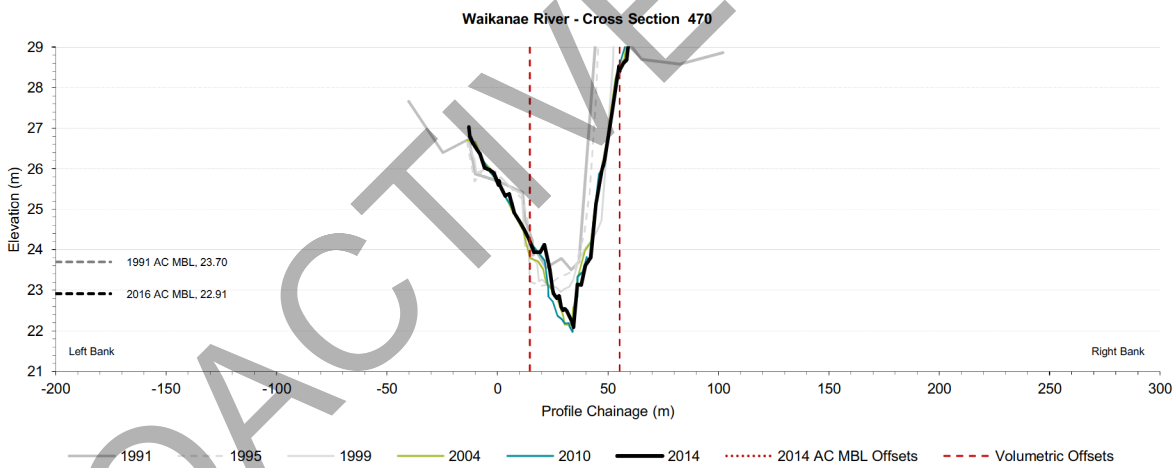


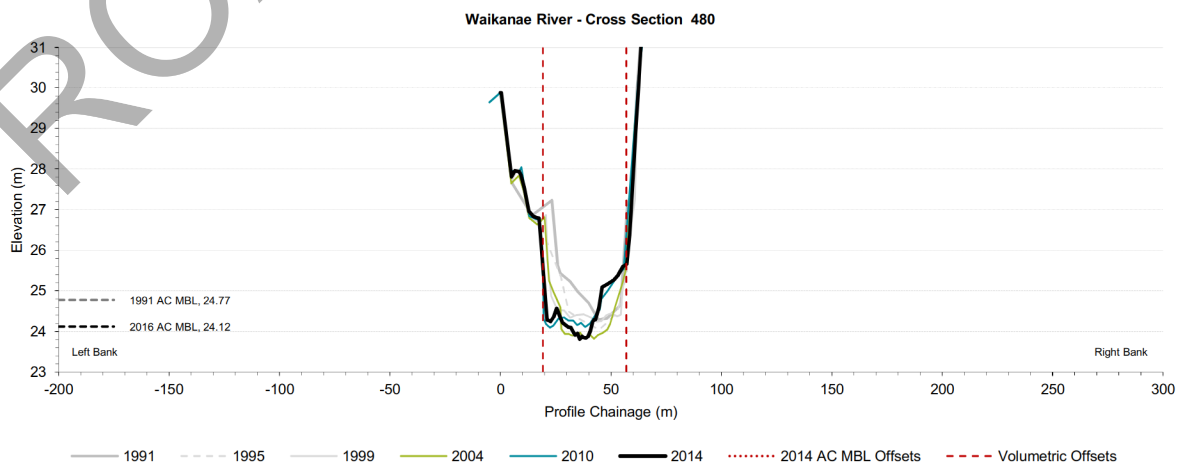
Waikanae River - Cross Section 440

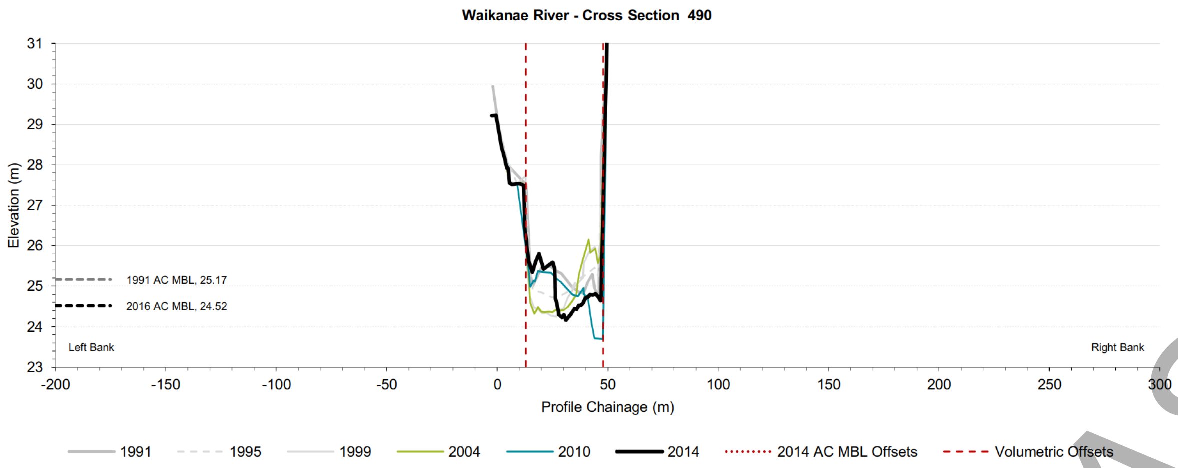


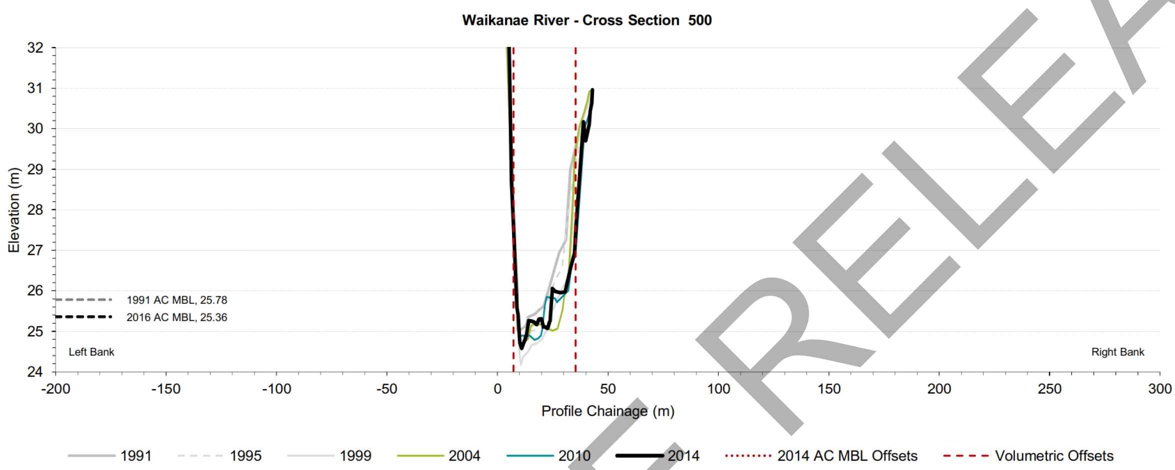

Waikanae River - Cross Section 450
Design Channel Zone
Elevation (m)
Profile Chainage (m)
1991 AC MBL, 22.26
2016 AC MBL, 21.52
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

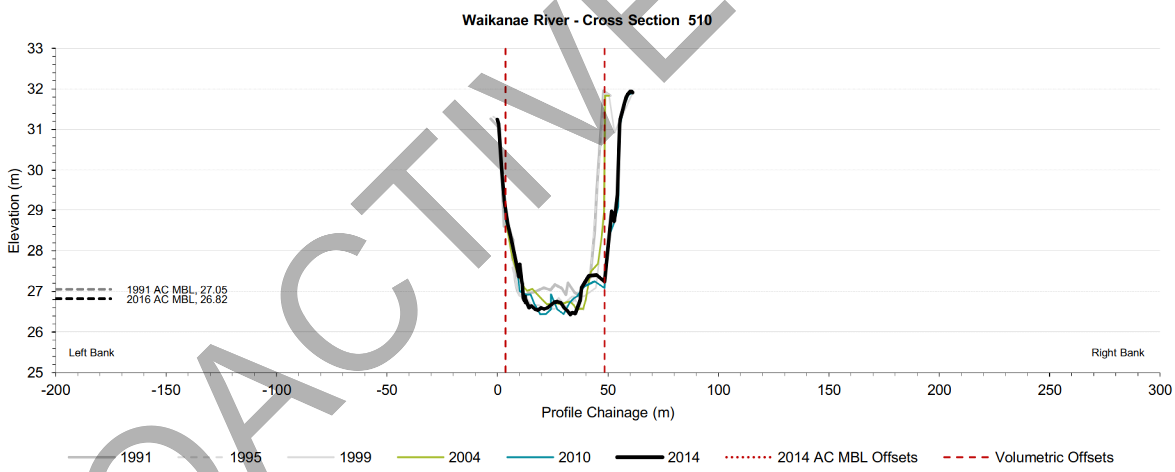

Waikanae River - Cross Section 460
Elevation (m)
Profile Chainage (m)
1991 AC MBL, 22.96
2016 AC MBL, 22.34
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

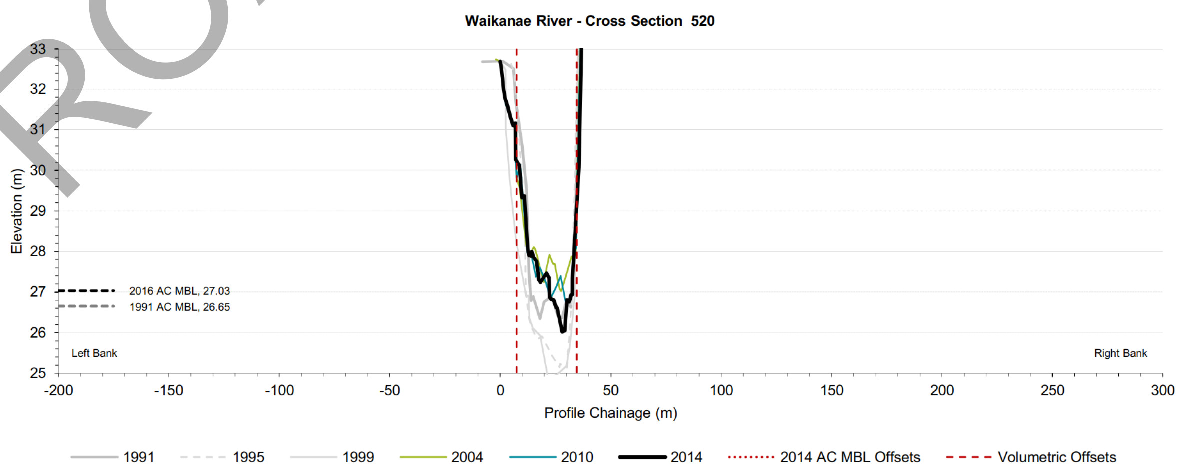

Waikanae River - Cross Section 470
Elevation (m)
Profile Chainage (m)
1991 AC MBL, 23.70
2016 AC MBL, 22.91
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

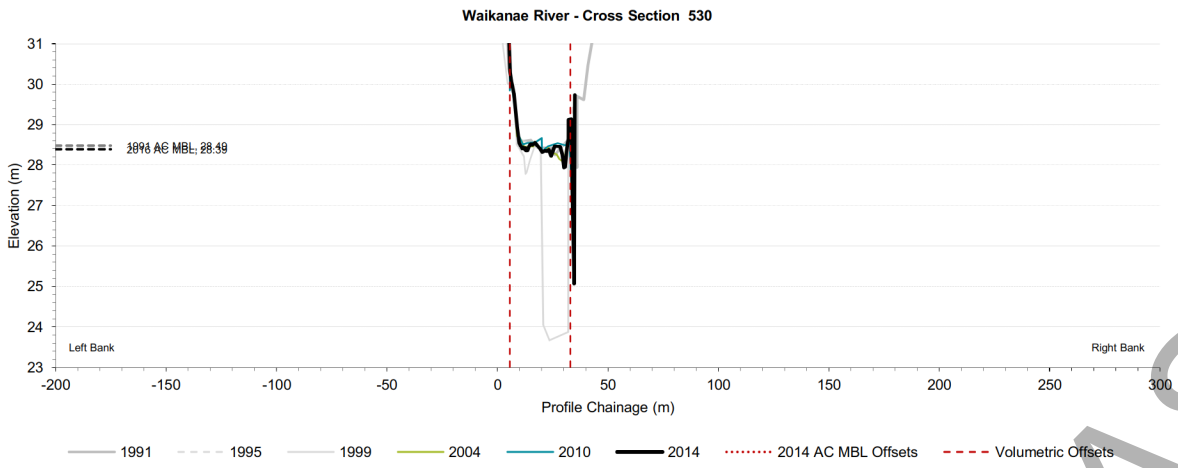

Waikanae River - Cross Section 480
Elevation (m)
Profile Chainage (m)
1991 AC MBL, 24.77
2016 AC MBL, 24.12
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

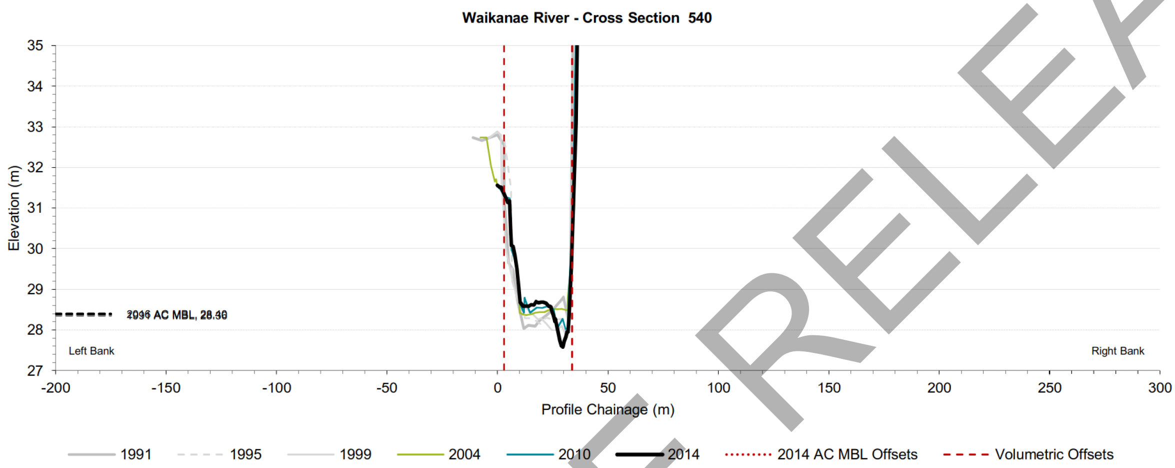

Waikanae River - Cross Section 490
Elevation (m)
1991 AC MBL, 25.17
2016 AC MBL, 24.52
Left Bank
Right Bank
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 500
Elevation (m)
1991 AC MBL, 25.78
2016 AC MBL, 25.36
Left Bank
Right Bank
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 510
Elevation (m)
1991 AC MBL, 27.05
2016 AC MBL, 26.82
Left Bank
Right Bank
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

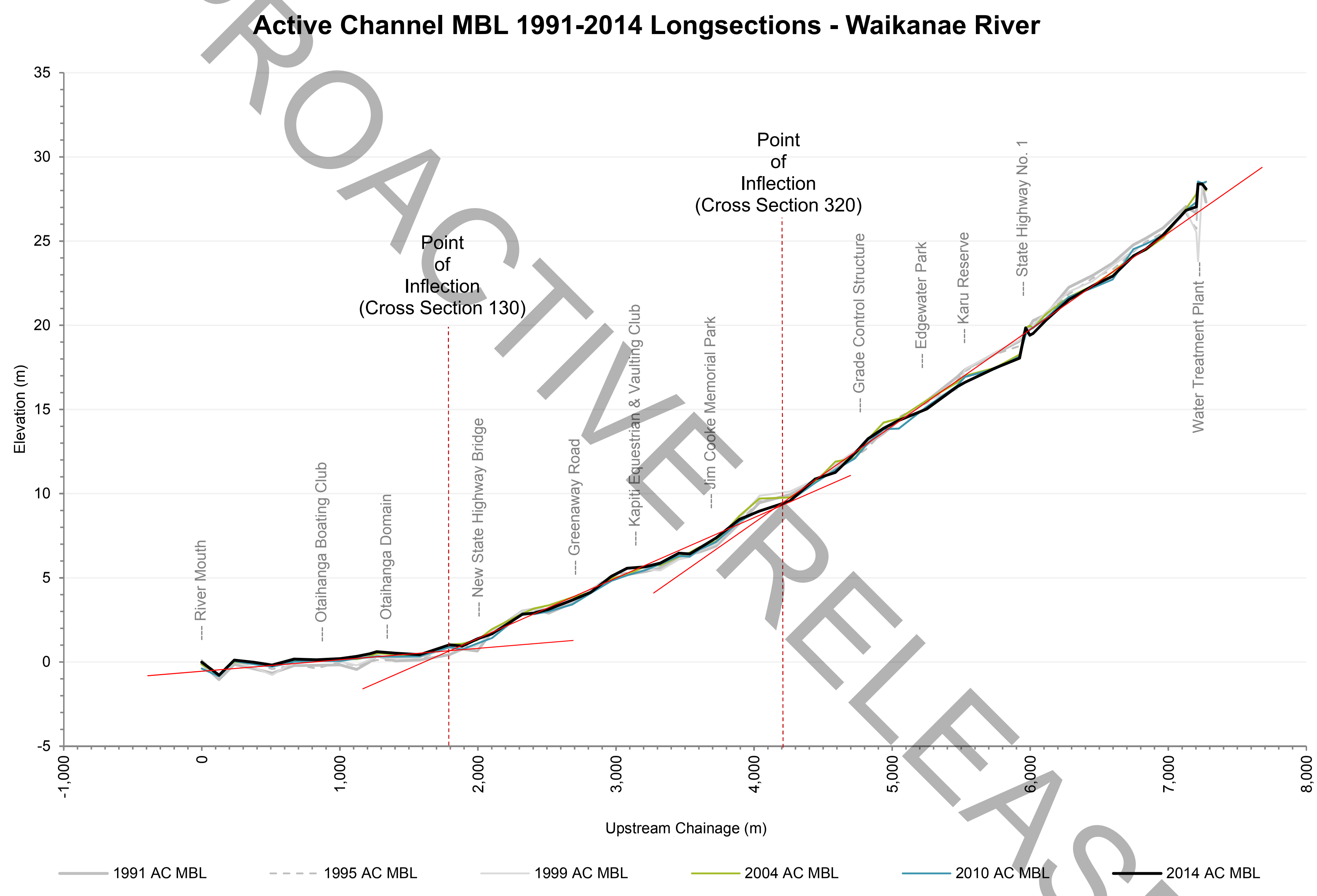

Waikanae River - Cross Section 520
Elevation (m)
2016 AC MBL, 27.03
1991 AC MBL, 26.65
Left Bank
Right Bank
Profile Chainage (m)
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 530
Elevation (m)
Profile Chainage (m)
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

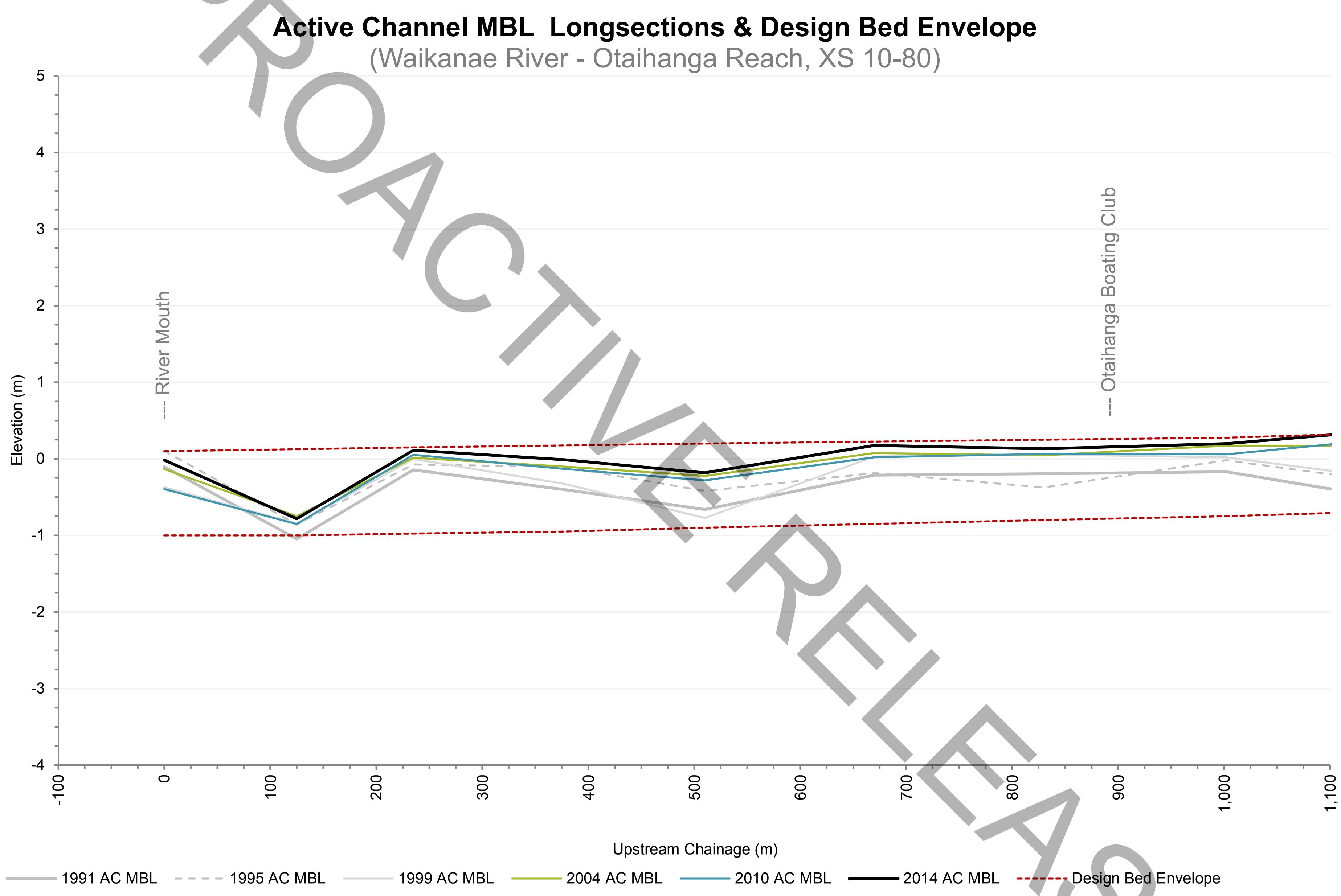

Waikanae River - Cross Section 540
Elevation (m)
Profile Chainage (m)
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets


Waikanae River - Cross Section 550
Elevation (m)
Profile Chainage (m)
2014 AC MBL, 28.10
1991 AC MBL, 27.31
Left Bank
Right Bank
1991
1995
1999
2004
2010
2014
2014 AC MBL Offsets
Volumetric Offsets

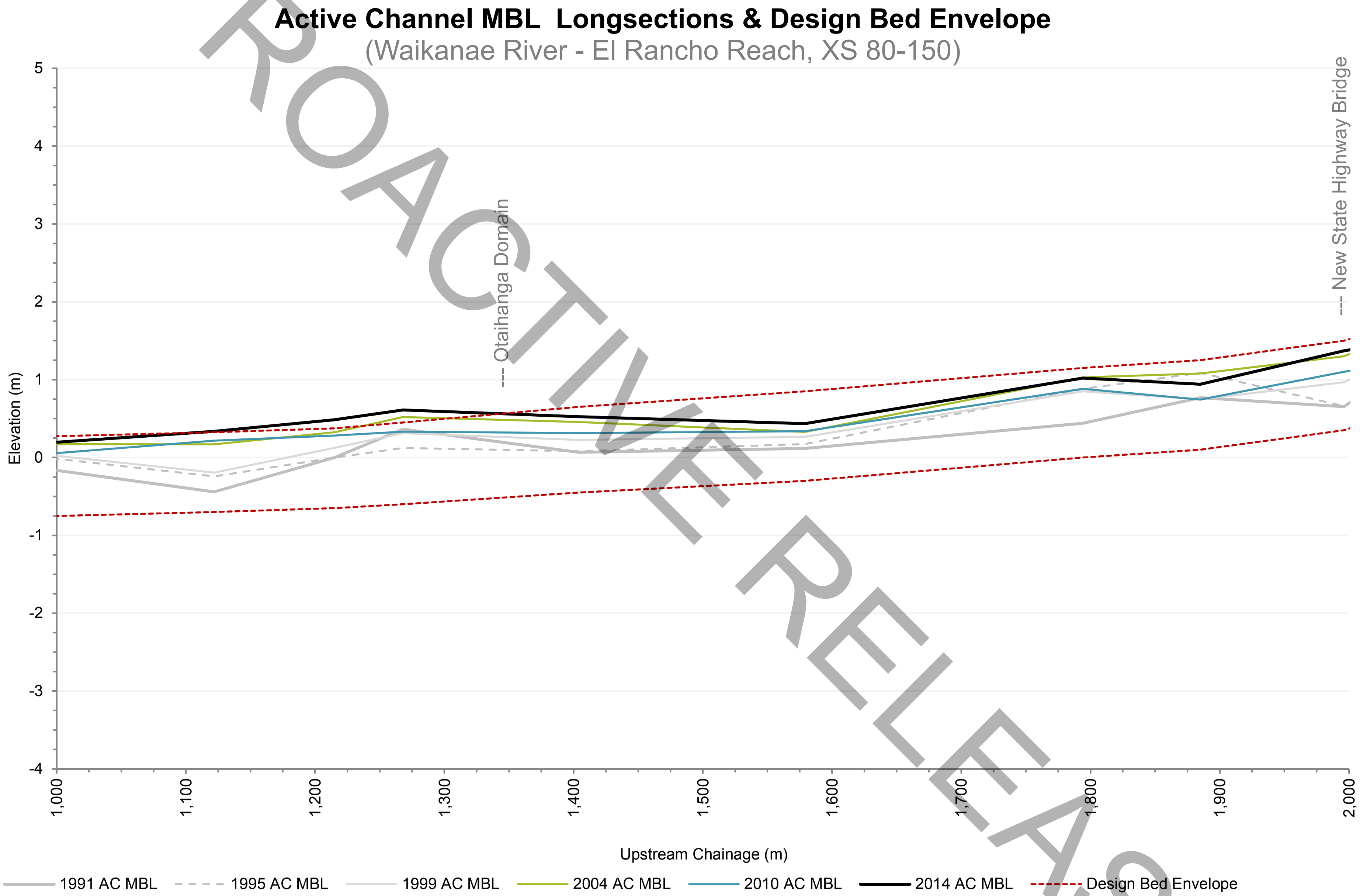
Appendix C – Active Channel MBL Longsections


Active Channel MBL 1991-2014 Longsections - Waikanae River
Elevation (m)
Upstream Chainage (m)
Point of Inflection (Cross Section 130)
Point of Inflection (Cross Section 320)
--- River Mouth
--- Otaihanga Boating Club
--- Otaihanga Domain
--- New State Highway Bridge
--- Greenaway Road
--- Kapiti Equestrian & Vaulting Club
--- Jim Cooke Memorial Park
--- Grade Control Structure
--- Edgewater Park
--- Karu Reserve
--- State Highway No. 1
Water Treatment Plant ---
1991 AC MBL
1995 AC MBL
1999 AC MBL
2004 AC MBL
2010 AC MBL
2014 AC MBL
PROACTIVE RELEASE

Appendix D – Reach by Reach MBL Longsections and Design Bed Envelope

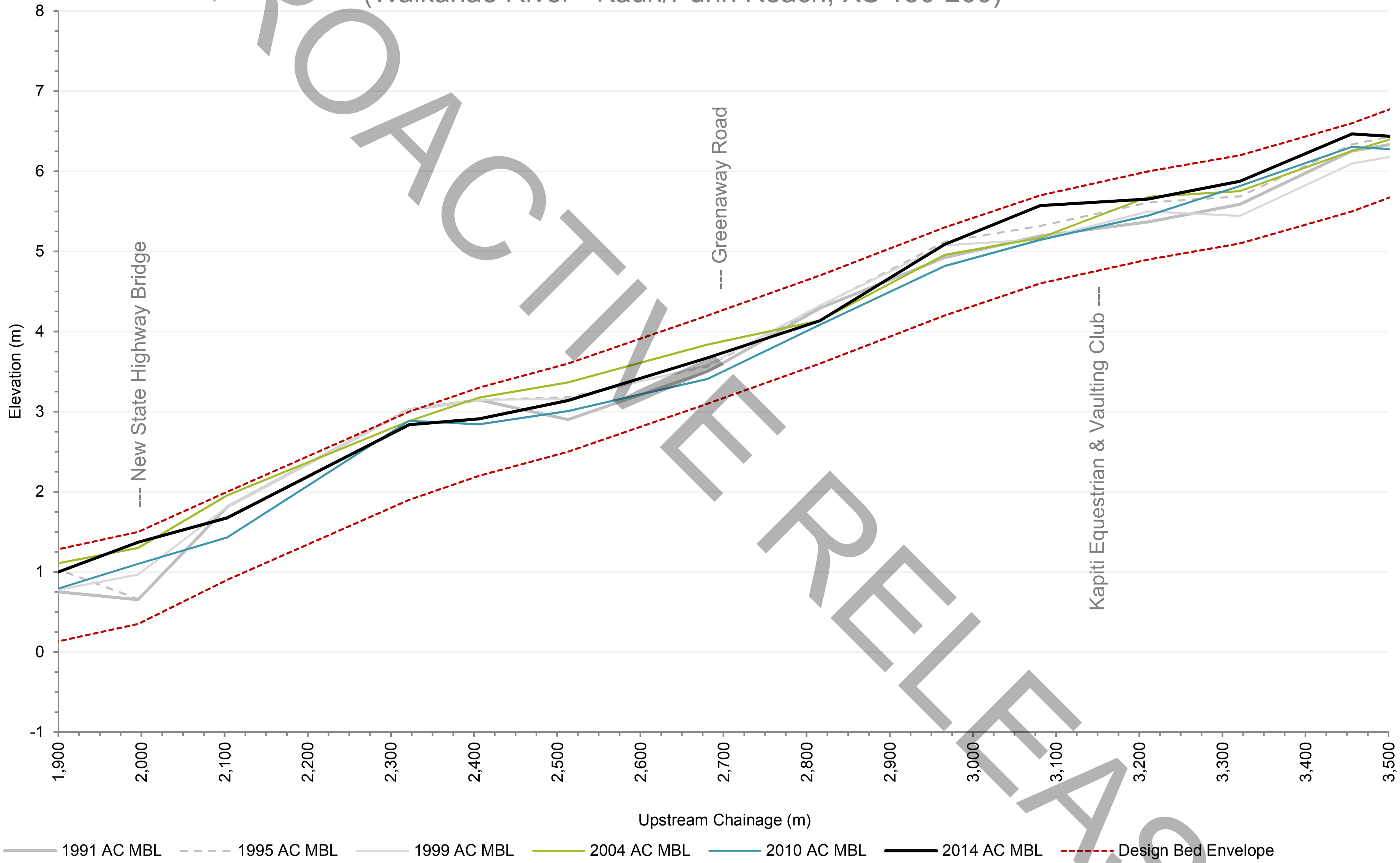


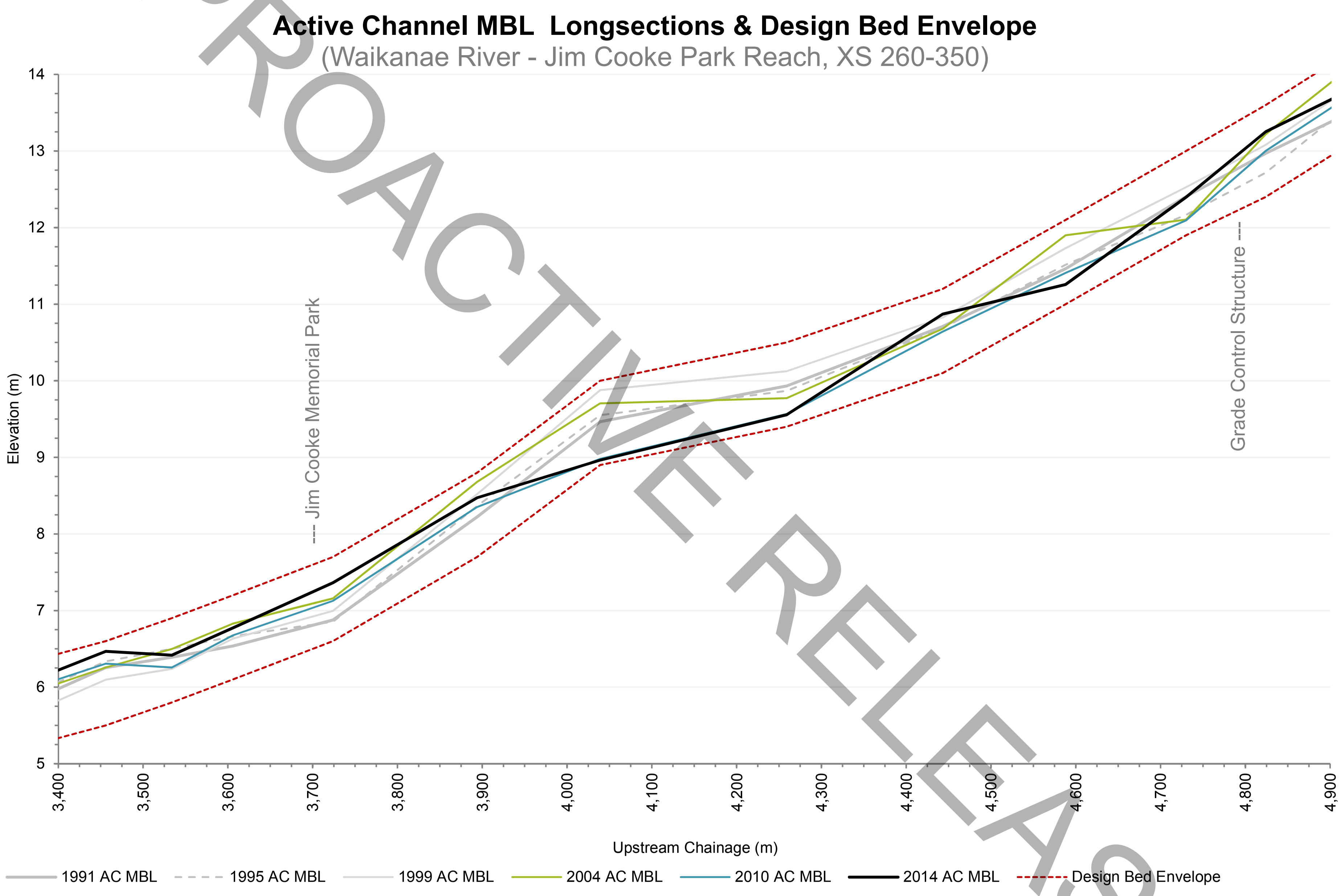
Active Channel MBL Longsections & Design Bed Envelope
(Waikanae River - Otaihanga Reach, XS 10-80)
--- River Mouth
--- Otaihanga Boating Club
Elevation (m)
5
4
3
2
1
0
-1
-2
-3
-4
-100
0
100
200
300
400
500
600
700
800
900
1,000
1,100
Upstream Chainage (m)
1991 AC MBL
1995 AC MBL
1999 AC MBL
2004 AC MBL
2010 AC MBL
2014 AC MBL
Design Bed Envelope


Active Channel MBL Longsections & Design Bed Envelope
(Waikanae River - El Rancho Reach, XS 80-150)
Elevation (m)
5
4
3
2
1
0
-1
-2
-3
-4
1,000
1,100
1,200
1,300
1,400
1,500
1,600
1,700
1,800
1,900
2,000
Upstream Chainage (m)
--- Otaihanga Domain
--- New State Highway Bridge
1991 AC MBL
1995 AC MBL
1999 AC MBL
2004 AC MBL
2010 AC MBL
2014 AC MBL
Design Bed Envelope

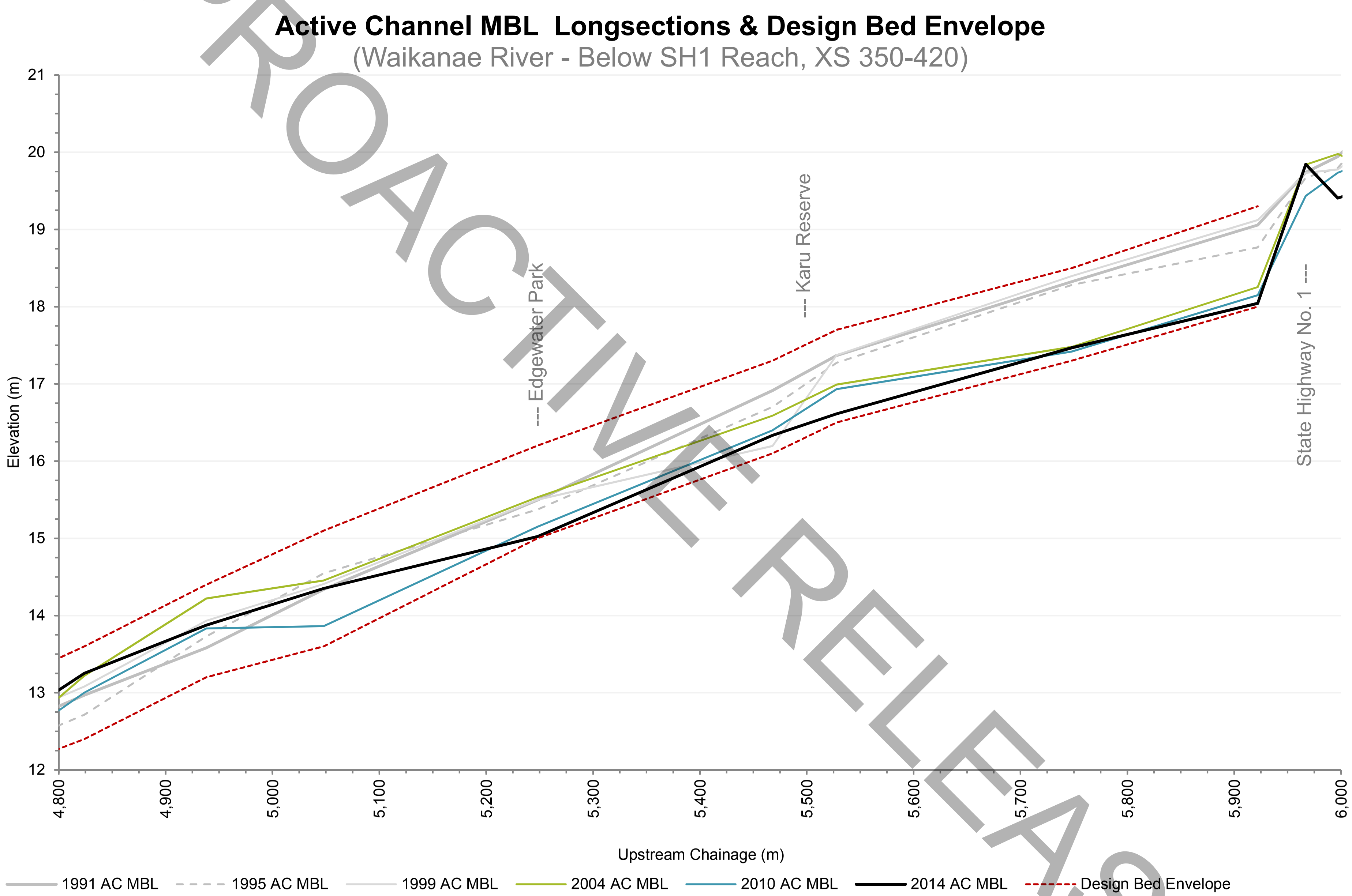
Active Channel MBL Longsections & Design Bed Envelope

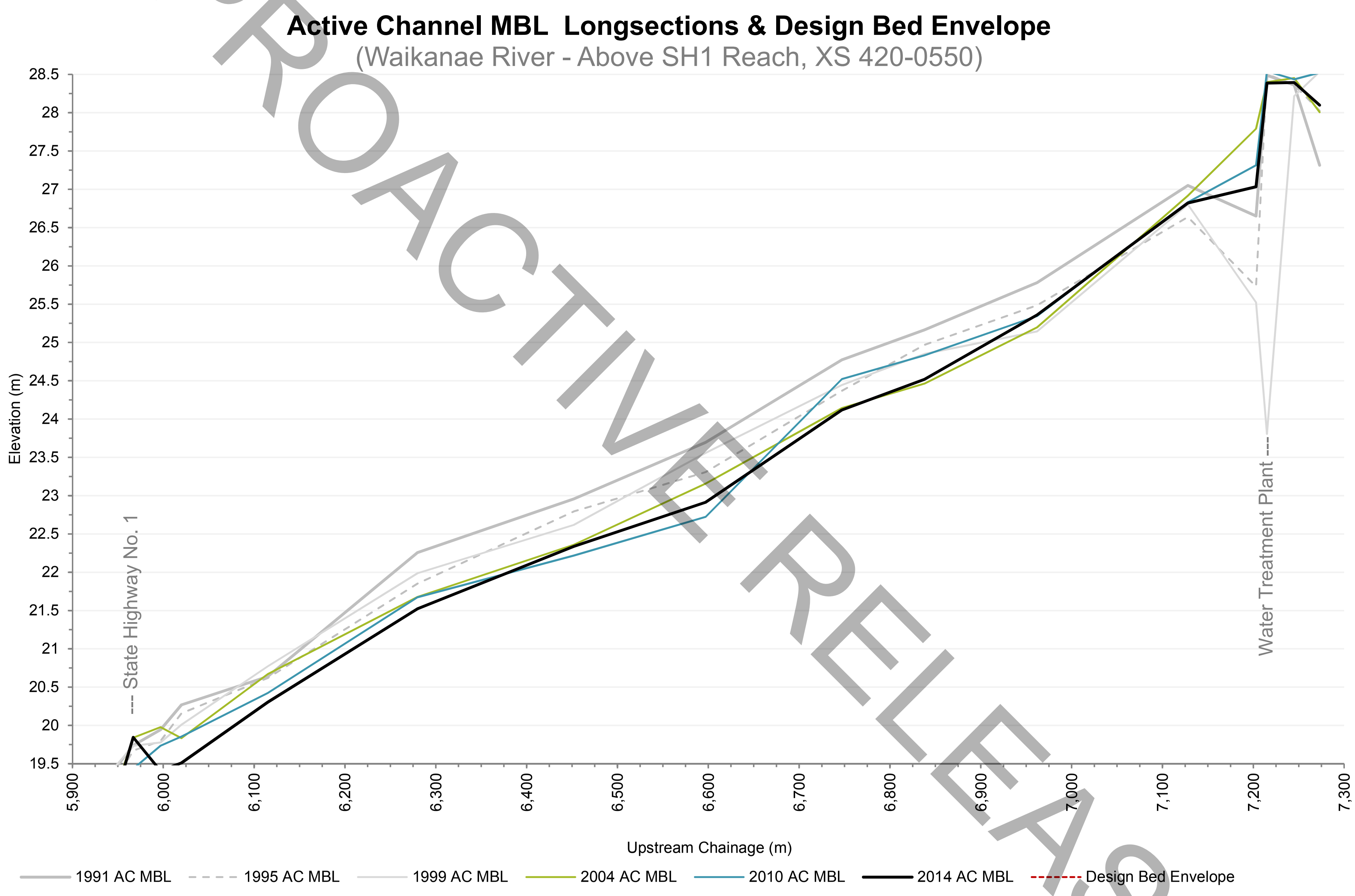
(Waikanae River - Kauri/Puriri Reach, XS 150-260)





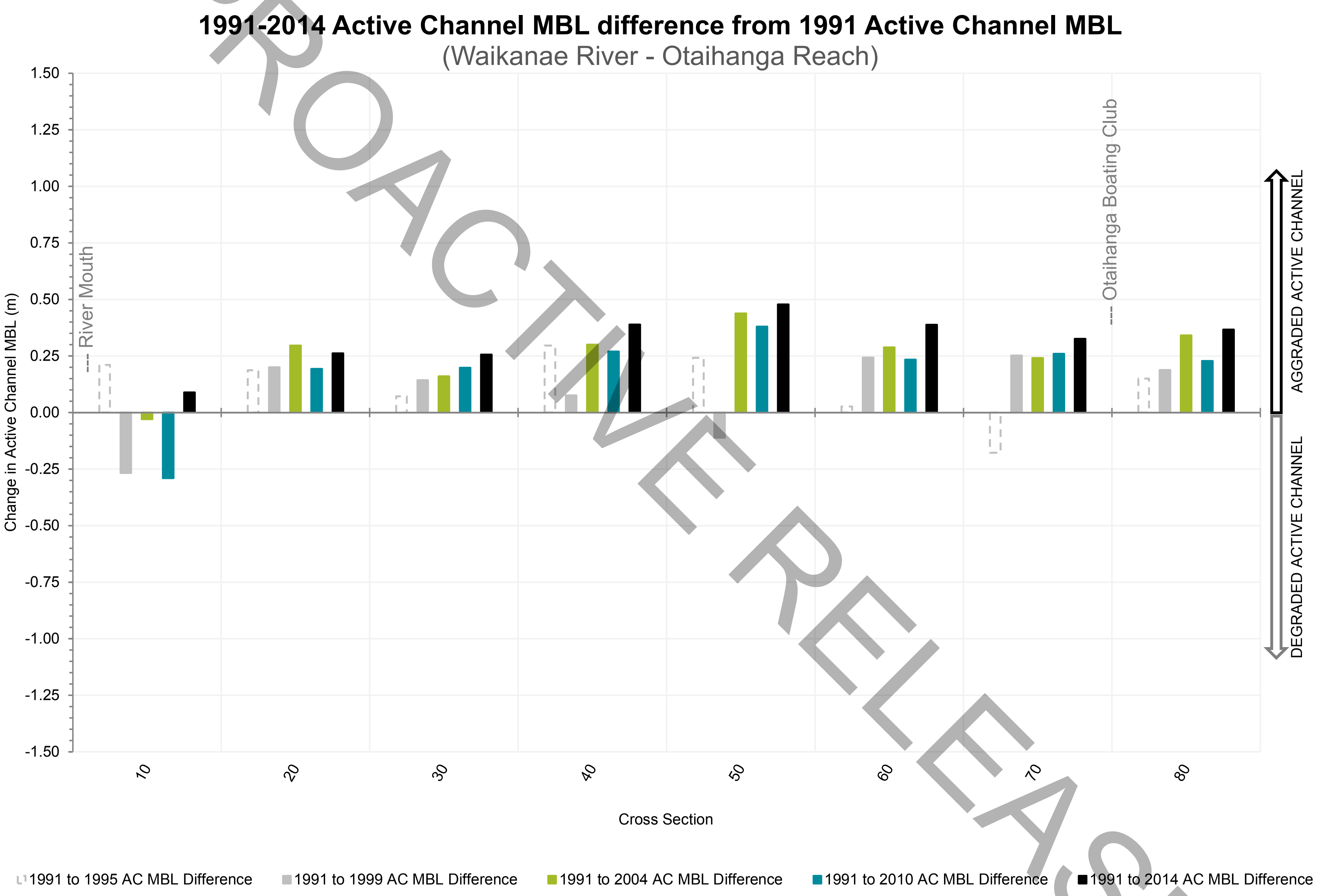
Active Channel MBL Longsections & Design Bed Envelope
(Waikanae River - Jim Cooke Park Reach, XS 260-350)
Elevation (m)
14
13
12
11
10
9
8
7
6
5
3,400
3,500
3,600
3,700
3,800
3,900
4,000
4,100
4,200
4,300
4,400
4,500
4,600
4,700
4,800
4,900
Upstream Chainage (m)
--- Jim Cooke Memorial Park
Grade Control Structure ---
1991 AC MBL
1995 AC MBL
1999 AC MBL
2004 AC MBL
2010 AC MBL
2014 AC MBL
Design Bed Envelope

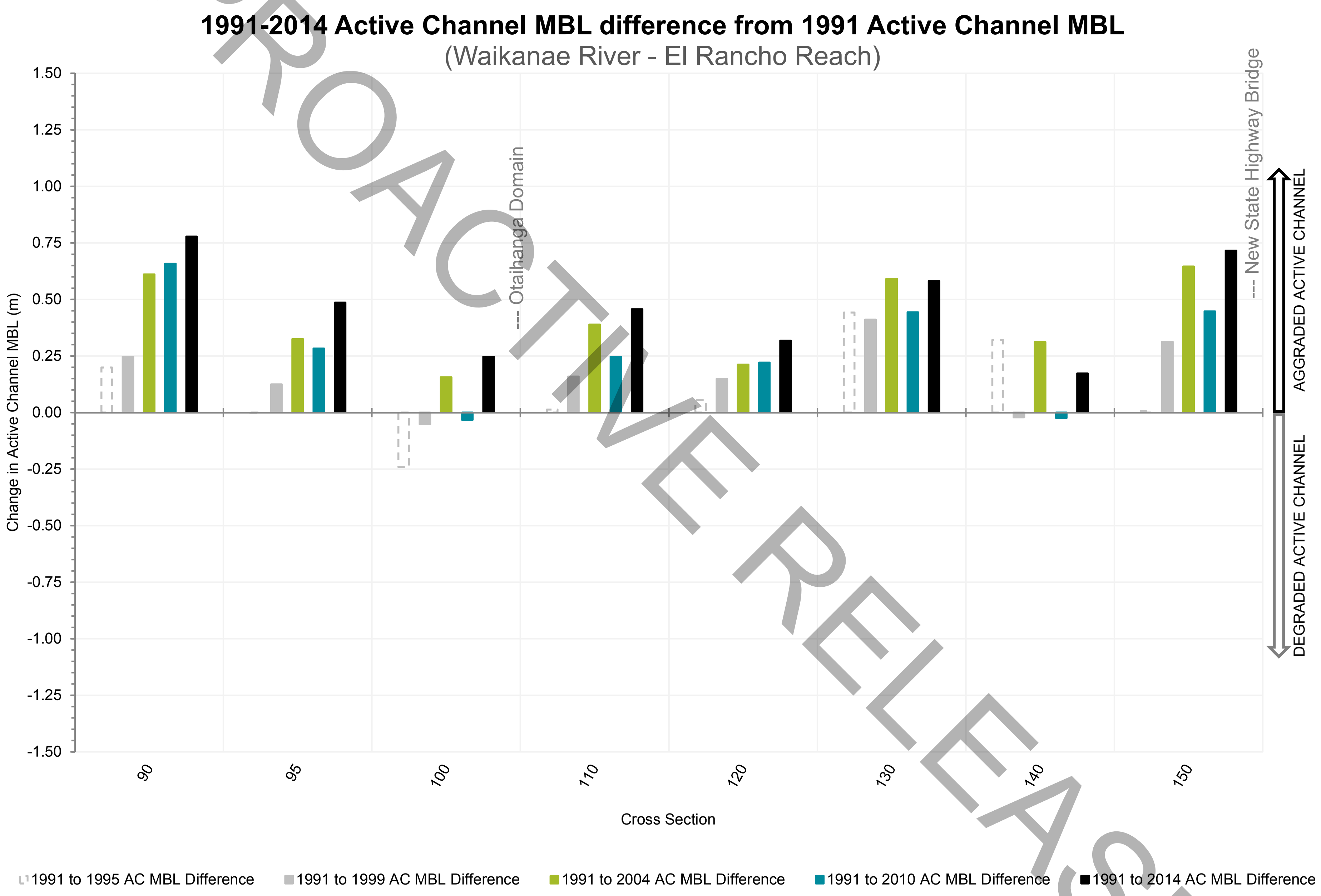

Active Channel MBL Longsections & Design Bed Envelope
(Waikanae River - Below SH1 Reach, XS 350-420)
Elevation (m)
21
20
19
18
17
16
15
14
13
12
4,800
4,900
5,000
5,100
5,200
5,300
5,400
5,500
5,600
5,700
5,800
5,900
6,000
Upstream Chainage (m)
--- Edgewater Park
--- Karu Reserve
State Highway No. 1 ---
1991 AC MBL
1995 AC MBL
1999 AC MBL
2004 AC MBL
2010 AC MBL
2014 AC MBL
Design Bed Envelope

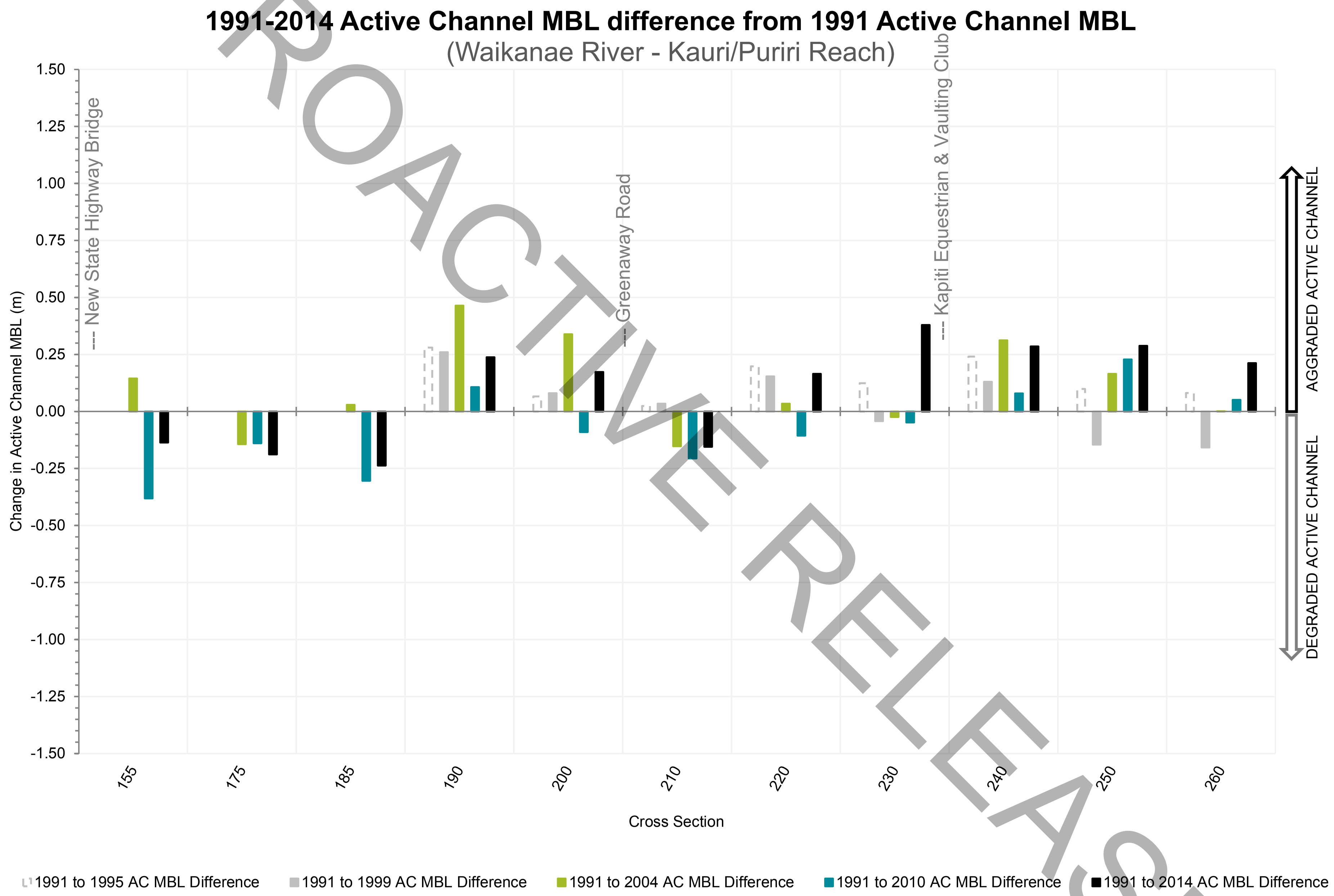


Active Channel MBL Longsections & Design Bed Envelope
(Waikanae River - Above SH1 Reach, XS 420-0550)
Elevation (m)
28.5
28
27.5
27
26.5
26
25.5
25
24.5
24
23.5
23
22.5
22
21.5
21
20.5
20
19.5
5,900
6,000
6,100
6,200
6,300
6,400
6,500
6,600
6,700
6,800
6,900
7,000
7,100
7,200
7,300
Upstream Chainage (m)
State Highway No. 1
Water Treatment Plant
1991 AC MBL
1995 AC MBL
1999 AC MBL
2004 AC MBL
2010 AC MBL
2014 AC MBL
Design Bed Envelope

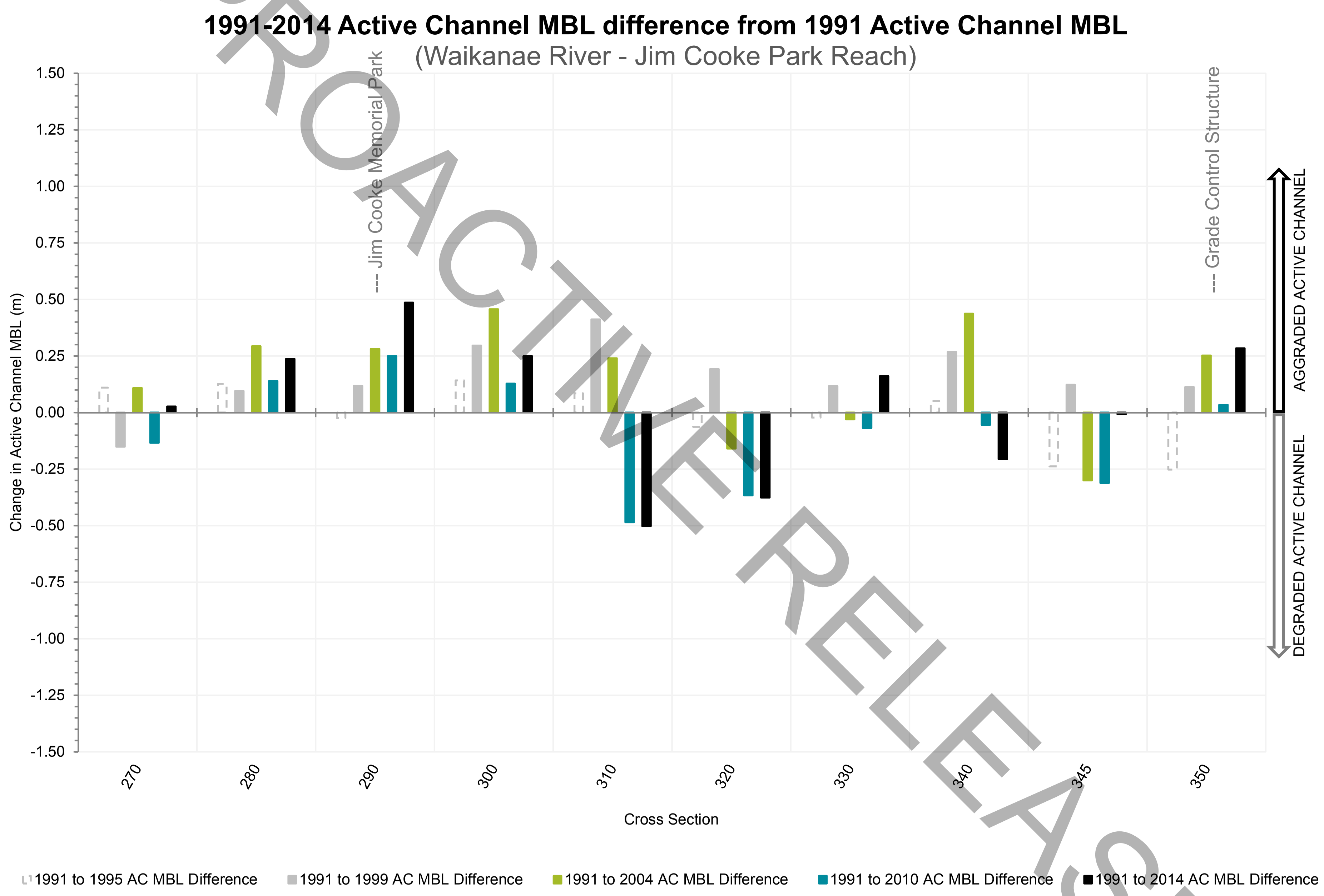
Appendix E – Reach by Reach Active Channel MBLs


1991-2014 Active Channel MBL difference from 1991 Active Channel MBL
(Waikanae River - Otaihanga Reach)
Change in Active Channel MBL (m)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
River Mouth
Otaihanga Boating Club
AGGRADED ACTIVE CHANNEL
DEGRADED ACTIVE CHANNEL
10
20
30
40
50
60
70
80
Cross Section
1991 to 1995 AC MBL Difference
1991 to 1999 AC MBL Difference
1991 to 2004 AC MBL Difference
1991 to 2010 AC MBL Difference
1991 to 2014 AC MBL Difference

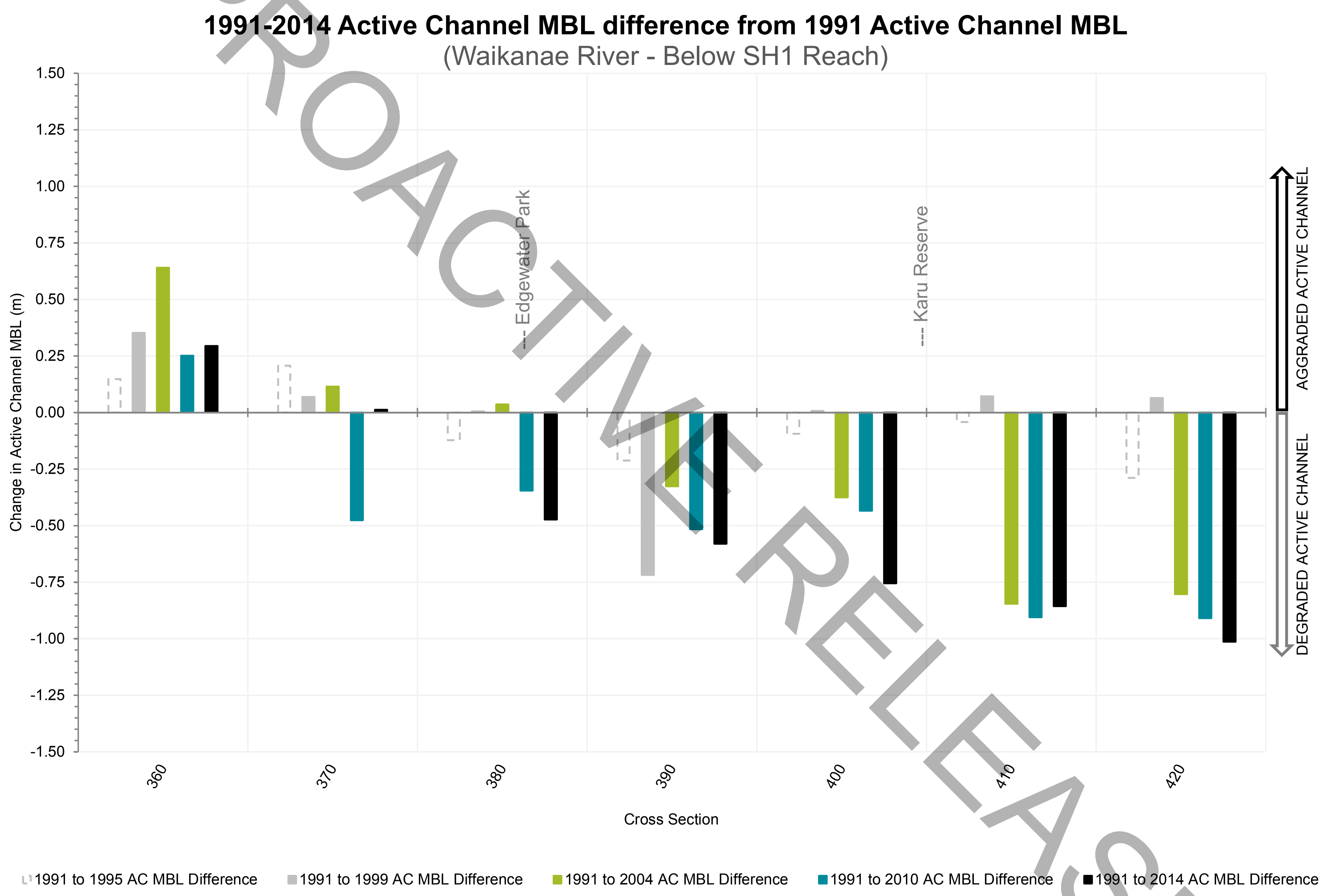

1991-2014 Active Channel MBL difference from 1991 Active Channel MBL
(Waikanae River - El Rancho Reach)
Change in Active Channel MBL (m)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
--- Otaihanga Domain
--- New State Highway Bridge
AGGRADED ACTIVE CHANNEL
DEGRADED ACTIVE CHANNEL
90
95
100
110
120
130
140
150
Cross Section
1991 to 1995 AC MBL Difference
1991 to 1999 AC MBL Difference
1991 to 2004 AC MBL Difference
1991 to 2010 AC MBL Difference
1991 to 2014 AC MBL Difference



1991-2014 Active Channel MBL difference from 1991 Active Channel MBL
(Waikanae River - Kauri/Puriri Reach)
Change in Active Channel MBL (m)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
New State Highway Bridge
Greenaway Road
Kapiti Equestrian & Vaulting Club
AGGRADED ACTIVE CHANNEL
DEGRADED ACTIVE CHANNEL
155
175
185
190
200
210
220
230
240
250
260
Cross Section
1991 to 1995 AC MBL Difference
1991 to 1999 AC MBL Difference
1991 to 2004 AC MBL Difference
1991 to 2010 AC MBL Difference
1991 to 2014 AC MBL Difference



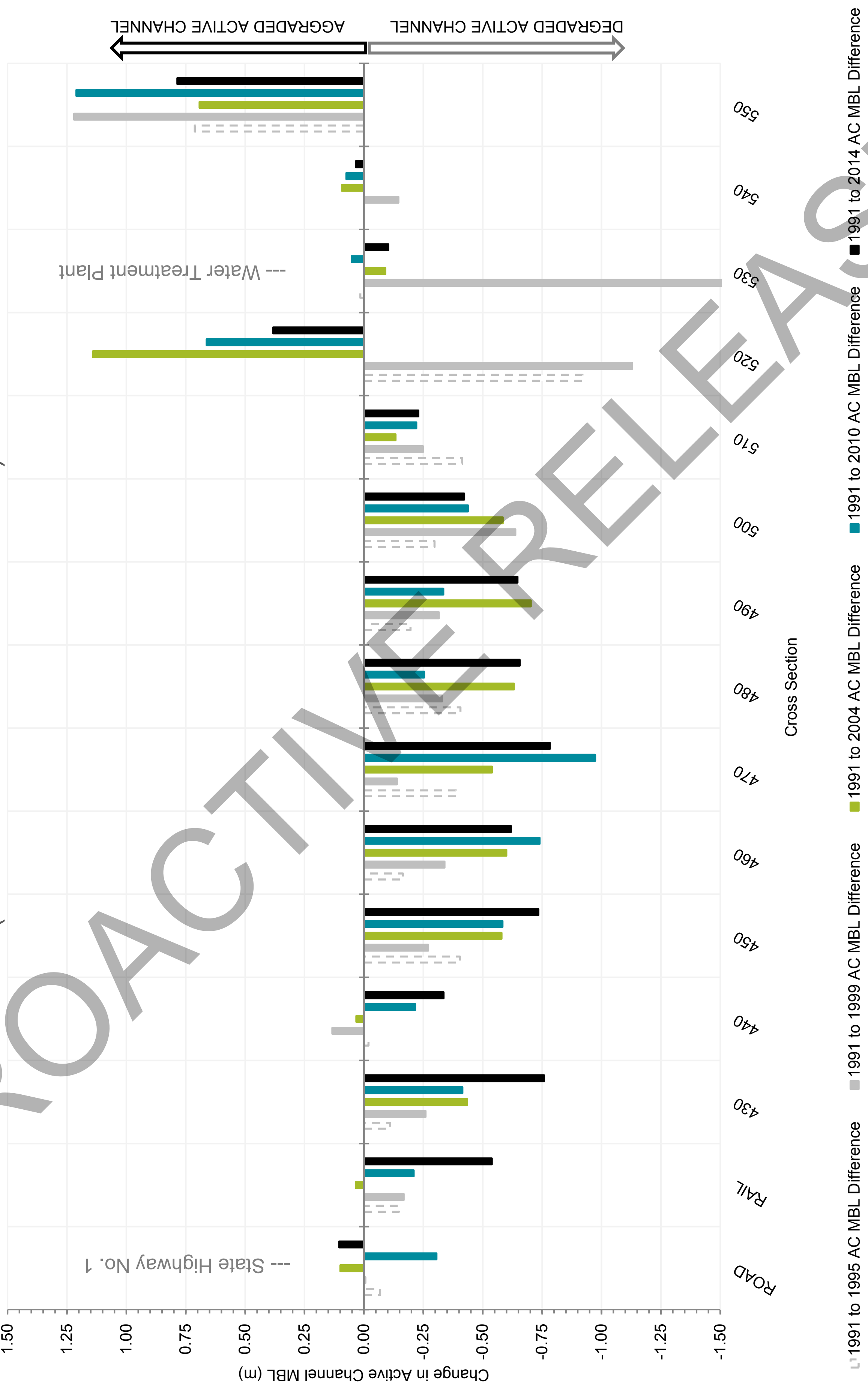
1991-2014 Active Channel MBL difference from 1991 Active Channel MBL
(Waikanae River - Jim Cooke Park Reach)
--- Jim Cooke Memorial Park
--- Grade Control Structure
AGGRADED ACTIVE CHANNEL
DEGRADED ACTIVE CHANNEL
Change in Active Channel MBL (m)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
270
280
290
300
310
320
330
340
345
350
Cross Section
1991 to 1995 AC MBL Difference
1991 to 1999 AC MBL Difference
1991 to 2004 AC MBL Difference
1991 to 2010 AC MBL Difference
1991 to 2014 AC MBL Difference

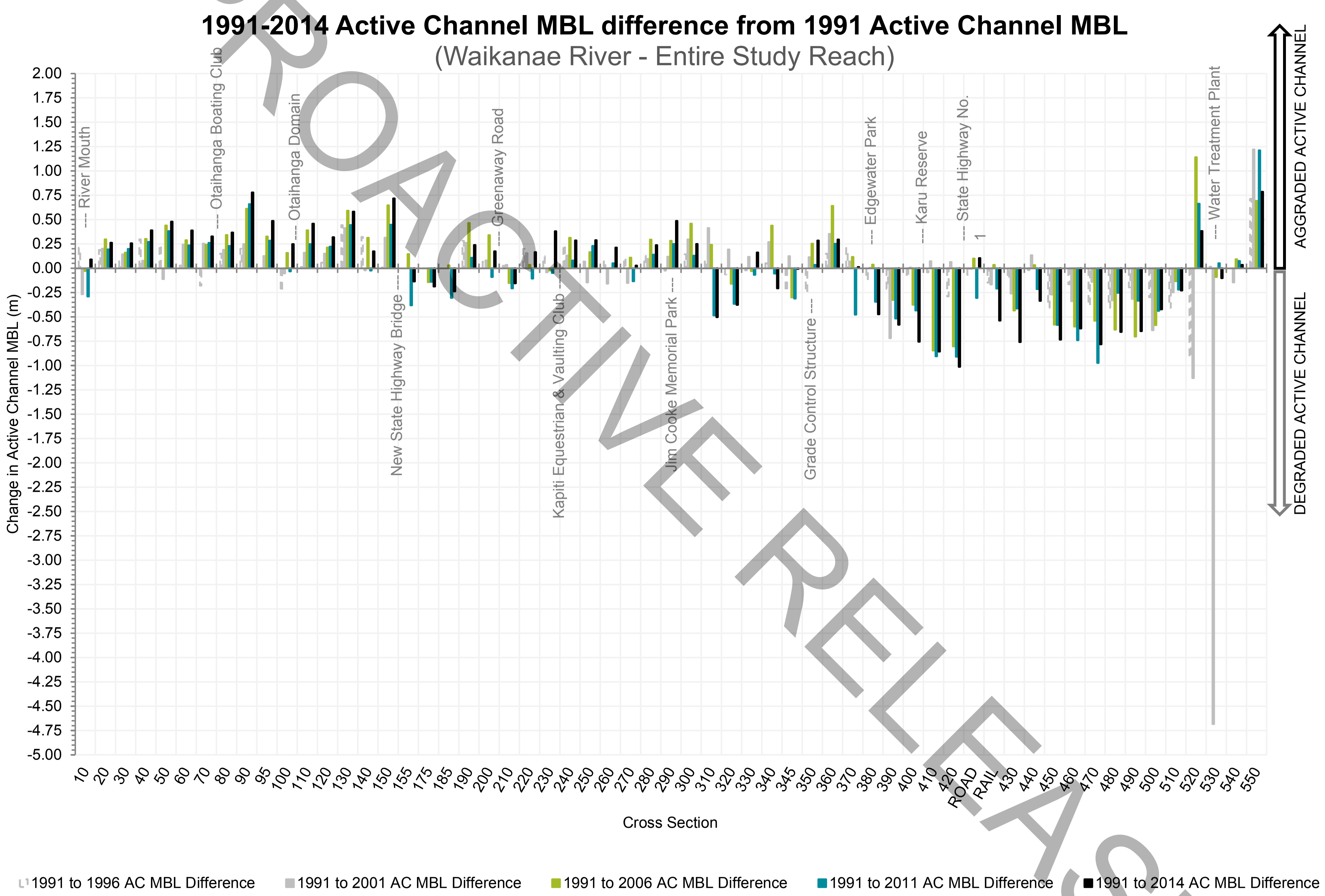


1991-2014 Active Channel MBL difference from 1991 Active Channel MBL
(Waikanae River - Below SH1 Reach)
Change in Active Channel MBL (m)
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
--- Edgewater Park
--- Karu Reserve
AGGRADED ACTIVE CHANNEL
DEGRADED ACTIVE CHANNEL
360
370
380
390
400
410
420
Cross Section
1991 to 1995 AC MBL Difference
1991 to 1999 AC MBL Difference
1991 to 2004 AC MBL Difference
1991 to 2010 AC MBL Difference
1991 to 2014 AC MBL Difference

1991-2014 Active Channel MBL difference from 1991 Active Channel MBL

(Waikanae River - Above SH1 Reach)

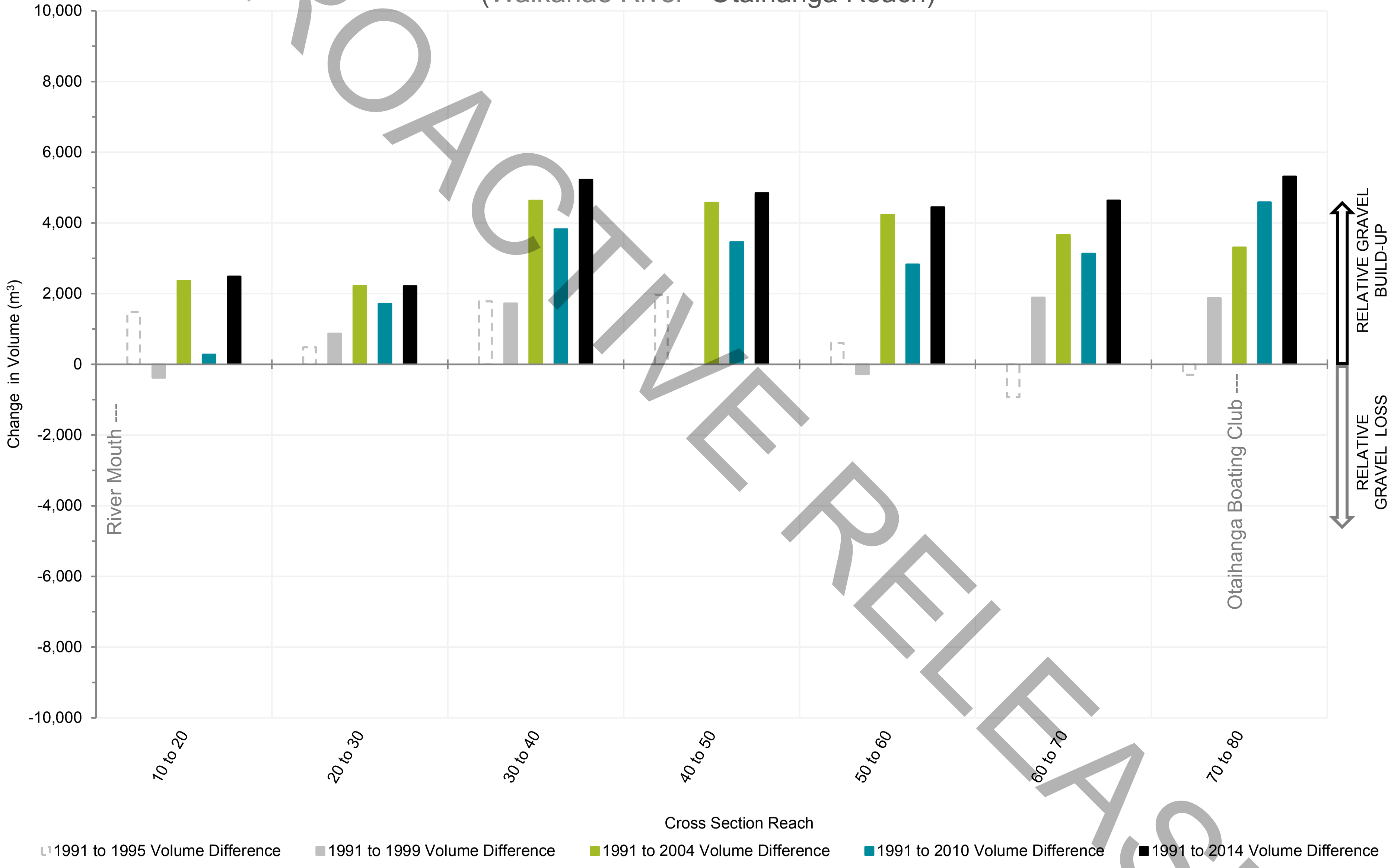



1991-2014 Active Channel MBL difference from 1991 Active Channel MBL
(Waikanae River - Entire Study Reach)
Change in Active Channel MBL (m)
Cross Section
AGGRADED ACTIVE CHANNEL
DEGRADED ACTIVE CHANNEL
--- River Mouth
--- Otaihanga Boating Club
--- Otaihanga Domain
New State Highway Bridge ---
--- Greenaway Road
Kapiti Equestrian & Vaulting Club ---
Jim Cooke Memorial Park ---
Grade Control Structure ---
--- Edgewater Park
--- Karu Reserve
--- State Highway No. 1
--- Water Treatment Plant
1991 to 1996 AC MBL Difference
1991 to 2001 AC MBL Difference
1991 to 2006 AC MBL Difference
1991 to 2011 AC MBL Difference
1991 to 2014 AC MBL Difference
PROACTIVE RELEASE

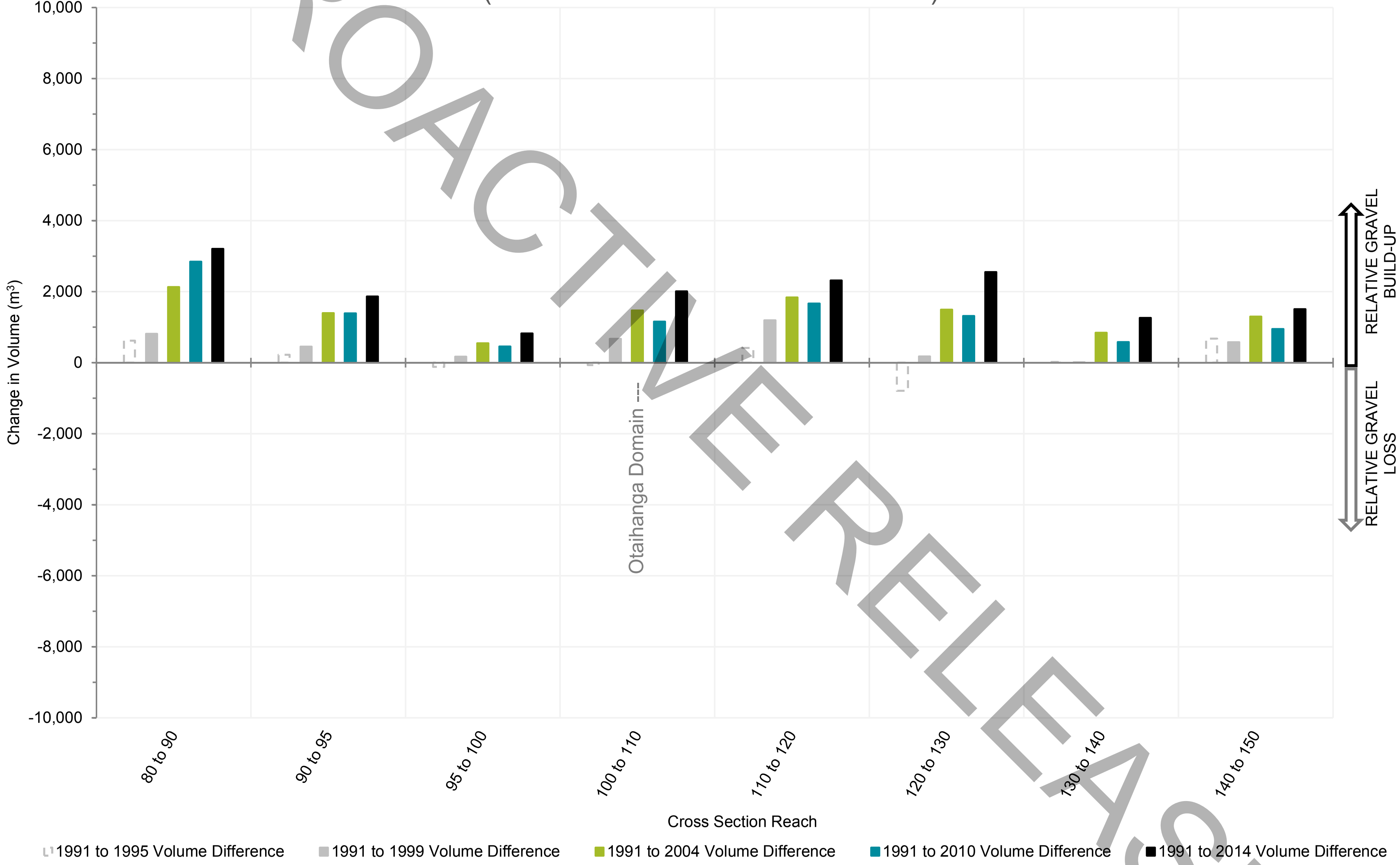
Appendix F – Reach by Reach Monitored Volume Estimates

1991-2014 Surveyed Volume difference from 1991 Floodway

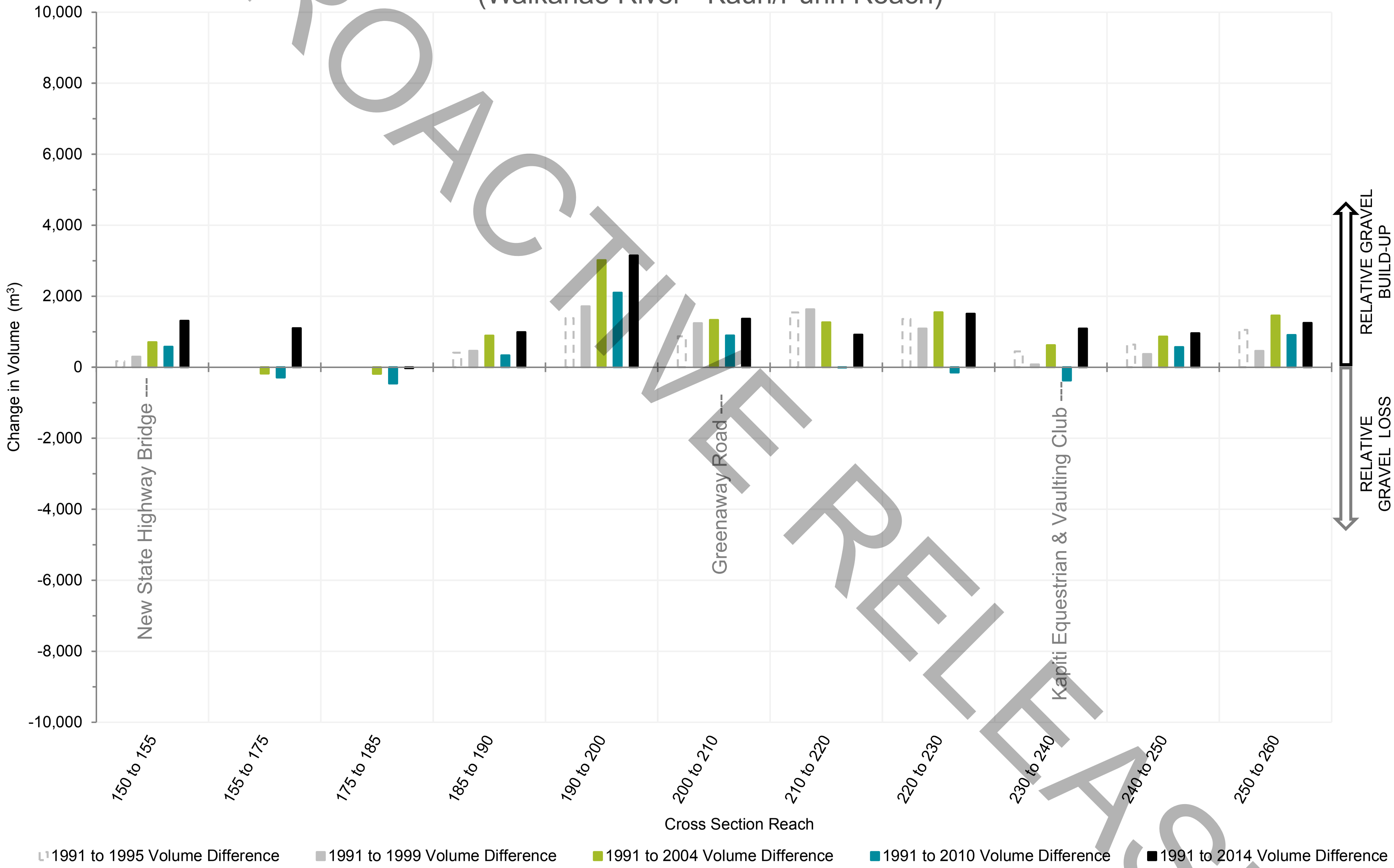
(Waikanae River - Otaihanga Reach)

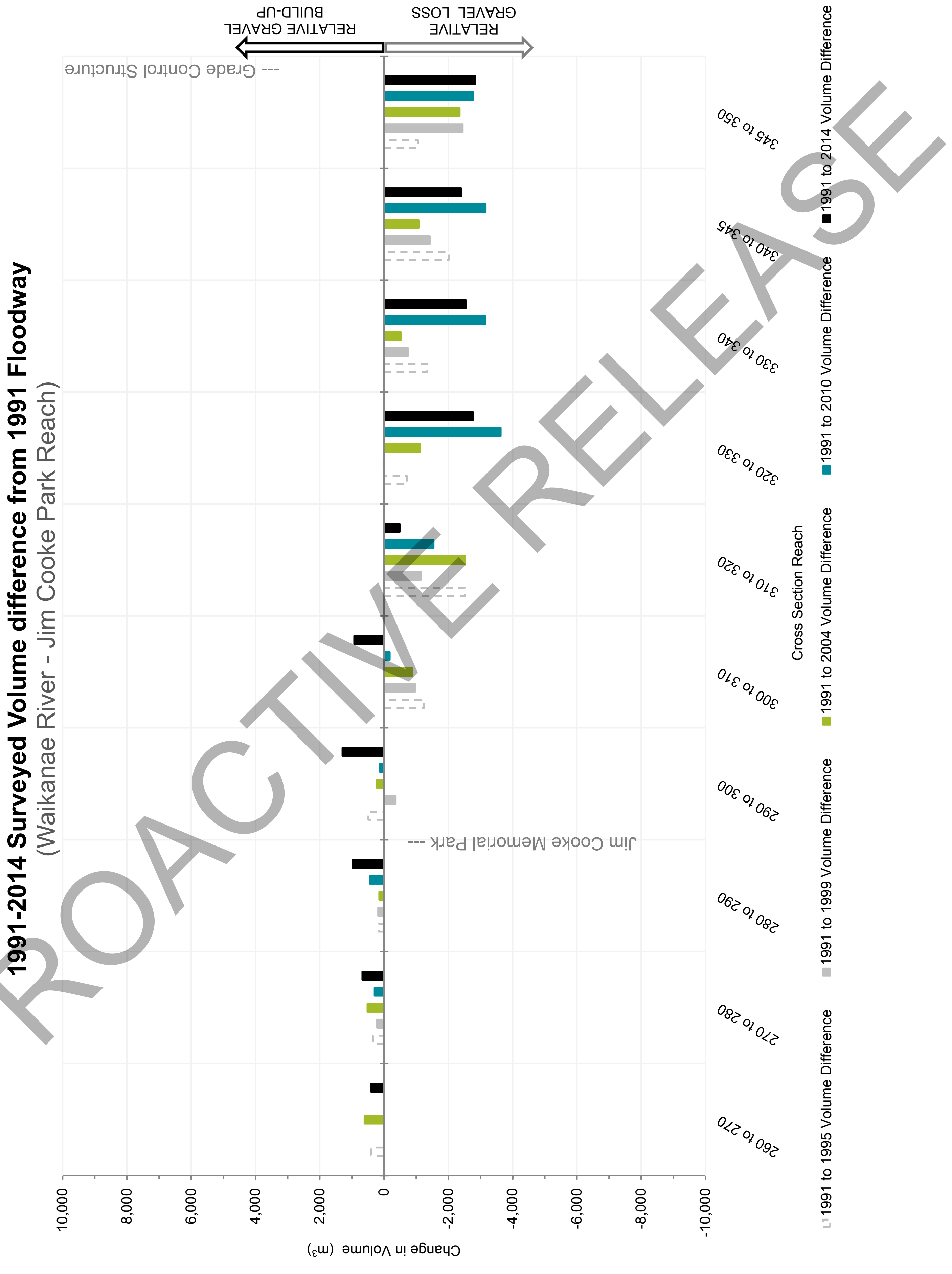


1991-2014 Surveyed Volume difference from 1991 Floodway
(Waikanae River - El Rancho Reach)

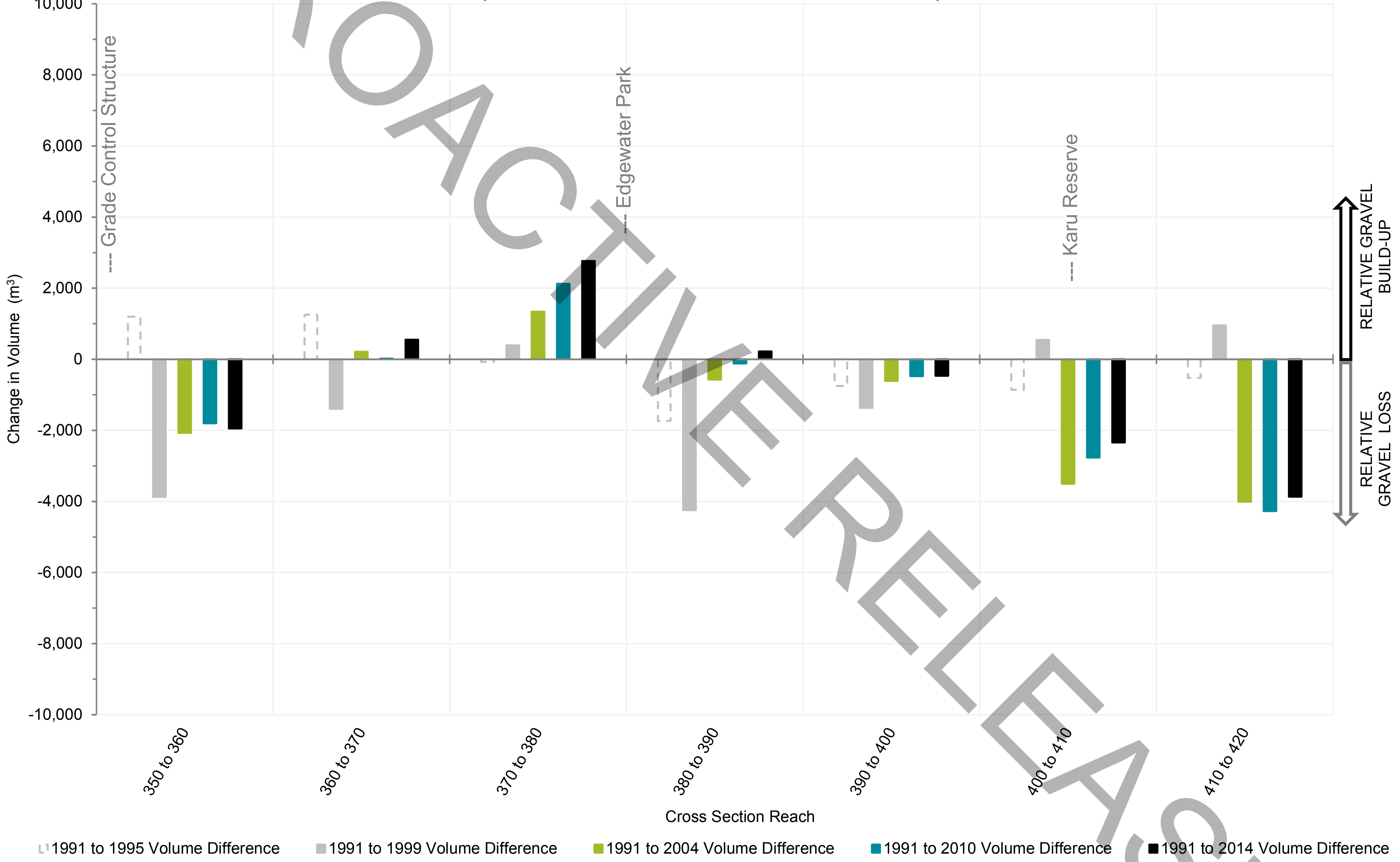


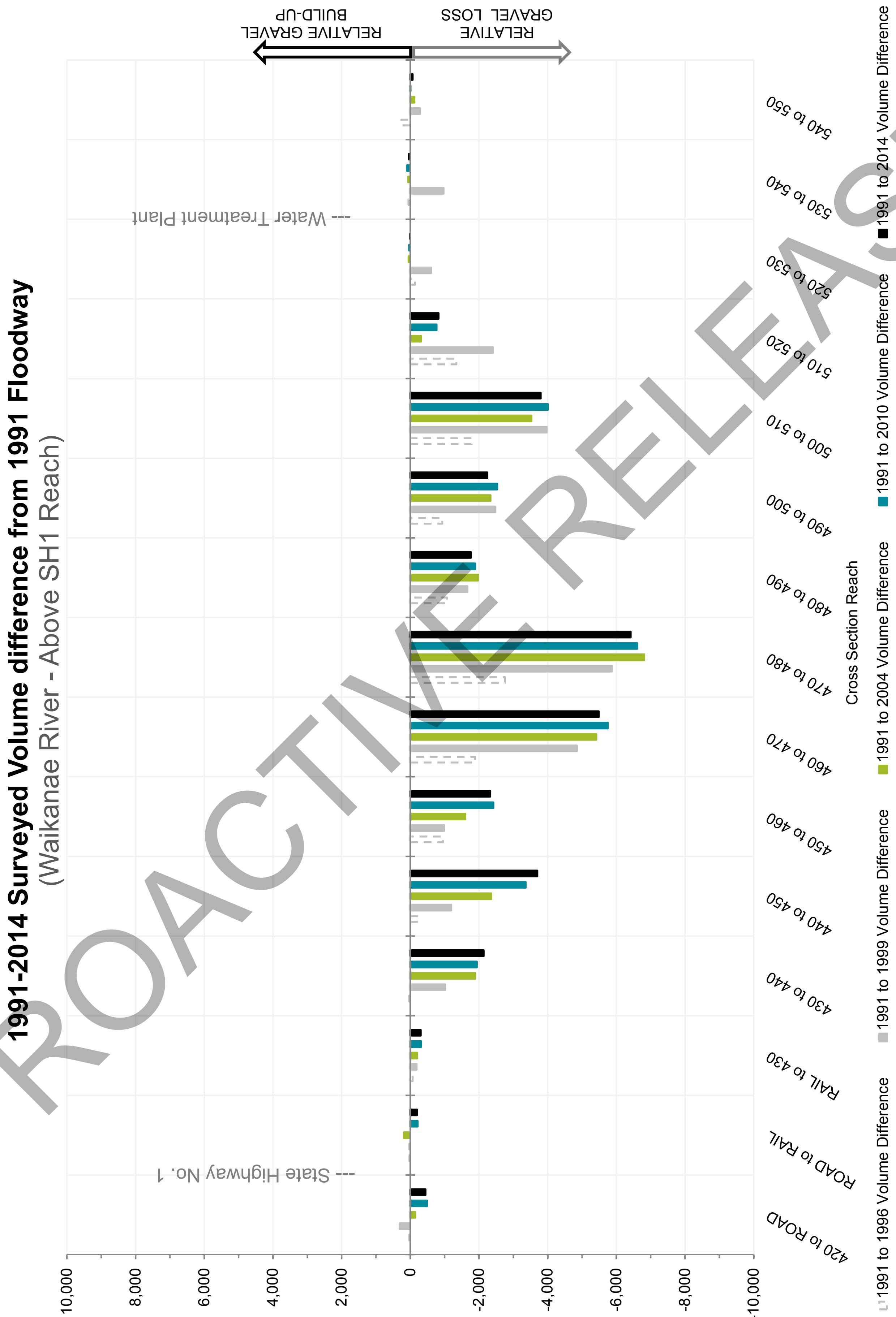
1991-2014 Surveyed Volume difference from 1991 Floodway
(Waikanae River - Kauri/Puriri Reach)

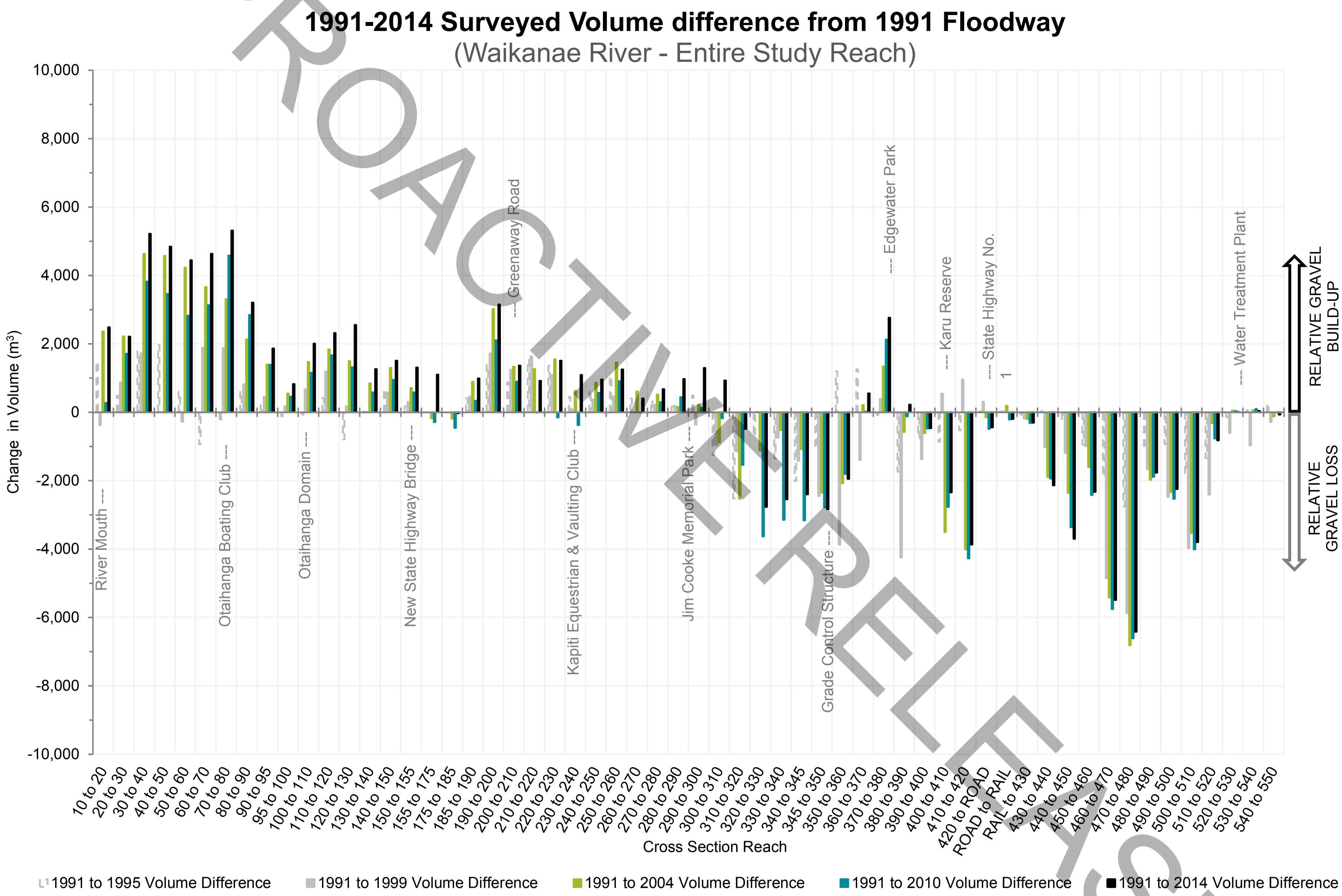



1991-2014 Surveyed Volume difference from 1991 Floodway
(Waikanae River - Jim Cooke Park Reach)
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
--- Grade Control Structure
Jim Cooke Memorial Park ---
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
260 to 270
270 to 280
280 to 290
290 to 300
300 to 310
310 to 320
320 to 330
330 to 340
340 to 345
345 to 350
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference

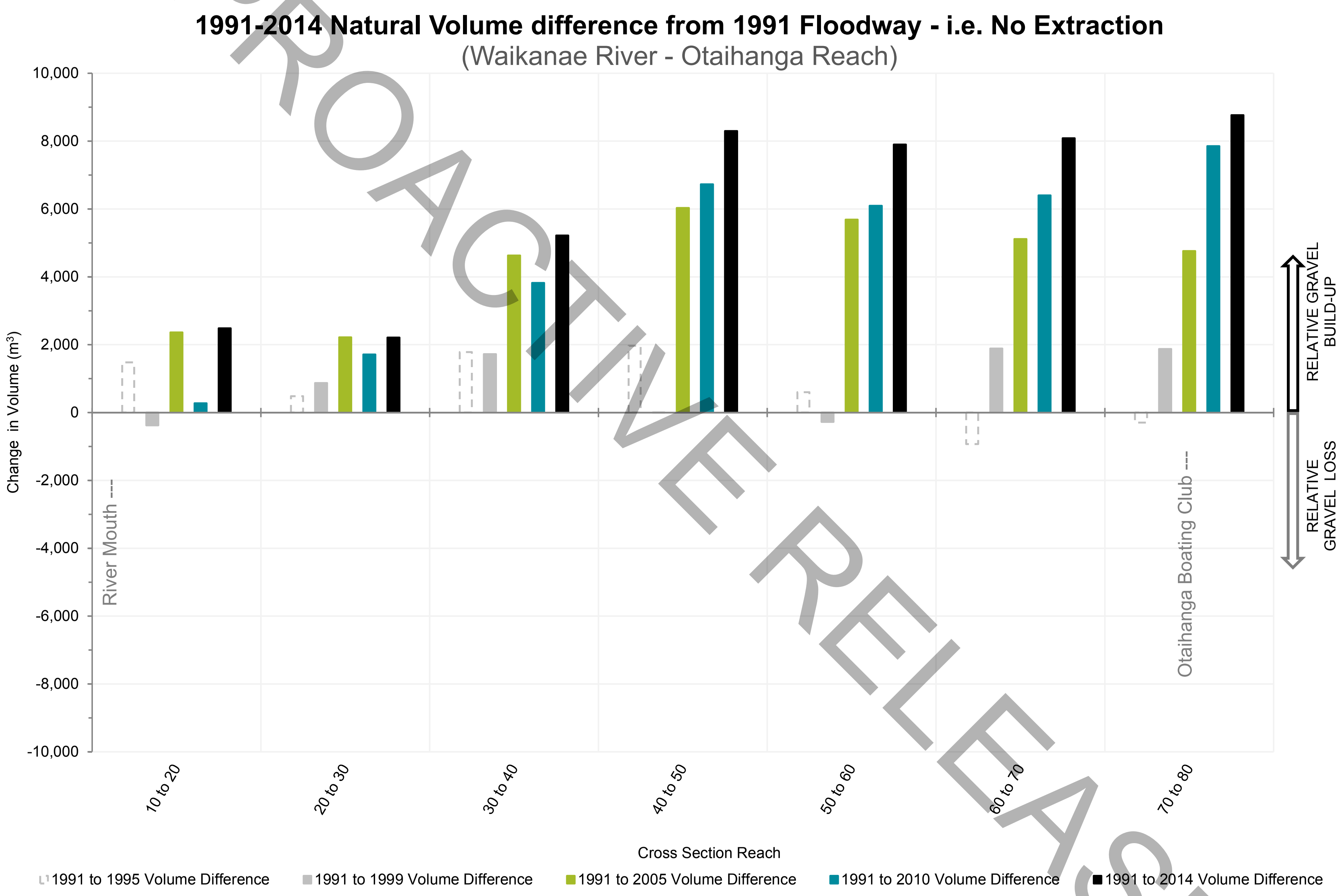
1991-2014 Surveyed Volume difference from 1991 Floodway
(Waikanae River - Below SH1 Reach)



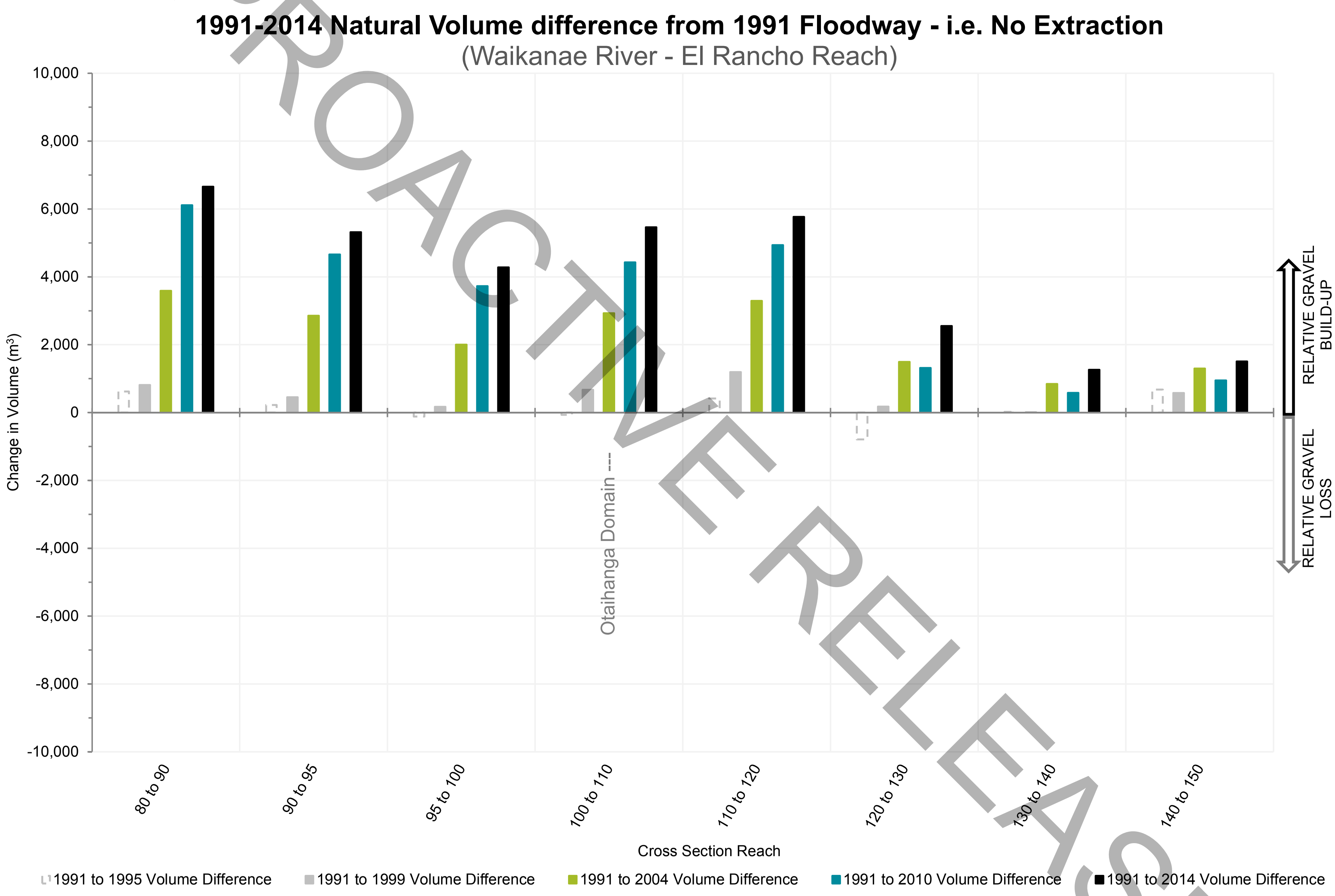

1991-2014 Surveyed Volume difference from 1991 Floodway
(Waikanae River - Above SH1 Reach)
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
--- Water Treatment Plant
--- State Highway No. 1
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
420 to ROAD
ROAD to RAIL
RAIL to 430
430 to 440
440 to 450
450 to 460
460 to 470
470 to 480
480 to 490
490 to 500
500 to 510
510 to 520
520 to 530
530 to 540
540 to 550
Cross Section Reach
1991 to 1996 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference

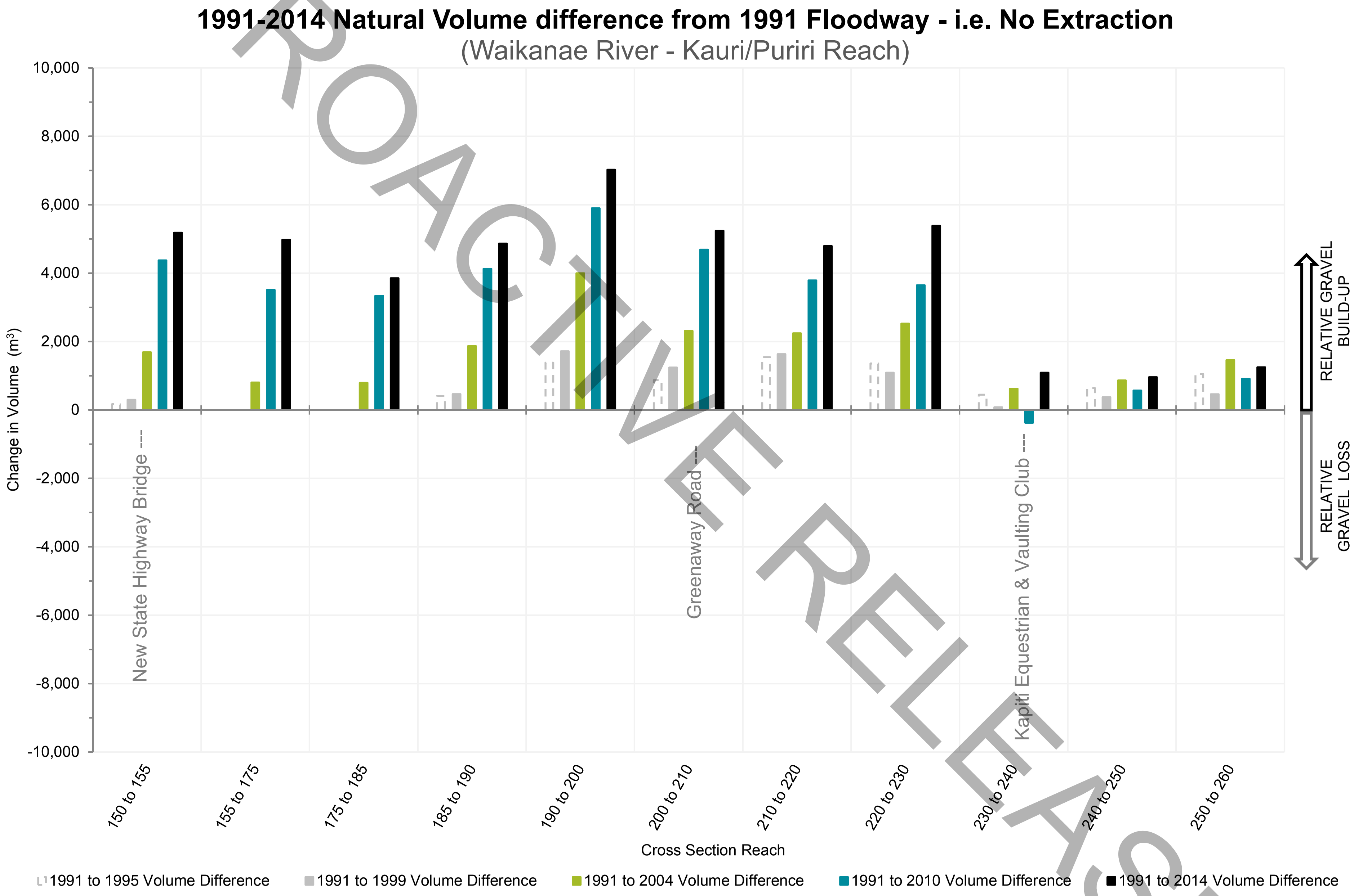

1991-2014 Surveyed Volume difference from 1991 Floodway
(Waikanae River - Entire Study Reach)
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
River Mouth ---
Otaihanga Boating Club ---
Otaihanga Domain ---
New State Highway Bridge ---
--- Greenaway Road
Kapiti Equestrian & Vaulting Club ---
Jim Cooke Memorial Park ---
Grade Control Structure ---
--- Edgewater Park
--- Karu Reserve
--- State Highway No. 1
--- Water Treatment Plant
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
10 to 20
20 to 30
30 to 40
40 to 50
50 to 60
60 to 70
70 to 80
80 to 90
90 to 95
95 to 100
100 to 110
110 to 120
120 to 130
130 to 140
140 to 150
150 to 155
155 to 175
175 to 185
185 to 190
190 to 200
200 to 210
210 to 220
220 to 230
230 to 240
240 to 250
250 to 260
260 to 270
270 to 280
280 to 290
290 to 300
300 to 310
310 to 320
320 to 330
330 to 340
340 to 345
345 to 350
350 to 360
360 to 370
370 to 380
380 to 390
390 to 400
400 to 410
410 to 420
420 to ROAD
ROAD to RAIL
RAIL to 430
430 to 440
440 to 450
450 to 460
460 to 470
470 to 480
480 to 490
490 to 500
500 to 510
510 to 520
520 to 530
530 to 540
540 to 550
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference

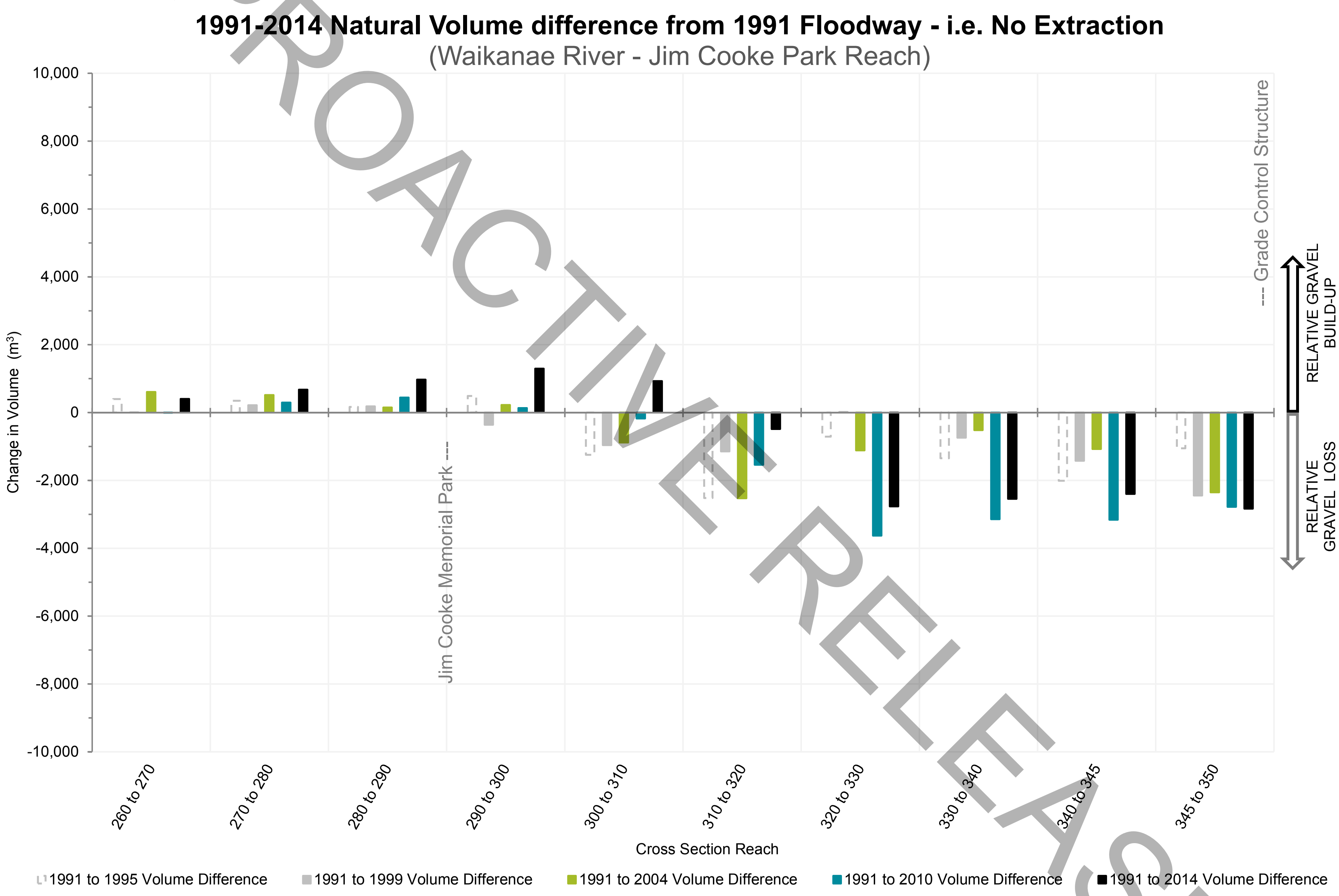
Appendix G – Reach by Reach Natural Volume Estimates

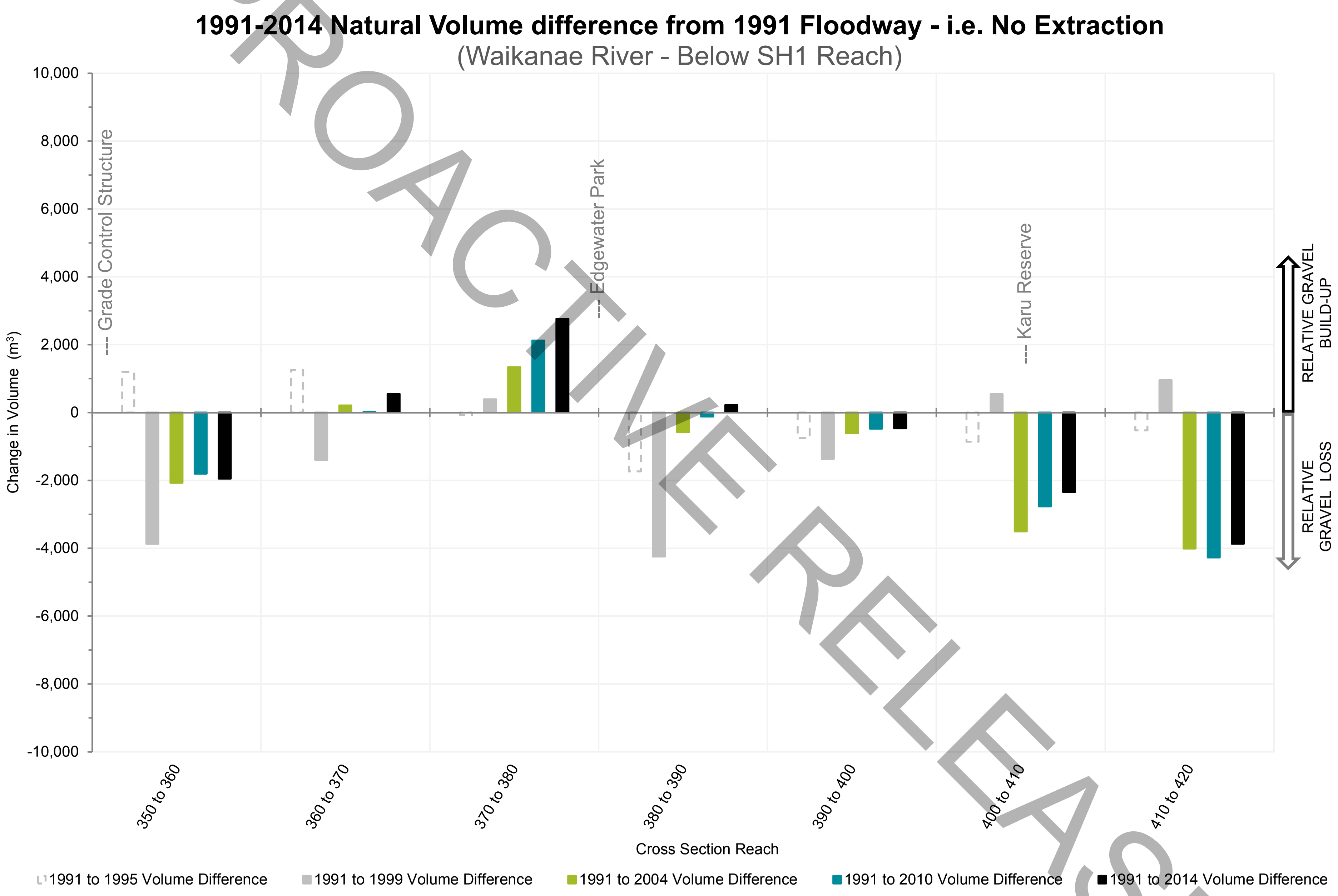


1991-2014 Natural Volume difference from 1991 Floodway - i.e. No Extraction
(Waikanae River - Otaihanga Reach)
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
River Mouth ---
Otaihanga Boating Club ---
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
10 to 20
20 to 30
30 to 40
40 to 50
50 to 60
60 to 70
70 to 80
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2005 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference

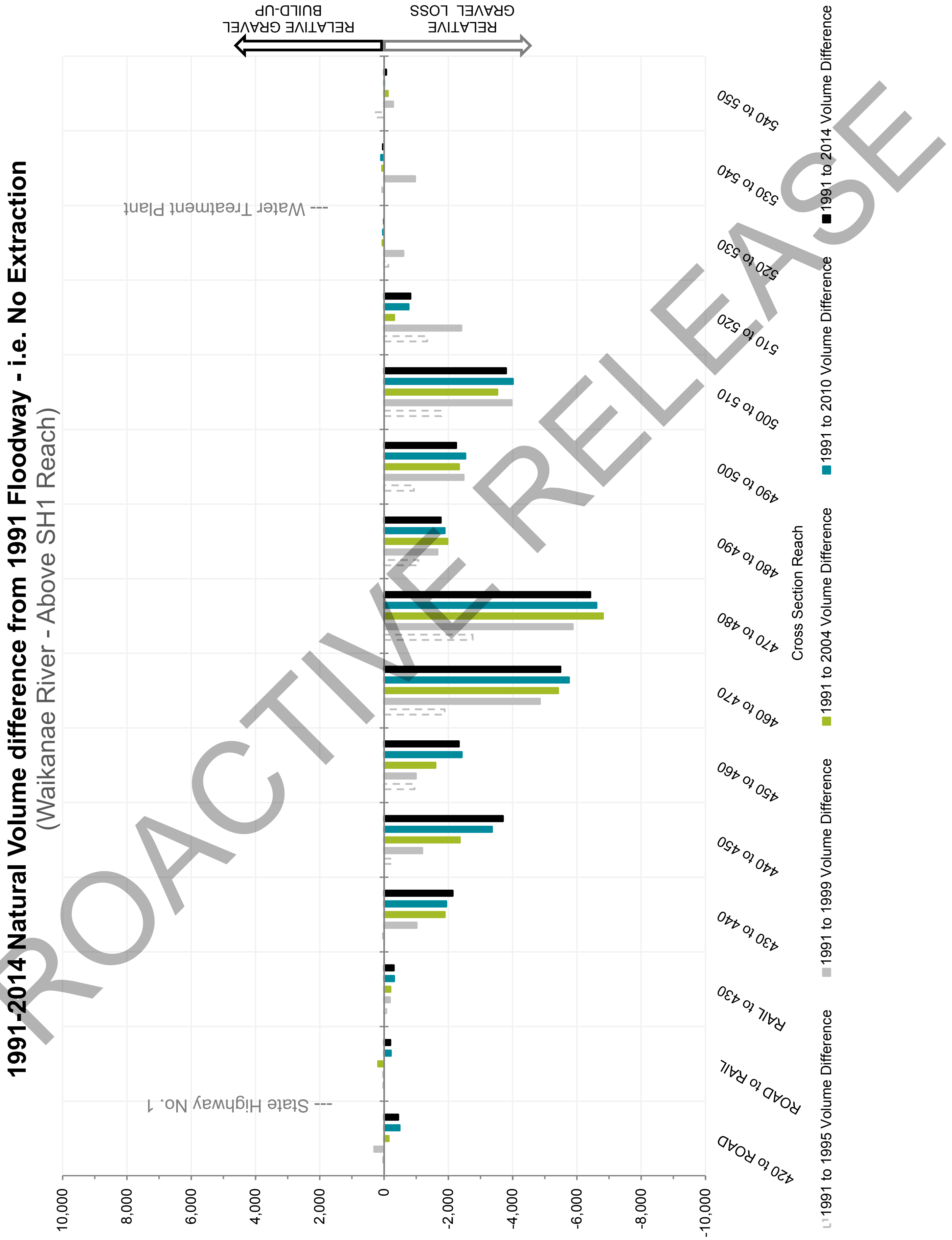

1991-2014 Natural Volume difference from 1991 Floodway - i.e. No Extraction
(Waikanae River - El Rancho Reach)
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
Otaihanga Domain ---
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
80 to 90
90 to 95
95 to 100
100 to 110
110 to 120
120 to 130
130 to 140
140 to 150
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference


1991-2014 Natural Volume difference from 1991 Floodway - i.e. No Extraction
(Waikanae River - Kauri/Puriri Reach)
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
New State Highway Bridge ---
Greenaway Road ---
Kapiti Equestrian & Vaulting Club ---
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
150 to 155
155 to 175
175 to 185
185 to 190
190 to 200
200 to 210
210 to 220
220 to 230
230 to 240
240 to 250
250 to 260
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference


1991-2014 Natural Volume difference from 1991 Floodway - i.e. No Extraction
(Waikanae River - Jim Cooke Park Reach)
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
Jim Cooke Memorial Park ---
--- Grade Control Structure
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
260 to 270
270 to 280
280 to 290
290 to 300
300 to 310
310 to 320
320 to 330
330 to 340
340 to 345
345 to 350
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference



1991-2014 Natural Volume difference from 1991 Floodway - i.e. No Extraction
(Waikanae River - Below SH1 Reach)
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
--- Grade Control Structure
--- Edgewater Park
--- Karu Reserve
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
350 to 360
360 to 370
370 to 380
380 to 390
390 to 400
400 to 410
410 to 420
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference

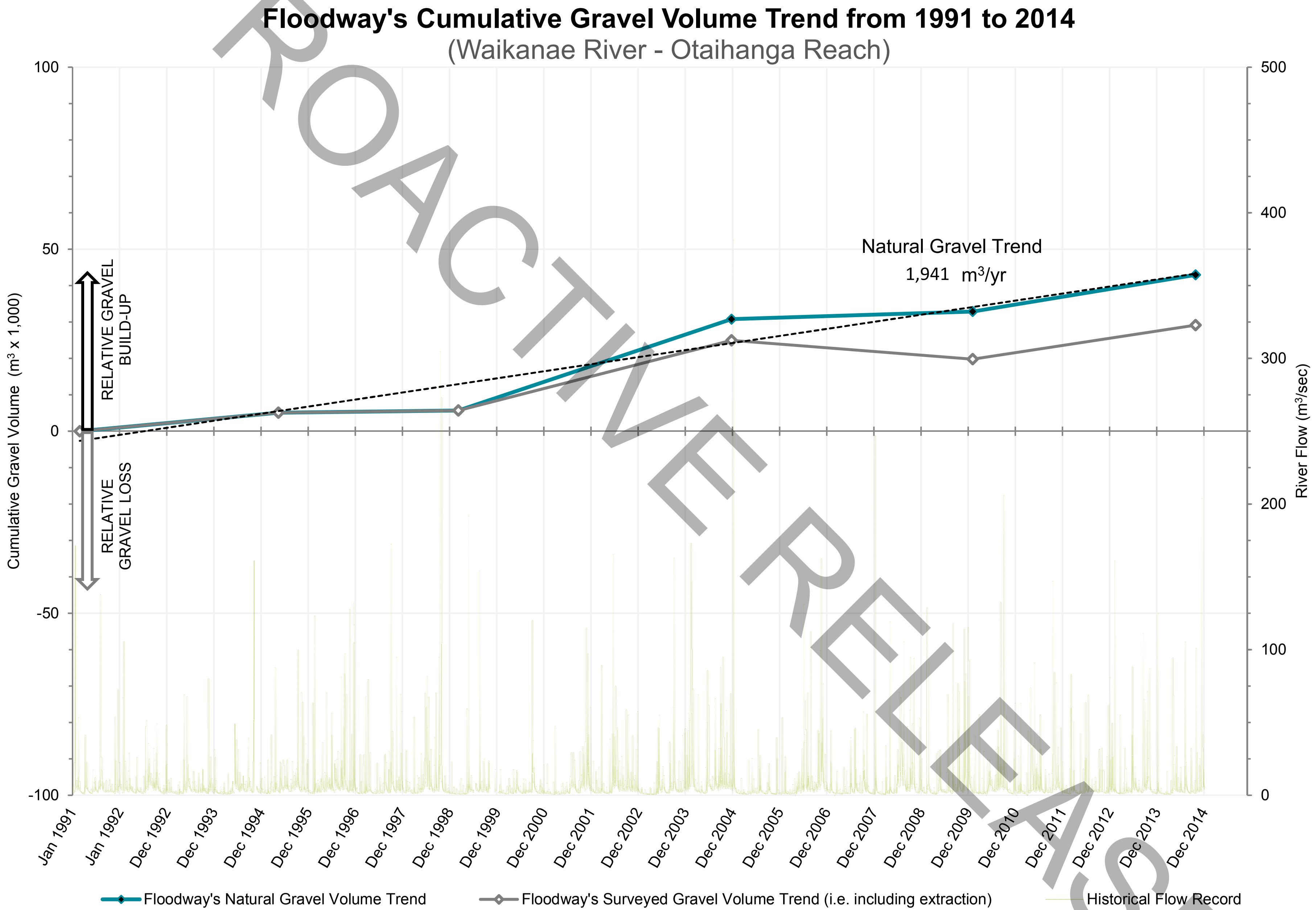


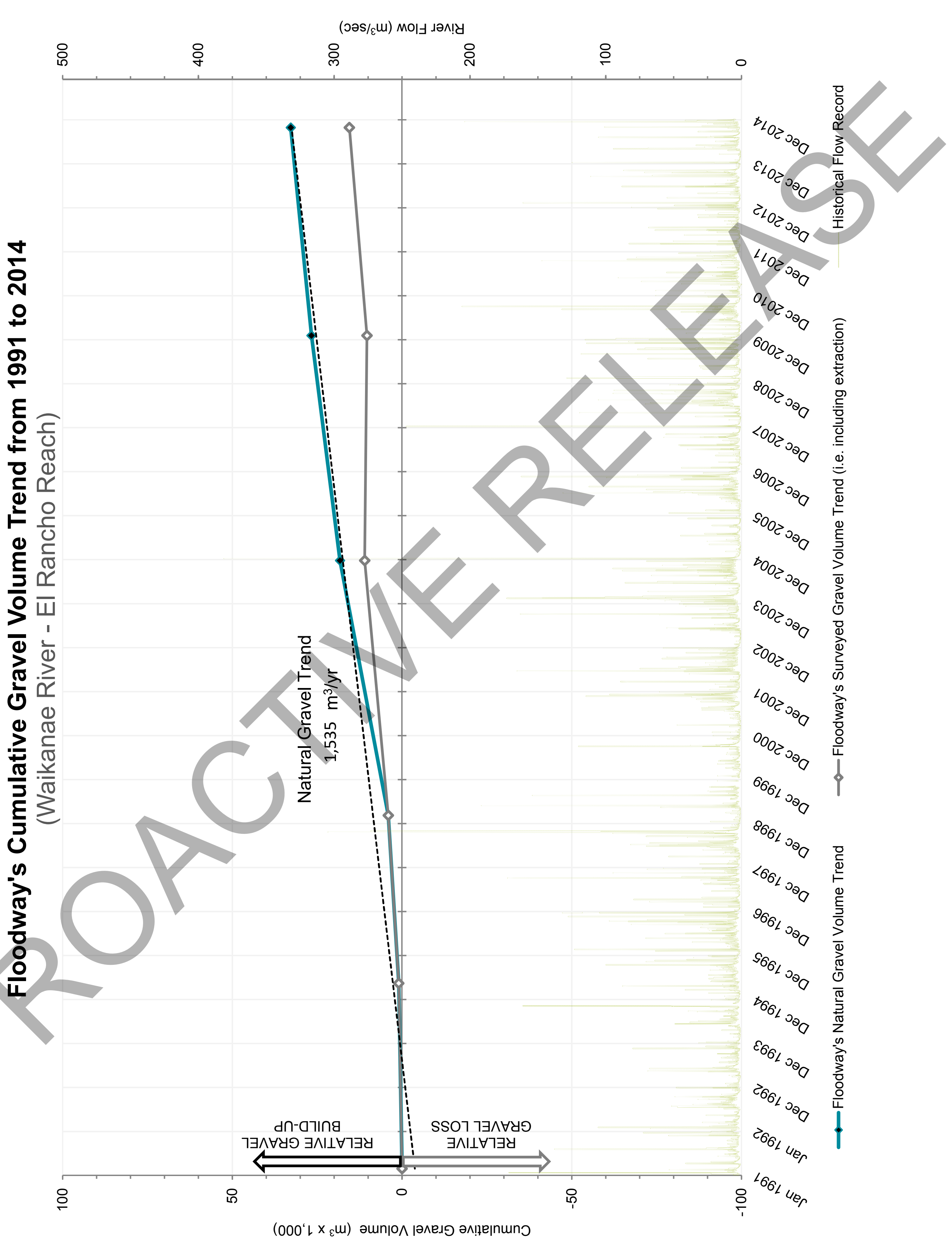
1991-2014 Natural Volume difference from 1991 Floodway - i.e. No Extraction
(Waikanae River - Above SH1 Reach)
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
--- Water Treatment Plant
--- State Highway No. 1
Change in Volume (m³)
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
-10,000
420 to ROAD
ROAD to RAIL
RAIL to 430
430 to 440
440 to 450
450 to 460
460 to 470
470 to 480
480 to 490
490 to 500
500 to 510
510 to 520
520 to 530
530 to 540
540 to 550
Cross Section Reach
1991 to 1995 Volume Difference
1991 to 1999 Volume Difference
1991 to 2004 Volume Difference
1991 to 2010 Volume Difference
1991 to 2014 Volume Difference

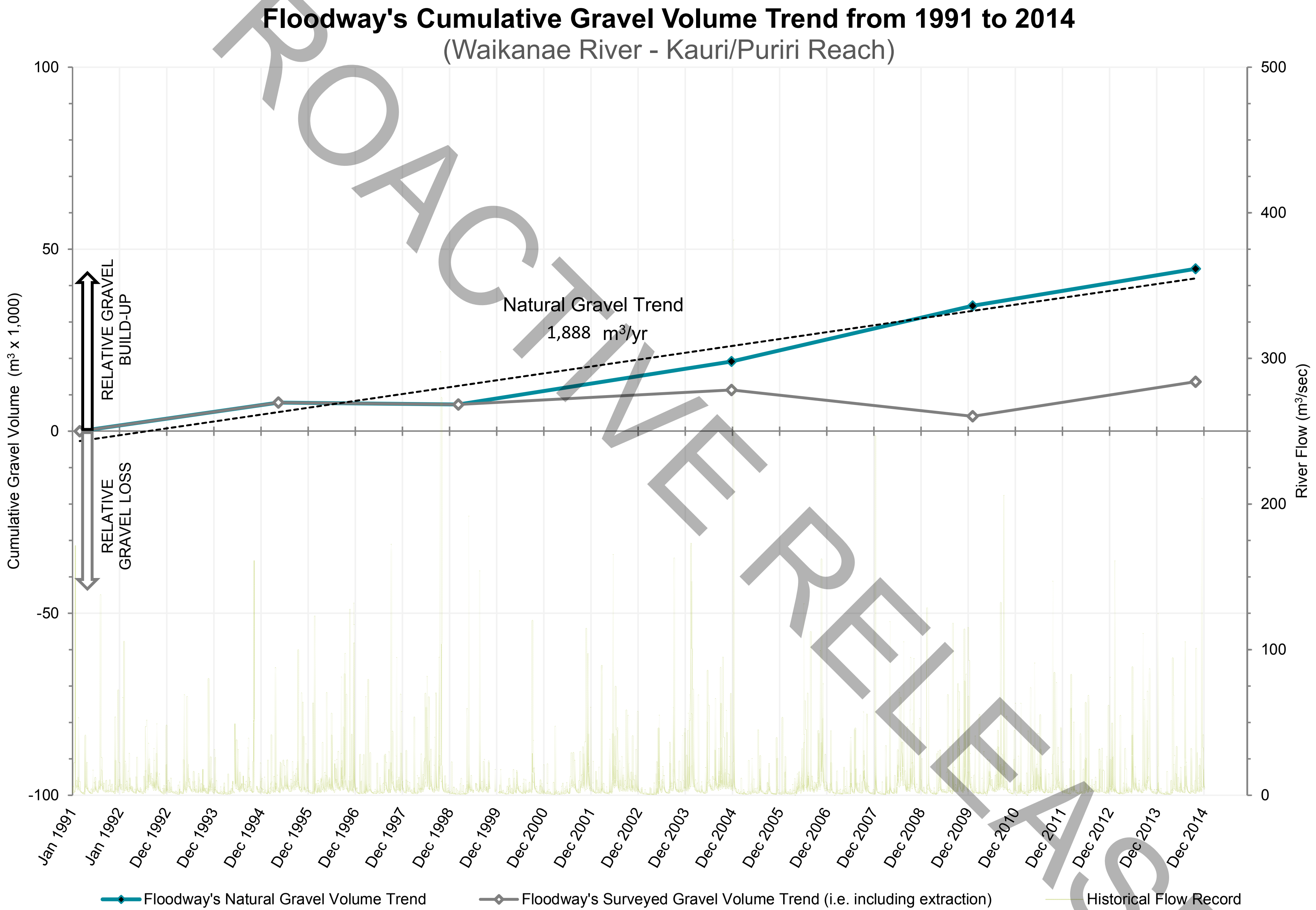
1996-2016 Natural Volume difference from 1991 Floodway - i.e. No Extraction

(Waikanae River - Entire Study Reach)

Appendix H – Reach by Reach Cumulative Volume Estimates and Natural Annual Trends

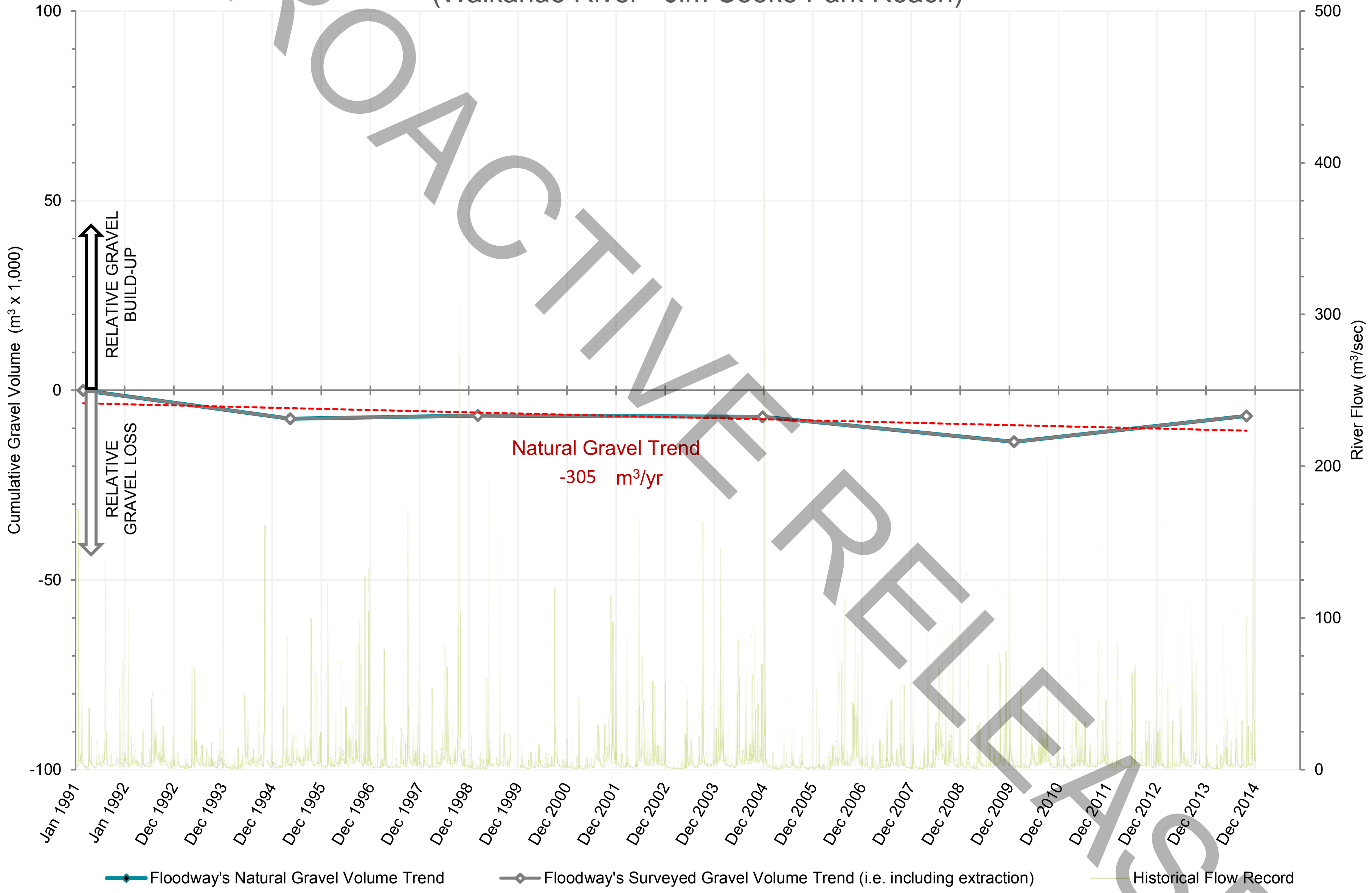

Floodway's Cumulative Gravel Volume Trend from 1991 to 2014
(Waikanae River - Otaihanga Reach)
Cumulative Gravel Volume (m3 x 1,000)
River Flow (m3/sec)
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
Natural Gravel Trend
1,941 m3/yr
100
50
0
-50
-100
500
400
300
200
100
0
Jan 1991
Jan 1992
Dec 1992
Dec 1993
Dec 1994
Dec 1995
Dec 1996
Dec 1997
Dec 1998
Dec 1999
Dec 2000
Dec 2001
Dec 2002
Dec 2003
Dec 2004
Dec 2005
Dec 2006
Dec 2007
Dec 2008
Dec 2009
Dec 2010
Dec 2011
Dec 2012
Dec 2013
Dec 2014
Floodway's Natural Gravel Volume Trend
Floodway's Surveyed Gravel Volume Trend (i.e. including extraction)
Historical Flow Record

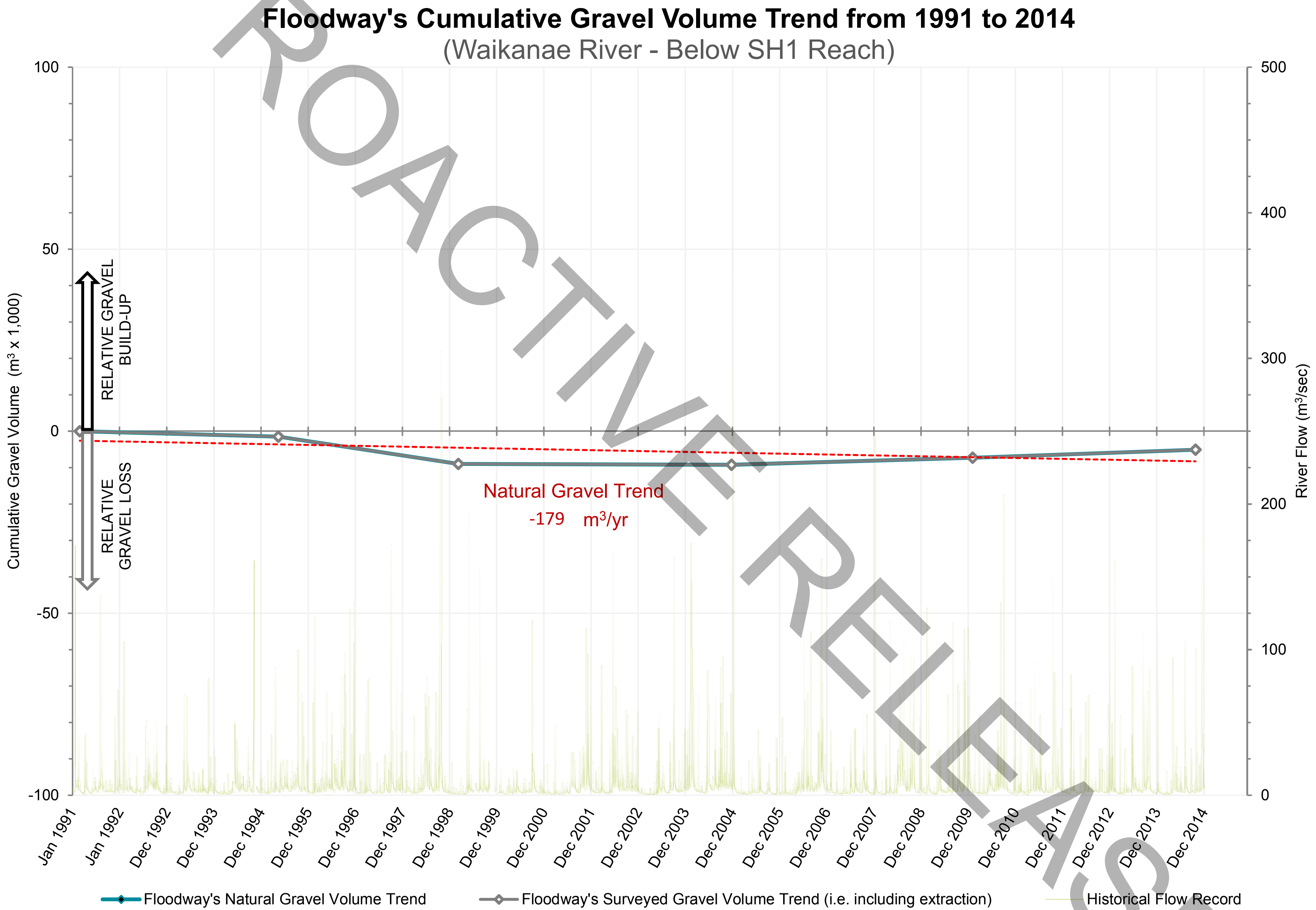

Floodway's Cumulative Gravel Volume Trend from 1991 to 2014
(Waikanae River - El Rancho Reach)
River Flow (m3/sec)
500
400
300
200
100
0
Cumulative Gravel Volume (m3 x 1,000)
100
50
0
-50
-100
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
Natural Gravel Trend
1,535 m3/yr
Jan 1991
Jan 1992
Dec 1992
Dec 1993
Dec 1994
Dec 1995
Dec 1996
Dec 1997
Dec 1998
Dec 1999
Dec 2000
Dec 2001
Dec 2002
Dec 2003
Dec 2004
Dec 2005
Dec 2006
Dec 2007
Dec 2008
Dec 2009
Dec 2010
Dec 2011
Dec 2012
Dec 2013
Dec 2014
Floodway's Natural Gravel Volume Trend
Floodway's Surveyed Gravel Volume Trend (i.e. including extraction)
Historical Flow Record


Floodway's Cumulative Gravel Volume Trend from 1991 to 2014
(Waikanae River - Kauri/Puriri Reach)
Cumulative Gravel Volume (m³ x 1,000)
River Flow (m³/sec)
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
Natural Gravel Trend
1,888 m³/yr
Floodway's Natural Gravel Volume Trend
Floodway's Surveyed Gravel Volume Trend (i.e. including extraction)
Historical Flow Record

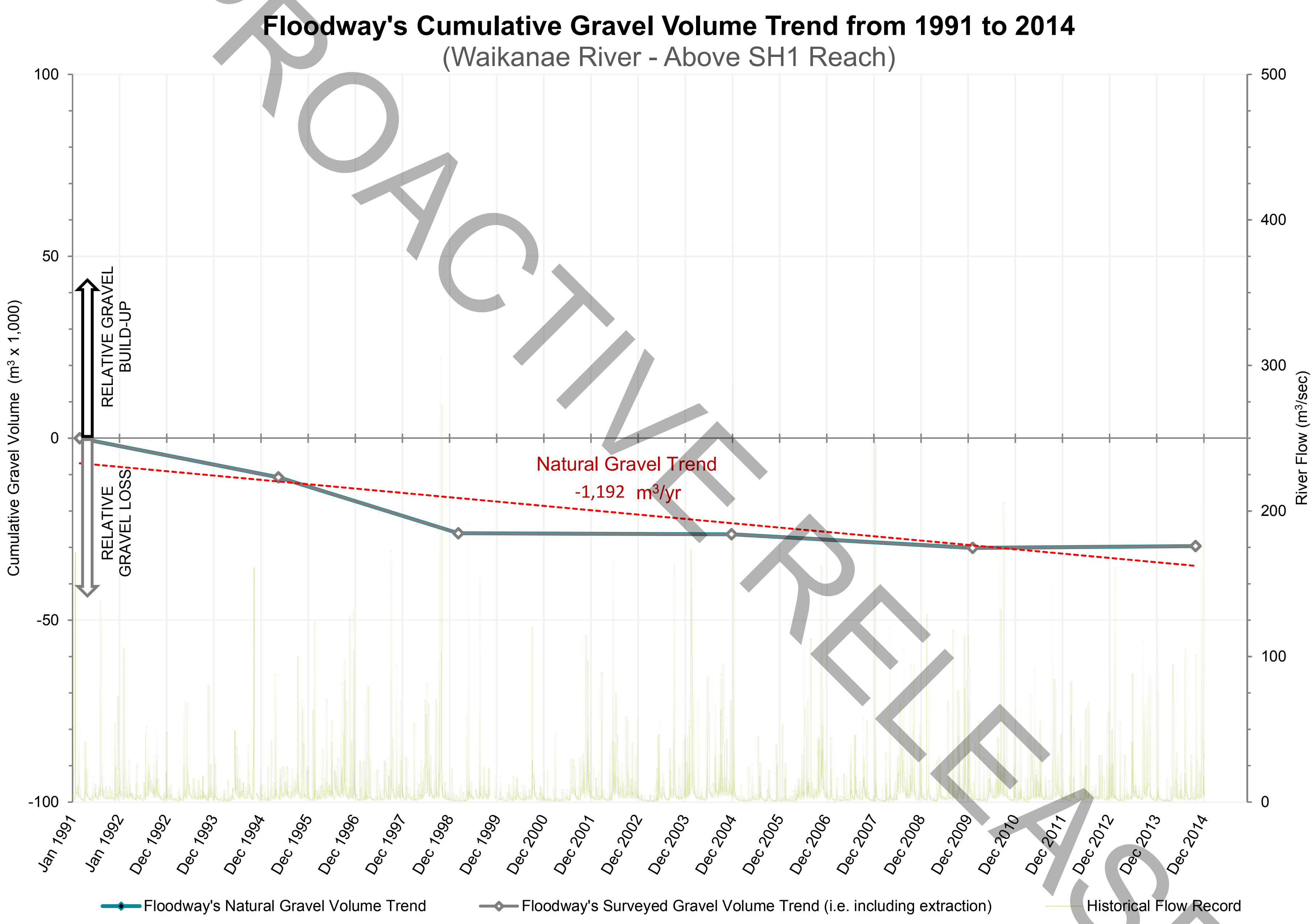
Floodway's Cumulative Gravel Volume Trend from 1991 to 2014

(Waikanae River - Jim Cooke Park Reach)

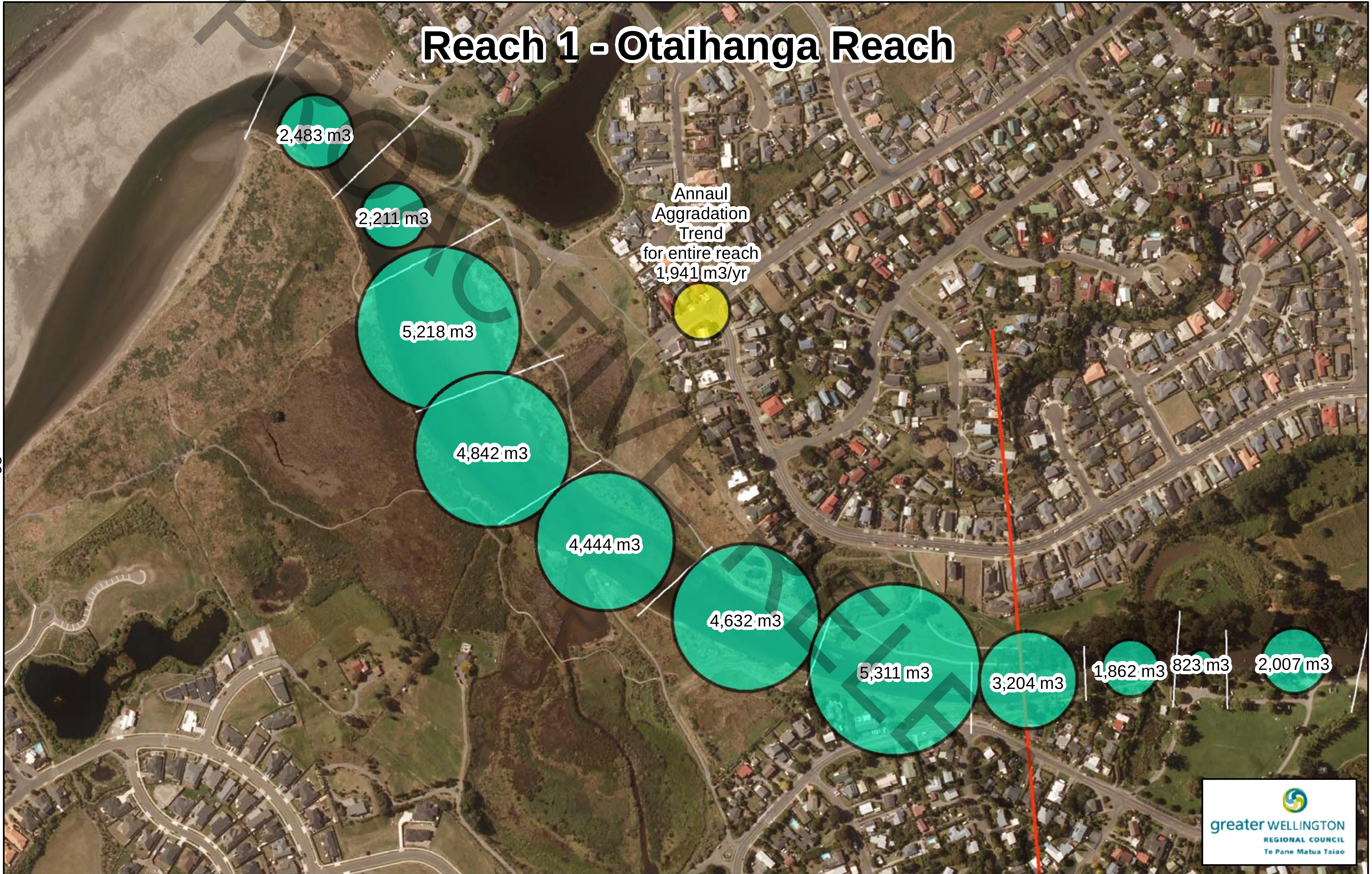




Floodway's Cumulative Gravel Volume Trend from 1991 to 2014
(Waikanae River - Below SH1 Reach)
Cumulative Gravel Volume (m³ x 1,000)
River Flow (m³/sec)
100
50
0
-50
-100
500
400
300
200
100
0
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
Natural Gravel Trend
-179 m³/yr
Jan 1991
Jan 1992
Dec 1992
Dec 1993
Dec 1994
Dec 1995
Dec 1996
Dec 1997
Dec 1998
Dec 1999
Dec 2000
Dec 2001
Dec 2002
Dec 2003
Dec 2004
Dec 2005
Dec 2006
Dec 2007
Dec 2008
Dec 2009
Dec 2010
Dec 2011
Dec 2012
Dec 2013
Dec 2014
Floodway's Natural Gravel Volume Trend
Floodway's Surveyed Gravel Volume Trend (i.e. including extraction)
Historical Flow Record


Floodway's Cumulative Gravel Volume Trend from 1991 to 2014
(Waikanae River - Above SH1 Reach)
Cumulative Gravel Volume (m³ x 1,000)
River Flow (m³/sec)
RELATIVE GRAVEL BUILD-UP
RELATIVE GRAVEL LOSS
Natural Gravel Trend
-1,192 m³/yr
Jan 1991
Jan 1992
Dec 1992
Dec 1993
Dec 1994
Dec 1995
Dec 1996
Dec 1997
Dec 1998
Dec 1999
Dec 2000
Dec 2001
Dec 2002
Dec 2003
Dec 2004
Dec 2005
Dec 2006
Dec 2007
Dec 2008
Dec 2009
Dec 2010
Dec 2011
Dec 2012
Dec 2013
Dec 2014
Floodway's Natural Gravel Volume Trend
Floodway's Surveyed Gravel Volume Trend (i.e. including extraction)
Historical Flow Record
PROACTIVE RELEASE

Appendix I – Graduated Illustration of Gravel Surplus Distribution since 1991



WAIKANAE RIVER - Aggraded Gravel Volumes 1991 to 2014

(bubbles are graduated in size to reflect volume extents relative to each location)

0 20 40 80 120 160 200 Metres

A4 Scale : 1:5,000

N

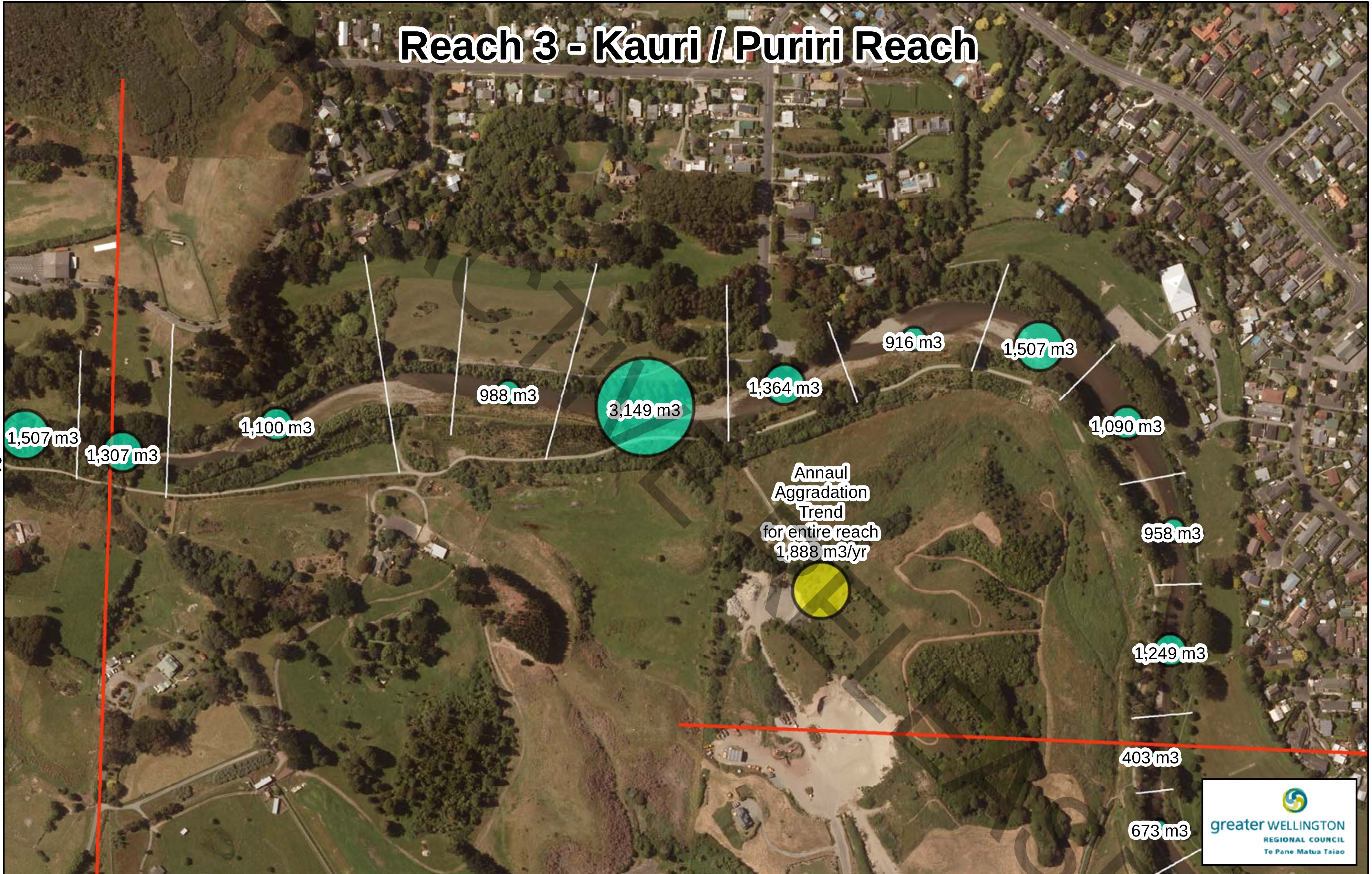
WAIKANAE RIVER - Aggraded Gravel Volumes 1991 to 2014

(bubbles are graduated in size to reflect volume extents relative to each location)

Regional Orthophotography Copyright : GWRC / NZAM 2013
Topographic and Cadastral data is copyright LINZ

0 20 40 80 120 160 200 Metres

A4 Scale : 1:5,000



WAIKANAE RIVER - Aggraded Gravel Volumes 1991 to 2014

(bubbles are graduated in size to reflect volume extents relative to each location)

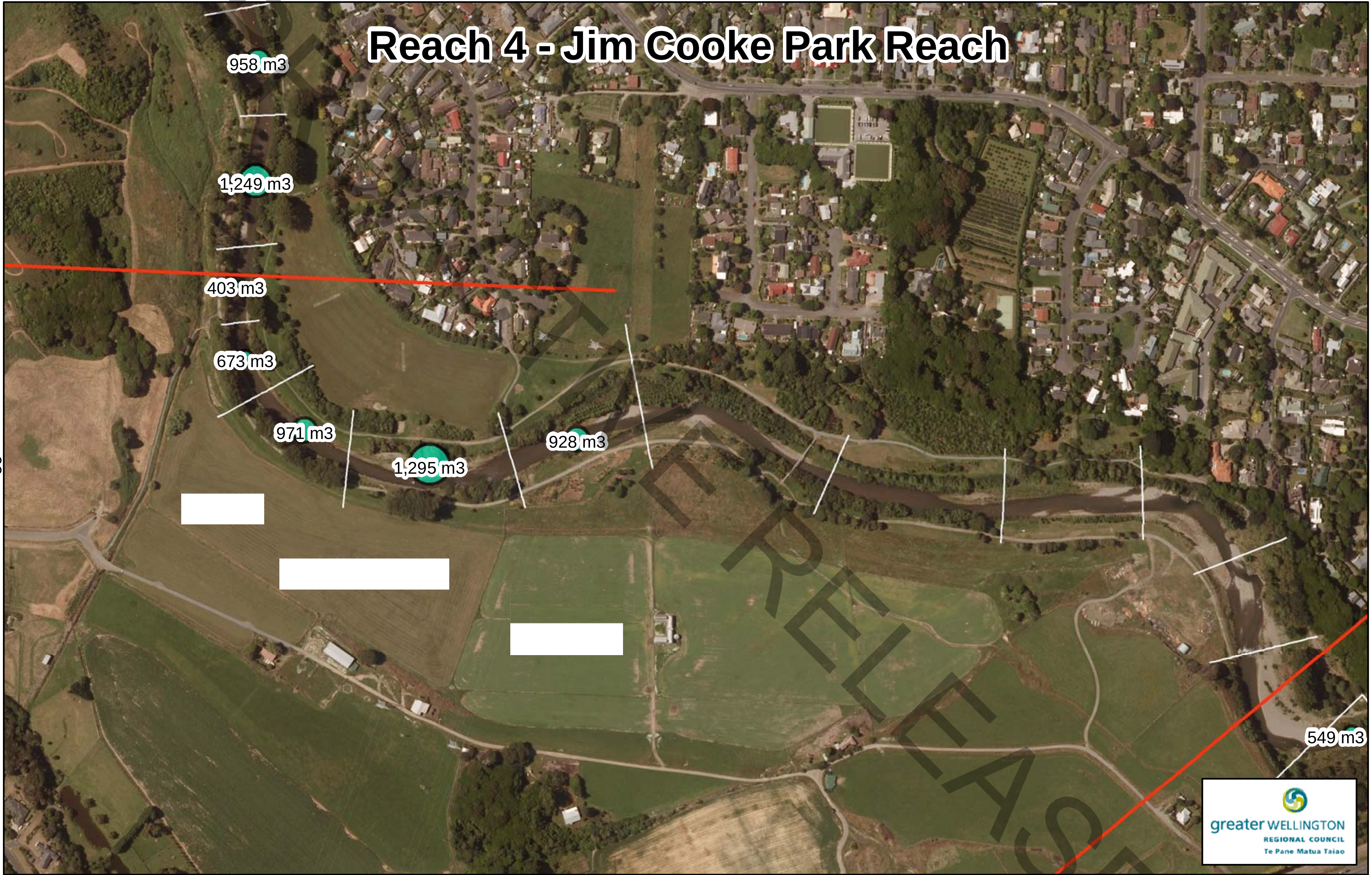
Regional Orthophotography Copyright : GWRC / NZAM 2013
Topographic and Cadastral data is copyright LINZ

0 20 40 80 120 160 200 Metres

A4 Scale : 1:5,000

N

Date Plotted : 9:16:58 a.m., 10/05/2017



WAIKANAE RIVER - Aggraded Gravel Volumes 1991 to 2014

(bubbles are graduated in size to reflect volume extents relative to each location)

0 20 40 80 120 160 200 Metres

A4 Scale : 1:5,000

N

WAIKANAE RIVER - Aggraded Gravel Volumes 1991 to 2014

(bubbles are graduated in size to reflect volume extents relative to each location)

0 20 40 80 120 160 200 Metres

A4 Scale : 1:5,000

N

WAIKANAE RIVER - Aggraded Gravel Volumes 1991 to 2014

(bubbles are graduated in size to reflect volume extents relative to each location)

Regional Orthophotography Copyright : GWRC / NZAM 2013
Topographic and Cadastral data is copyright LINZ

0 20 40 80 120 160 200 Metres

A4 Scale : 1:5,000

N

Date Plotted : 9:19:38 a.m., 10/05/2017

Appendix J – Cross Section Historical Offsets

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HISTORICAL ACTIVE CHANNEL & VOLUMETRIC OFFSETS (WAIKANAE RIVER)

Cross Section	U/S Chainage (m)	2014 AC MBL Left Offset (m)	2014 AC MBL Right Offset (m)	2010 AC MBL Left Offset (m)	2010 AC MBL Right Offset (m)	2004 AC MBL Left Offset (m)	2004 AC MBL Right Offset (m)	1999 AC MBL Left Offset (m)	1999 AC MBL Right Offset (m)	1995 AC MBL Left Offset (m)	1995 AC MBL Right Offset (m)	1991 AC MBL Left Offset (m)	1991 AC MBL Right Offset (m)	1987-2010 Volumetric Left Offset (m)	1987-2010 Volumetric Right Offset (m)
10	0	10.30	98.30	10.30	98.30	10.00	98.40	12.30	102.70	9.20	106.50	8.00	105.60	8.00	106.50
20	125	4.00	66.00	3.10	63.60	3.30	63.00	2.80	65.80	3.20	66.70	5.40	66.60	2.76	66.70
30	235	7.70	138.00	10.00	138.90	9.80	133.80	5.60	138.30	8.50	139.00	8.40	137.70	5.60	139.04
40	377	7.50	105.20	7.50	105.20	10.10	105.20	11.20	108.70	4.90	110.50	13.40	112.70	4.90	134.14
50	510	6.00	92.20	6.80	92.30	7.90	92.10	9.00	89.80	1.70	84.40	9.60	87.60	1.70	92.31
60	670	16.30	86.20	13.90	86.00	19.70	85.40	8.20	83.60	9.20	81.70	11.90	79.50	8.17	86.20
70	830	13.90	57.70	12.40	57.80	11.10	57.40	3.80	57.60	4.00	57.60	3.50	57.80	3.50	57.83
80	1002	32.40	64.50	31.40	61.60	24.50	60.70	22.50	62.10	22.10	61.20	21.70	61.20	21.66	64.51
90	1122	11.20	42.70	11.60	43.00	11.00	40.00	10.70	42.50	8.90	40.10	8.90	39.40	8.88	43.00
95	1215	14.50	42.80	14.10	43.00	14.60	44.10	12.80	43.90	12.60	43.50	12.60	43.70	12.58	44.15
100	1268	34.20	63.70	35.90	63.70	29.50	63.60	30.90	63.30	31.50	63.30	24.90	64.40	24.86	64.43
110	1404	40.90	64.40	41.00	64.00	40.00	63.60	40.50	63.70	40.10	63.70	38.40	64.90	38.40	64.93
120	1579	14.90	33.70	15.00	34.00	15.60	33.80	15.60	33.80	13.80	35.50	14.30	35.90	13.80	35.90
130	1794	10.40	28.20	8.70	30.40	9.00	29.90	9.20	34.30	8.30	32.90	4.10	19.60	0.00	34.31
140	1885	15.20	31.40	15.20	32.00	15.50	33.30	15.70	35.60	15.60	39.40	14.10	38.30	14.07	39.40
150	1996	31.90	47.30	31.90	47.80	32.00	48.60	32.00	47.80	30.20	45.30	33.20	47.40	30.20	48.60
155	2103	29.70	45.90	29.20	48.00	28.20	56.70	27.30	55.30	27.30	55.30	27.30	55.30	27.26	56.73
175	2322	77.40	112.50	71.40	113.40	74.00	112.60	71.70	112.70	71.70	112.70	71.70	112.70	71.40	113.40
185	2406	26.50	50.20	23.60	51.20	17.30	52.20	13.10	47.50	13.10	47.50	13.10	47.50	10.73	52.20
190	2513	47.10	71.30	47.00	72.80	42.60	74.10	42.90	74.90	39.40	71.00	39.30	68.50	39.30	74.94
200	2681	13.60	44.20	11.70	40.60	11.70	43.40	11.80	40.90	9.10	35.90	6.70	42.70	5.40	48.45
210	2816	33.70	67.80	34.70	67.90	34.50	68.20	35.10	68.30	32.90	68.60	32.20	68.80	30.77	70.75
220	2966	31.00	75.30	31.80	75.00	41.80	78.50	40.00	80.00	36.10	77.30	35.10	86.30	31.00	86.30
230	3081	26.80	61.80	24.60	61.00	38.40	63.00	34.00	63.00	36.30	63.60	29.30	61.80	24.60	63.60
240	3211	36.60	56.10	33.60	56.10	28.40	57.70	33.40	60.50	36.10	60.50	39.00	58.90	28.40	60.50
250	3321	12.70	35.40	11.60	35.20	16.60	35.40	15.40	34.40	15.50	34.00	6.30	34.80	6.29	35.43
260	3456	13.30	39.60	13.00	39.00	13.20	33.40	13.60	37.90	11.90	35.60	12.40	36.80	11.85	39.63
270	3534	6.90	29.00	6.20	30.30	5.70	26.10	6.30	26.60	6.30	28.10	5.40	30.90	5.38	32.48
280	3606	18.40	32.20	17.50	35.10	11.30	32.10	12.50	32.30	11.60	30.90	10.60	30.20	8.63	35.10
290	3724	19.30	37.60	18.00	36.90	18.30	37.80	16.90	34.70	17.10	33.30	17.90	33.60	16.89	37.80
300	3894	24.00	49.30	22.50	52.50	11.00	52.10	12.90	54.20	15.10	44.40	15.60	44.90	10.99	54.20
310	4039	34.10	56.90	33.90	64.00	30.90	94.30	26.20	94.20	36.40	93.00	43.40	92.70	18.00	94.79
320	4259	26.90	46.90	26.60	48.40	26.40	50.40	18.50	47.80	23.90	50.00	25.00	53.30	18.50	53.30
330	4443	16.40	54.50	17.40	52.40	27.00	52.90	24.70	49.60	26.20	51.90	29.10	51.80	14.89	59.24
340	4588	24.00	50.40	20.50	54.30	28.00	63.50	31.00	69.10	33.60	65.30	28.60	59.20	20.47	69.10
345	4730	13.50	54.30	18.80	55.50	27.10	57.30	35.50	76.50	32.90	66.20	36.50	75.70	13.15	76.50

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HISTORICAL ACTIVE CHANNEL & VOLUMETRIC OFFSETS (WAIKANAE RIVER)

Cross Section	U/S Chainage (m)	2014 AC MBL Left Offset (m)	2014 AC MBL Right Offset (m)	2010 AC MBL Left Offset (m)	2010 AC MBL Right Offset (m)	2004 AC MBL Left Offset (m)	2004 AC MBL Right Offset (m)	1999 AC MBL Left Offset (m)	1999 AC MBL Right Offset (m)	1995 AC MBL Left Offset (m)	1995 AC MBL Right Offset (m)	1991 AC MBL Left Offset (m)	1991 AC MBL Right Offset (m)	1987-2010 Volumetric Left Offset (m)	1987-2010 Volumetric Right Offset (m)
350	4824	15.10	59.10	14.30	43.60	14.70	57.60	25.80	63.50	27.30	56.80	26.50	64.70	5.96	64.73
360	4938	42.10	77.90	41.70	81.20	38.60	82.70	14.40	61.30	12.00	50.30	13.50	60.00	11.97	89.41
370	5048	48.70	78.30	62.90	78.40	48.30	76.90	55.30	89.60	40.50	83.00	31.90	69.40	29.05	89.60
380	5248	25.80	48.00	24.60	51.20	26.10	63.70	21.30	59.20	32.30	66.70	31.90	80.00	21.30	80.05
390	5468	25.00	61.90	26.20	60.40	23.40	59.10	7.30	48.10	14.10	55.30	-0.40	52.90	-0.40	61.91
400	5528	35.00	68.80	33.00	69.20	28.20	75.80	20.90	80.70	23.60	87.90	20.30	85.00	20.30	87.93
410	5748	11.80	39.30	11.30	35.40	8.90	36.60	15.40	44.10	16.80	48.70	16.00	49.00	6.02	51.99
420	5922	17.50	38.70	14.90	40.00	16.30	42.90	21.20	47.10	19.10	44.20	16.20	47.20	14.90	47.20
ROAD	5967	21.40	62.50	24.80	51.90	23.70	57.10	25.90	57.10	27.80	57.50	24.50	61.20	21.35	62.52
RAIL	5997	21.60	47.50	9.10	47.90	13.60	47.50	12.90	47.40	17.60	47.20	9.80	45.80	9.07	51.48
430	6020	16.30	38.70	6.90	39.20	2.10	39.80	7.00	40.40	4.20	39.60	3.60	39.20	2.08	41.72
440	6115	16.30	52.90	15.90	55.00	13.40	55.30	14.10	51.60	14.40	43.20	14.20	44.60	13.40	76.46
450	6280	24.70	47.20	17.30	47.10	16.00	42.00	10.90	42.60	15.80	43.10	4.50	44.00	4.50	47.22
460	6452	19.60	46.00	19.60	41.80	20.50	45.50	23.90	48.60	20.90	48.10	20.80	48.70	19.56	51.33
470	6597	24.40	42.60	23.00	41.30	14.70	42.20	15.20	47.20	14.80	37.30	15.70	37.00	14.70	55.30
480	6747	21.10	42.40	19.90	55.90	27.20	56.50	21.80	55.10	30.90	57.00	25.90	54.50	19.23	57.00
490	6838	26.40	47.00	14.90	47.90	14.70	36.40	14.40	46.10	15.60	44.00	15.00	45.80	13.00	47.90
500	6962	9.80	30.50	9.50	31.90	9.80	32.80	10.20	32.20	9.50	29.30	9.00	29.00	7.28	35.37
510	7128	11.70	48.50	9.70	48.50	8.90	45.70	8.00	44.50	10.60	39.40	11.00	42.00	3.69	48.50
520	7203	13.20	32.70	12.00	34.30	8.80	34.30	13.20	34.00	11.60	32.50	13.60	32.30	7.50	34.70
530	7215	9.80	32.10	9.30	32.00	8.60	32.10	20.60	32.10	9.70	32.10	8.50	31.70	5.60	33.00
540	7245	9.90	32.50	10.10	31.90	9.90	31.90	11.30	31.90	6.60	31.70	11.50	33.00	3.00	33.80
550	7273	20.90	42.00	17.10	42.20	20.30	42.10	20.40	42.10	27.30	41.50	24.90	39.90	10.02	42.27

Appendix K –Workshop Minutes

MINUTES

SUBJECT	**Waikanae River Gravel Bed Workshop**
WHEN	Tuesday 9 May 2017
WHERE	SHED39 - Training Room
ATTENDEES	Laddie Kuta, Tracy Berghan, Gary Williams, Mark Hooker, Graeme Campbell, James Flanagan, and Jacky Cox
APOLOGIES	Colin Munn, Mike Jensen, and Jeff Evans
FILE NUMBER	FMGT-7-291

Introduction

Gravel Management Goal

Understand and then Engage

Same as previous analysis, 6 reaches:

1. Otaihanga Reach
2. El Rancho Reach
3. Kauri-Puriri Reach
4. Jim Cooke Park Reach
5. Below SH1 Reach
6. Above SH1 Reach

MEAN BED LEVELS

Two main points of inflection are observed when looking at the long section of the river's MBL.

This is a good example to illustrate the clear trends in the river and to inform people who are concerned about the new state highway bridge and possible impacts it might have.

Otaihanga Reach – peak aggradation occurs just by boating club - point bar. The island of visible gravel that is located close by might be investigated to see if there are any marine silts or clays underlying the river gravels and sands. There might be some deeper soil properties that might impact what is happening at bed level. The coastal management area starts just downstream of river cross section 50. 2 lots of separate extraction that was completed did not remove the target 40,000m^3 of material initially earmarked to be removed. The channel has become wider; perhaps from the 1998 flood? A quick look at the aerial photos showed the mouth was blown open during the 1998 and 2005 flood events.

El Rancho Reach – Prior to the new bridge, there was a build-up of material around river cross section 150 to 155. There was some work to control erosion around the true-right bank near river cross section 120 back in 1999. This area is still below the point of inflection, so there will be growing beaches of material in this location. The new bridge was almost completed to Gary William's design; however, the downstream transition on the TRB was not completed as per his design. Widening of the channel here may be a future priority.

Vaulting Club – river cross sections 210, 220, and 230. The true-left bank across from the equestrian and vaulting club would be a good location for future extraction of gravels. If there is to be annual extractions then this would be one of the obvious locations to complete the work. There were some channel works completed in 1997. Removal of gravel materials here will not stop the build-up of materials downstream. It is only if limited extraction is required from this reach that we have the ideal location to complete this.

Jim Cooke Park and Upstream – Active channels MBL's trending to the extreme. The degradation in the channel is at the lower limit of the current bed level envelope in the upstream reach; whereas, MBLs are shown to be at the upper limit of this current bed level envelope in the downstream aggrading reaches.

GRAVEL VOLUMES

The natural volumes show a more defined transition in aggradation/degradation dynamics, which occurs downstream of Jim Cooke Park.

The Recap in presentation needs to be reworded in the first bullet point due to the MBL and Volume changes not reflecting each other.

A management decision needs to be made about what extraction plan is best:

- Big Whammy – Large gravel extraction over a season significant effects but only takes place every 5 to 10 years. Take enough gravel out to have an effect on the build-up and in the incoming gravel volumes.

- Annual programme (based on 10 year cycle) – Extraction each year, would be limited in scope, duration and locations.

- Manage the existing levels; taking action on gravels which build up from this point onwards. This is maintenance at the upper edge of the gravel envelope in the aggrading reaches.

- What is to be done about the degrading reaches? Installation of new and repair of existing grade controls.

We don't understand or haven't yet identified the mechanism at play in our study reach which is causing degradation in the upstream part and aggradation in the downstream part of the river. Due to this I recommend that we take a conservative approach to any management. I would recommend that we don't take measures which might work out to be too drastic given this lack of understanding.

James Flanagan
Senior Engineer
Flood Protection

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Waikanae Channel Capacity Assessment

Kirsty Duff – Engineer Investigations

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Contents

Version	2.0 Update follow J.Cox Comments	
Date of issue	4th July 2022	
Prepared by	Kirsty Duff	Engineer Investigations
Reviewed by	Susan Borrer	Hydraulic Modeller
Approved for issue by	Andy Brown	Team leader

1. Purpose

This report summarises the results of the Waikanae Channel Capacity Assessment conducted by the Investigations, Strategy & Planning Team of GWRCs Flood Protection Department to assess the impact of aggradation in the lower reaches of the Waikanae River on the level of flood protection.

2. The Problem

Natural aggradation in the lower reaches of the Waikanae River have been thought to be reducing the channel capacity and consequently reducing the level of flood protection provided to the Otaihanga community. The recent gravel analysis showed a significant natural trend of aggradation between cross section 10 to 260. Considerable concern has been raised about the formation of a gravel island between cross section 10 and 70 in the Waikanae River this thought to be reducing channel capacity and consequently reducing the level of flood protection provided to the Otaihanga community. This section of the Waikanae is within a scientific and coastal marine reserve meaning that any extraction or channel capacity works must be carefully assessed, planned and managed.

Upstream of the aggraded section is the Otaihanga flood wall (CS100). This reinforced concrete flood wall that has been identified as being below capacity, and with concerns over structural stability during flood conditions.

The target level of protection for Otaihanga and Waikanae is 1% AEP plus climate change. The Waikanae Flood Management Plan (FMP) states a 1% AEP level of protection was to be provided in 1997 but subsequent department policy and recent construction of the Jim Cook Park stop bank to a higher standard the target level of protection from the Waikanae River is 1% AEP plus climate change.

2.1 Key Questions

The Investigations, Strategy & Planning team were asked to investigate the impact of aggradation on the level of service and whether the Otaihanga flood wall is of sufficient capacity to contain the design flood.

This investigation will inform the Flood Protection Departments approach to channel management in the Waikanae and any further investigations.

The following key questions are addressed:

<u>Aggradation</u>

1. Does the aggradation observed impact the level of flood protection provided to the Waikanae community?
    a. What is the impact of the gravel build up within the scientific reserve, does this impact the level of flood protection provided to the Waikanae community?
2. If an impact is observed then where and how much aggregated material should be extracted from the Waikanae River
3. If an impact is not observed do we still provide the target 1% AEP plus climate change level of service to the Waikanae Community

<u>Otaihanaga Flood Wall</u>

4. Does the otaihanga floodwall overtop in the design flood.

In the broader context GWRC is applying for resource consent for river management activities, including wet gravel extraction in the Waikanae River upstream of the Coastal Marine Area (CMA) upstream of cross section 70. Which has been flagged as critital to the Flood Protection Opertations Team. The Department of Conservation and Mana whenua has requested this channel capacity investigation is conducted to inform the resource consent and provide the basis for decisions on how much, and where, gravel extracted is from.

There is also significant iwi and community interest in the management of gravel in the Waikanae River.

3. Methodology

To address the questions above the Investigations, Strategy & Planning Team has conducted a modelling investigation.

This modelling investigation has been progressed in two phases:

- **Phase 1 -** Created two hydraulic models - one depicting the catchment as it was in 1991 and another which was updated to represent the 2019 catchment.
- **Phase 2 -** Assessed scenarios in the 2019 model to determine channel capacity and the impact of channel management. Developed scenarios to assess the impact of other factors such as changes in hydrology and climate change.

Investigating future aggradation was proposed as part of the initial project scope. However, the results of the investigation have indicated that climate change will have a greater impact on the flood hazard on the community and as such a more strategic assessment is required. Phase 1 Summary

In Phase One the comparison of the two models, 1991 and 2019 indicated an increase in flood waters from the end of the Kauri/Puriri reach downstream to Otaihanga reach (Figure 1). However, it was difficult to draw a conclusion regarding the cause of the increased flooding in this area. The Waikanae catchment has undergone many changes in the past 30 years including

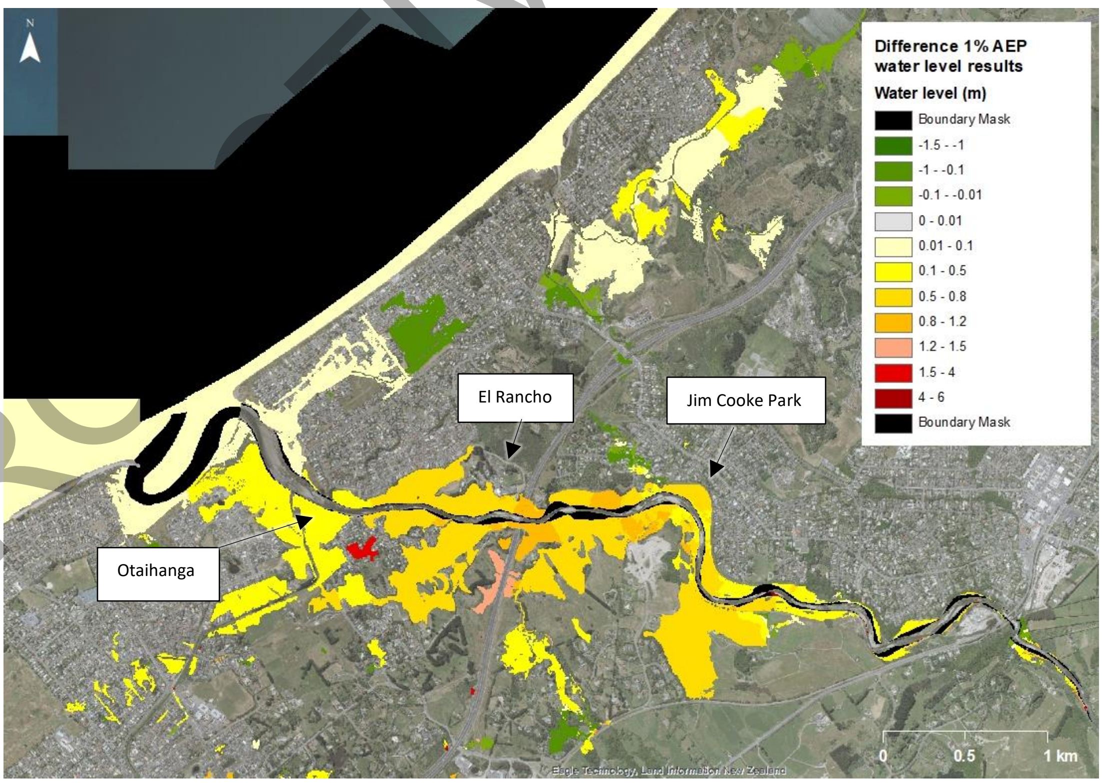

Figure 1 Difference in water level between the 1991 and 2019 models

the construction of two stopbanks along Jim Cooke Park and Greenaway Reserve. The construction of these stopbanks has increased the protection to houses along the right bank as it has reduced an overflow from Waikanae River towards Waimea Stream. However, this has forced the water that would be lost by this overflow to be redirected down the Waikanae River channel. This could be one of the factors increasing flood depths downstream to the Otaihanga area.

Additional modelling was carried out to assess the impact of the stopbanks on the redirection of flood waters. The 1991 model was run with 'glass walls' where the stopbanks are now situated in Jim Cooke Park and Greenaway Road Reserve. The results of this can be seen in Figure 2 the blue lines indicate where the elevation was raised significantly to mimic the current stopbank structures. The 'stopbanks' increase flood depths in the Otaihanga area by up to 0.2 m. The comparison for the 2019 and 1991 flood plan showed an increase in depth of 0.5 m, with some locations being as high as 0.8 m. This indicates that the increase to flood waters is not solely the creation of the stopbanks redirecting flow down the main channel of the Waikanae River.

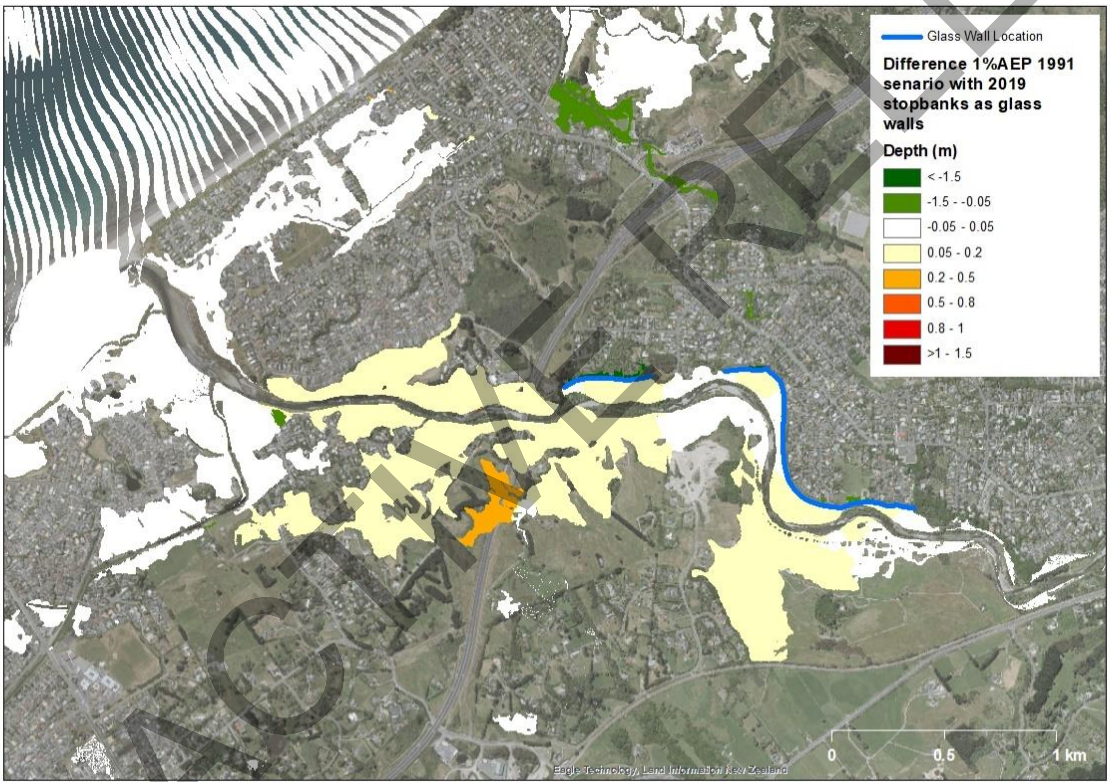

Figure 2 Difference map between 1991 results and 1991 with 2019 stopbank structures as glass walls

Phase One also highlighted the need to update the hydrology used within the model. The peak flows in the Phase One model were taken from the last peer-reviewed hydrological analysis of the Kāpiti Coast which was undertaken in 2009 (McKerchar, 2009). The impact of 12 years of extra flow record indicated a potential 5% increase to the peak flows. The increased peak flow along with an updated climate change scenario, were run in Phase Two of the project.

3.1 Phase 2 Summary

In phase two the 1D network in the 2019 model was lowered to mimic gravel extraction. This way we can investigate if reverting the channel morphology to the 1991 mean bed levels (MBL) will increase the level of service provided to the Otaihanga area. A number of or scenarios were also ran including:

- Waikanae MBL reduction (XS70 - 260)
- Waikanae MBL reduction (XS20 - 260)
- Peak hydrology 422m^3/s
- Climate change

The following sections outline the model build and present the findings from Phase Two of the project.

4. Results

4.1 Model Modifications and Scenarios

During Phase Two some changes were made to the baseline 2019 model. Links between the 1D and 2D model at the south side of the mouth were pushed further out of the estuary to the top of the first sand dune. A larger area of the estuary was left in the 2D model in Phase One, as it was believed that this area would see significant fluctuations in flood levels. However, this was incorrect, and the largest area of change was seen is within the Otaihanga area further upstream. Some modifications to the stormwater culverts that were added in 2017 to the model by DHI were also made. As on further investigation into the model showed that some of the links between stormwater ponds and culverts were set up with incorrect inlet or outlet elevations. The 2019 baseline model was run again to incorporate these changes so that when comparing the mean bed level and hydrology scenarios the model outputs were the same.

Within Phase Two, two models with different mean bed level and two models with different hydrological components were built. The table below summarises these different models and the results are discussed in Sections 4.2 and 4.3.

Model name	Description
Baseline 2019	This model is the baseline, or current environment, model used within Phase Two of the project. It depicts the catchment as it was when it was last surveyed in 2019. This model includes the updates described above regarding culvert outfalls and 2D link changes.
Waikanae MBL reduction (XS70 - 260)	In this model the active channel was lowered to the cross sectional mean bed level (MBL) that was observed in 1991. This was done from cross sections 70 to 260. This section of the river was highlighted as the aggrading reaches within the most recent gravel analysis. The changes to MBL stop at cross section 70 in this model as it is the last cross section before the Department of Conservation's (DoC) Waikanae Estuary Scientific Reserve.
Waikanae MBL reduction (XS20 - 260)	This model is similar to Waikanae MBL Reduction (XS70 - 260), although the active channel in cross sections 20 to 260 were all lowered to the 1991 MBL. This was done to investigate if the removing the gravel build up within the Scientific Reserve would create any further reduction on flood levels.
Peak hydrology 422m^3/s	In Phase One of the project it was highlighted that there is potentially a 5-10% increase to peak flows due to an extra 12 years of flow record now available. This model adjusted the hydrograph to peak at 422 m^3/s, a 5% increase from the Baseline model which is 400 m^3/s.
Climate change	The effects of climate change were applied to the Waikanae model inflows. RPC 6.0 was used to adjust Waikanae River inflow and the tide level was increased to incorporate sea level rise. The percentage increase to rainfall was mirrored within the hydrograph, this an equated to a 23.3% increase in flow. The hydrograph was adjusted to have a peak of 493 m^3/s and a 1.35 m sea level rise was added to the tide levels

4.2 MBL Reduction Model Results

4.2.1 MBL reduction in the aggregating reach above the Scientific Reserve (XS70 - 260)

The difference between the 2019 baseline model and the Waikanae MBL reduction (XS70 - 260) scenario can be seen in Figure 3. The change in water level within the Otaihanga is approximately 0.1 m across the area. There is a slightly larger reduction of 0.2 m in locations with stormwater interactions, such as the around Kokako Road and SH1.

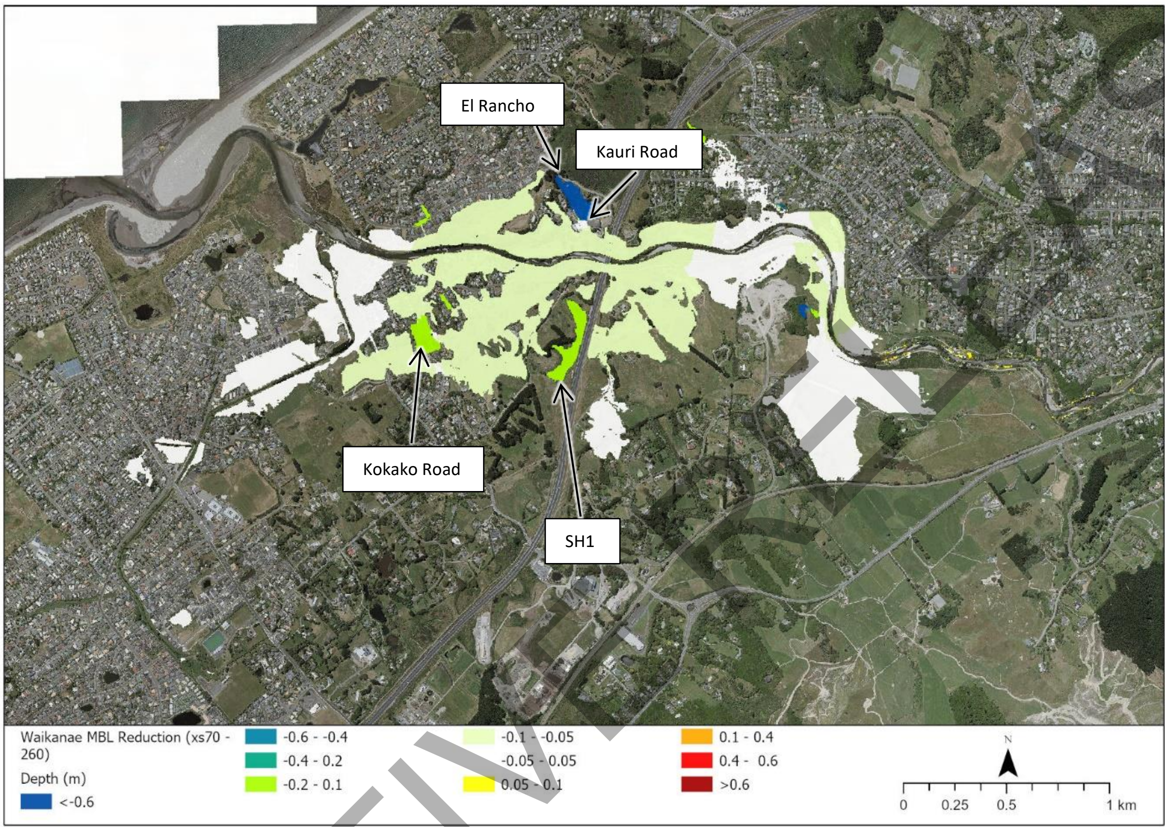

Figure 3 depth difference between 2019 Baseline model and Waikanae gravel extracted (xs 70 to xs 260) model run.

The most notable reduction is the levels is at El Rancho, where water depths have changed by 0.9 m. The cabins of El Rancho, which sit in the dark blue location in Figure 3, are effectively within a basin where Kauri Road acts as a high point protecting the cabins from flooding. Kauri Road is only overtopped as the peak flow passes down the river. The reduction in depths within the MBL scenario, is believed to be due to the extra capacity around the SH1 Bridge leading to less water being pushed up and overflowing into the El Rancho car park. Once water overtops Kauri Road it is trapped for the longevity of the model run, it should also be noted that when it enters this location it fills fast. The water depth is in this basin is roughly was 1.3 m in the 2019 baseline model and this reduces to 0.4 m with the reduction of MBL. Therefore increasing the channel capacity the upper section of the El Rancho Reach will help reduce the magnitude of flooding to El Rancho.

There have been recent works removing material and re-aligning some of the channel bed, due to the added aggradation that has been caused by the express way's new bridge pier. These works were completed in July 2019 and the survey that was used within this model was taken in January 2020. Since the works have been completed, aerial photography shows that an island has begun to form again behind the pillar. This model shows that this area should be monitored and material removed if build up is seen.

4.2.2 MBL reduction along all the aggrading reach including the Scientific Reserve (XS20 – 260)

There has been significant concern about the gravel build up within the Waikanae Estuary Scientific Reserve. To understand the possible flooding impacts this material build up could have on the Waikanae community, the Waikanae MBL reduction (XS20 - 260) scenario was run. This reduced the MBLs along all the aggrading reaches. The difference between this and the 2019 baseline model can be seen in Figure 4 below. The most significant change that occurs within this model run is a reduction to the flooding at the south end of Kokako Road (Figure 4). Lowering the MBLs within the Scientific Reserve did not result in a significant reduction of the flooding within Otaihanga or Waikanae Beach. Most of the Otaihanga reach had a reduced flood depth of 0.1 m. Some areas within the Science Reserve and around the Mazengarb Stream show a slight reduction of water depths that wasn’t present in the MBL XS 70 – 260 model.

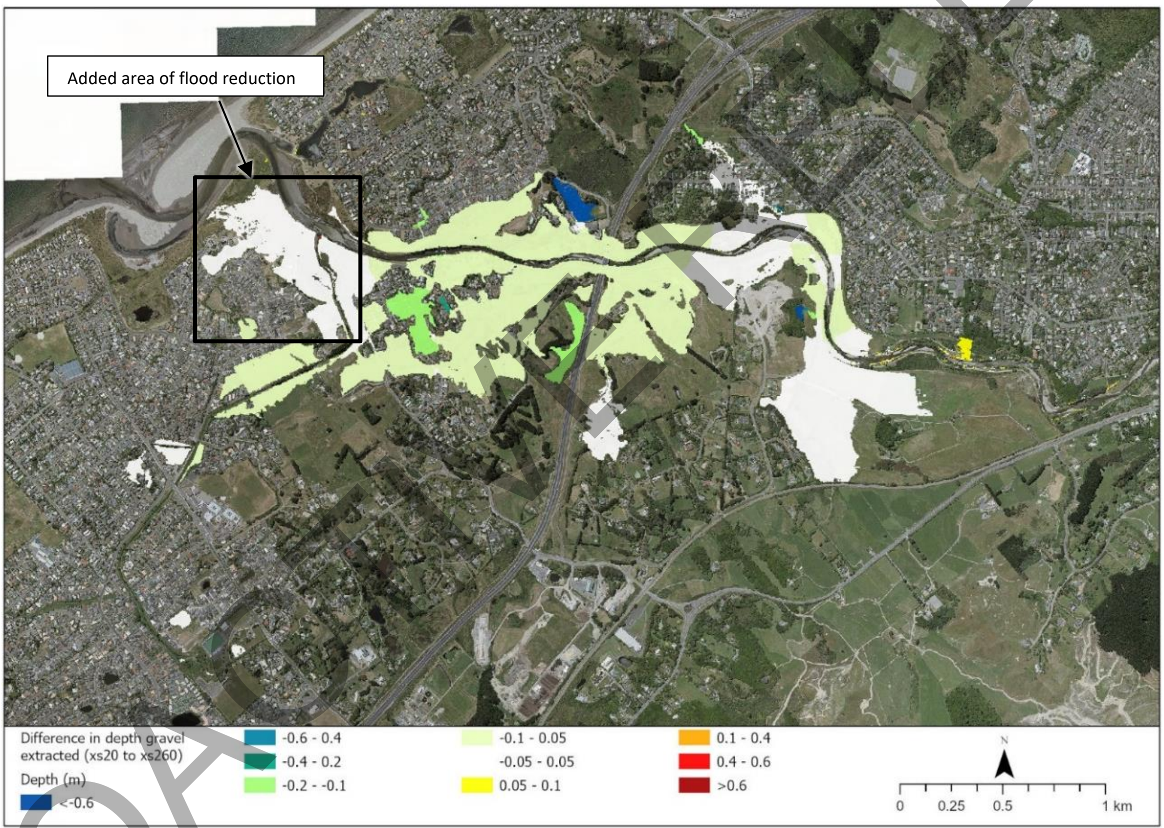

Figure 4 Difference between 2019 Baseline and Waikanae gravel extraction (XS20 to XS260)

The difference between the two MBL models shows very little benefit from the extraction further into the aggrading reach. There are only a few locations that have reduced flood water due to the added capacity in the Scientific Reserve, these locations can be seen in Figure 5. There is only 0.1 m or less of change to flood depth in areas near the Mazengarb Stream and some of the stormwater ponds and outlets also see the same reduction. The geomorphology within the Scientific Reserve is vastly different to upstream; this area is a natural delta and is one of the widest parts of the Waikanae floodplain. This therefore means the Scientific Reserve has significant flood storage. The capacity issue is further upstream where channel is much straighter, constrained, and developed. Water has already exited the river channel in the in the El Rancho reach before the river delta has exceed capacity.

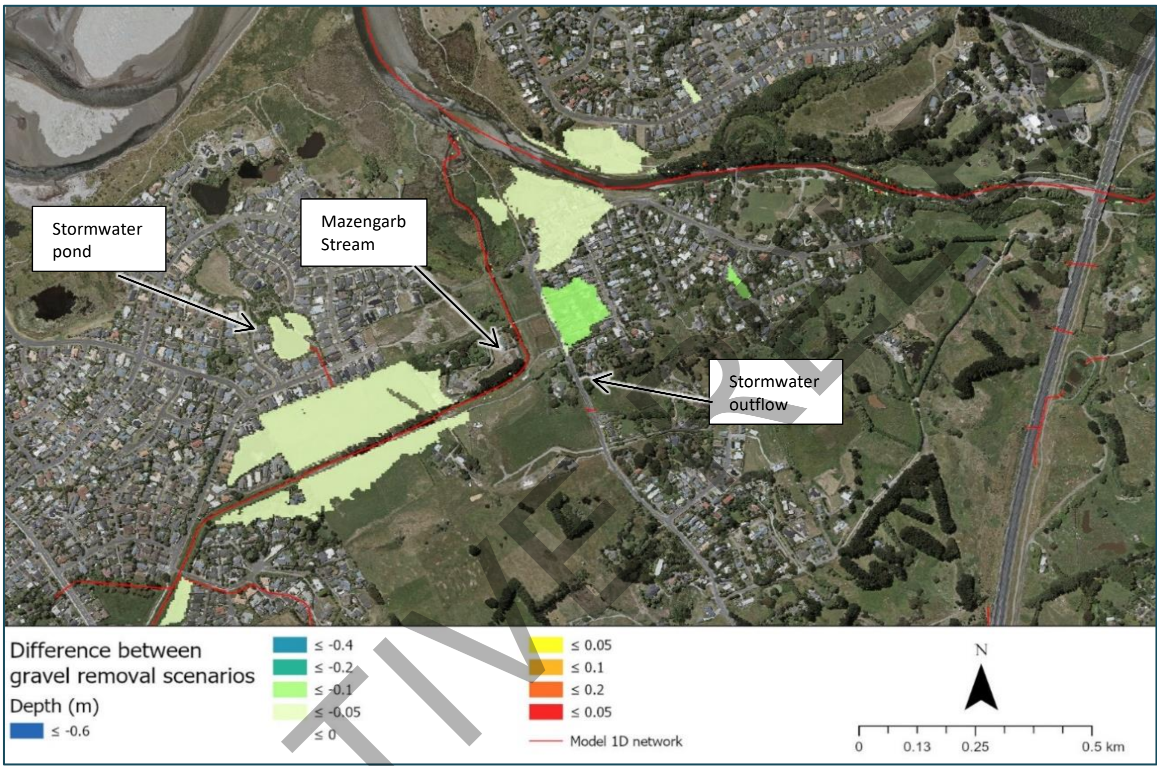

Figure 5 Depth difference between the two gravel scenarios, Waikanae MBL Reduced (XS20-260) and Waikanae MBL Reduced (XS70-260)

Therefore, the removal of material from the Scientific Reserve is not recommend as its reduction to flood depths is not significant to the Otaihanga and Waikanae Beach communities.

4.3 Hydrology Models (Peak 422 m^3/s and Climate Change)

4.3.1 Peak 422 m^3/s

The peak 422 m^3/s scenario shows very little change to the flood extent across the Waikanae floodplain Figure 6. There is a small area that is increased, from the overflow that comes out by Greenway Road. On Average the overall flood depth is increased up to 0.1 m, with El Rancho having an increase of flood depths of nearly 0.4 m (Figure 7)

Figure 6 flood extents of the hydrology peak 422 m3/s and 2019 baseline map.

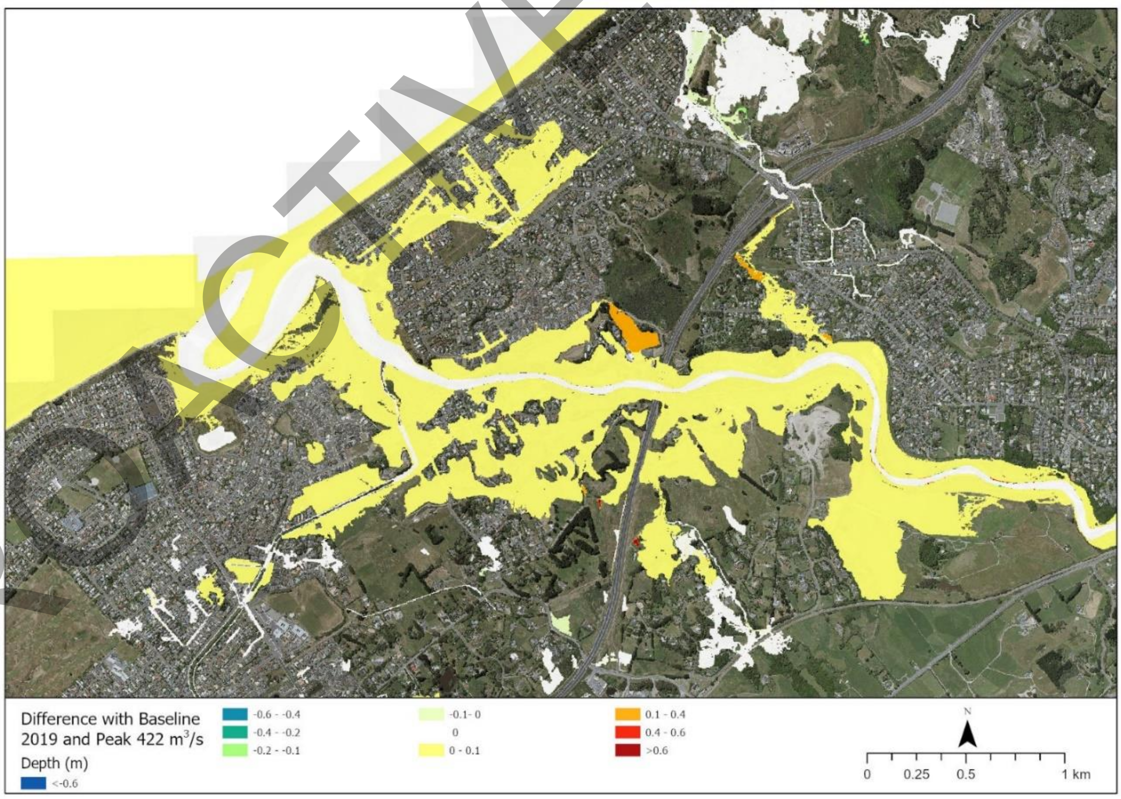

Figure 7 Difference in flood depth between the Baseline 2019 scenario and the Adjusted Hydrology Peak Flow 422m^3/s scenario

4.3.2 Climate change

Predicted climate change effects have a significant impact on the flooding within the Waikanae catchment, the extent of flooding within the coastal area increases significantly (Figure 8). Many areas of Paraparaumu Beach and Waikanae Beach become inundated. The increase in sea level pushes the tidal interaction higher, which in-turn causes the flood waters to pond for longer forcing water to move further onto the floodplain (Figure 9). The extent to of the overflow at Greenway Road is also increased, with much of Weggery Drive becoming flooded. The El Rancho Reach to above SH1 shows an increase of flood waters by 0.6 m, with El Rancho itself increasing in flood depths by over 1 m (Figure 9). Houses situated between Otaihanga Road and Kokako

Figure 8 Comparison of the climate change flood extent (light blue) with the baseline 2019 scenario (dark blue)

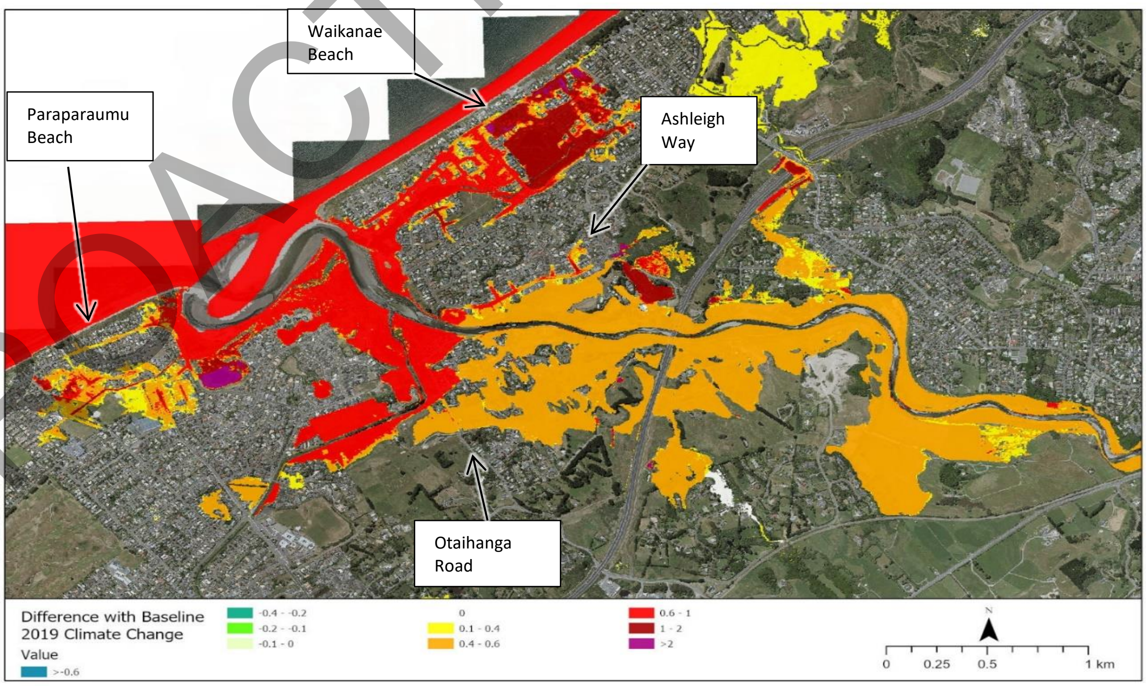

Figure 9 Difference in flood depth between the baseline 2019 scenario and the climate change scenario

Road will see an increase in flooding by nearly 1 m. It should also be noted that Otaihanga Road becomes significantly inundated within the climate change scenario with a predicted 0.6 m – 1 m increase in flood depths (Figure 9). This road is the only access way to Otaihanga and if it gets cut off it will be very difficult to get aid to the Otaihanga community during a flood event.

4.4 Houses within the flood extent

The substantial increase of the flood extent within the climate change scenario raised the question of how many properties will be affected by the changing climate. Therefore, a GIS analysis was undertaken to quantify the effect to the local community. The table below shows the number of properties within the flood extent (Table 1).

By increasing the channel capacity within the aggrading reach there is a reduction of 18 properties within the flood extent. Removing more material from the Scientific Reserve will only protect one more property from being within the flood extent. The number of properties that have significant flooding (over 0.5 m) is not reduced with the extra removal. However, ten of these properties are located within the overflow at Greenaway Road and the removal of material reduces this overflow and therefore provides more protection to the properties within this area.

In climate change scenario the number of properties within the flood extent increases significantly. This is due two large overflows that occur towards the coast at Paraparaumu Beach and Waikanae Beach. There are also 27 properties that will be affected along Weggery Drive as the overflow here is increased. This causes a cluster of five properties as far away as Ashleigh Way to be within the flood extent (Figure 9). Not only is there a significant increase in the number of properties that will be affected by flooding, but also there is an increase to the number of properties that will be subjected to deep flood waters. There is an increase of 317 properties having flood waters above 0.5 m within the climate change scenario model.

Table 1: Number of houses within the flood extent along with total number of houses where flood waters exceed 0.5m. The number in brackets is the difference in houses between the baseline 2019 and the particular scenario. Blue for an increase in flooding properties and green for a decrease.

Model scenario	Properties with flood waters above 0.5m deep	Total number of properties within the flood extent
2019 baseline	227	645
MBL reduced	211 (- 16)	628 (-17)
MBL reduced Scientific Reserve	211 (-16)	626 (-19)
Peak hydrology 422m^3/s	237 (+10)	654 (+9)
Climate change	544 (+317)	1323 (+678)

4.5 Otaihanga Flood Wall

The Otaihanga flood wall is a line of defence for many residents along Makora Road. The wall sits along the edge of the Otaihanga Domain and is designed protect up to a 1% AEP flood event, though the flood levels within this modelling project have shown that the wall is overtopped within the 2019 baseline results (Figure 10) The as-built height of the wall is 4.16 m, this is overtopped within all of the flood scenarios (Table 2). Increasing the capacity within the river will reduce the magnitude the wall will get overtopped though it will not solve the problem. It should also be noted that the wall was added into the model as a bund like structure, therefore the force applied to the wall due to the flooding is unknown. It should also be mentioned that within the 2019 baseline model, the wall was overtopped for 15 hours. This is a significant duration and should be considered if any works are undertaken to improve the wall.

Table 2: Modelled water levels from all the scenarios at the Otaihanga flood wall, the amount of water that the wall is overtopped by is within the brackets

Model	As-built crest level	Modelled Water level at Otaihanga	Difference
Waikanae 2019 baseline	4.16 m	4.6 m	0.44m
Waikanae MBL reduction (XS70 - 260)	4.16 m	4.4 m	0.24m
Waikanae MBL reduction (XS20 - 260)	4.16 m	4.4 m	0.24m
Peak hydrology 422m^3/s	4.16 m	4.6 m	0.44m
Climate change	4.16 m	4.9 m	0.74m

5. Conclusions

The assessment carried out by the Investigations, Strategy, and Planning Team has concluded the following:

5.1 Aggradation

1. *Does the aggradation observed impact the level of flood protection provided to the Waikanae community?*

In some of the more confined locations along the river the reduced capacity has an impact on the flood hazard. Such as cross-section 90 - 110 which has housing very close to the river channel or between cross-sections 130 – 210 where the channel has been realigned and the SH1 Bridge is situated.

a. *What is the impact of the gravel build up within the scientific reserve, does this impact the level of flood protection provided to the Waikanae community?*

No, we assess that the measured bed level change between cross-section 10 and 70 does not pose a flood risk to the Waikanae community. A minor impact to modelled levels is indicated but it is within +/-5mm so falls within modelling error.

It should be noted that this the widest part of the Waikanae River channel so proportionally the aggradation is small in regard to the available cross section. The modelling has indicated that spilling occurs further upstream around the expressway / Jim Cook park reach before reaching the mouth.

2. *If an impact is observed then where and how much aggregated material should be extracted from the Waikanae River*

No meaningful impact was observed but the modelling has indicated that channel management should take place between cross section 90 and 230 in the vicinity of El Rancho to Jim Cook Park to prevent flooding of El Rancho. It is recommended that this is maintained to the 1991 mean bed levels. This action would reduce flood risk to approximately 20 properties.

3. *If an impact is not observed do we still provide the target 1% AEP plus climate change level of service to the Waikanae Community*

No, the modelling assessment has indicated that a significant portion of the community is at risk of flooding on the 1% AEP + climate change scenario. It should be noted that the 2019 baseline model with a 1% AEP without climate change indicates approximately 645 properties are at risk. This number rises to 1323 properties. Additionally, the stop banks do not overtop in the 1% AEP or the 1% AEP plus climate change but get outflanked. The Otaihanga floodwall and other road raising do overtop on the climate change scenario.

Furthermore, a recent population forecast undertaken by BERL for Kāpiti Coast District Council (KCDC) has estimated population growth of approximately 32,000 people to 90,000 by 2051, requiring close to 14,000 additional dwellings across the region. Locations that have been highlighted as prone to increase flood risk within the climate change scenario (Otaihanga, Paraparaumu Beach, and Waikanae Beach) have a medium predicted dwelling growth 140, 163 and 1,431 respectively (Cox and Dixon, 2020). This is significant growth and will not only stretch our current flood protection infrastructure within the Waikanae catchment, but also our emergency response capabilities.

5.2 Otaihanga Flood Wall

4. Does the Otaihanga floodwall overtop in the design flood?

Yes, the modelling assessment indicates that the floodwall overtops in the 1% AEP and the 1% AEP plus climate change scenario. The modelling also indicates that the floodwall is loaded for approximately 15 hours during the design flood. We have also observed evidence in recent events that the sump systems on the landward side of the wall surcharge in small events causing surface water flooding. We also have concerns about the structural stability of the flood wall and should highlight that there's are properties directly behind the wall if a breach was to occur.

6. Recommendations

In response to these findings the Investigations Strategy and Planning Team recommends the following actions are undertaken for:

6.1 Aggradation

- Continue to manage the channel in the area of cross-section 90 to 230 to reduce the flood risk to El Rancho, the overflow at Greenaway Road, and Weggery Drive. Paying particular attention to the following:
    - XS90 to 110 – to increase capacity along the Otaihanga flood wall
    - XS130 to 150 – to reduce the flooding occurring at El Rancho
    - XS185 to 230 – to reduce the size of the overflow that occurs at Greenaway Road
- The recent works that have been undertaken to remove gravel downstream of SH1 Bridge were included in the survey that was used for this modelling. The modelling shows that increasing the capacity here will help provide better protection to El Rancho. Therefore, it is recommended that this location is monitored, and if the channel begins to lose capacity here, material is removed.
- It is also recommended that material is removed between XS90 to 110 and XS185 to 230 to reduce the flooding and increase the level of service being provided to the Waikanae community.
- The locations above coincide with areas highlighted as possible areas to widen the channel in transport work undertaken by Opus (Opus, 2012). This report was an options analysis and did not recommend any design criteria. DoC is also conducting geomorphologic

assessments in along the Waikanae River. If sediment traps were desirable as a management option, it is recommended that we work with the geomorphologist to get specific design criteria and evaluate that as an option through the wider review of flood and erosion risk management.

- Progress planning and mapping actions as outlined in 6.3 below.

6.2 Otaihanga Flood Wall

- Proceed with the structural assessment of the Otaihanga floodwall as the risk of breach remains high.
- Operations Planning develop an emergency action plan for the floodwall
- Incorporate the longer-term future of the floodwall in the review options for the management of flood risk of Waikanae through an FMP Review.

6.3 Planning and Mapping

- Upgrade the flood hazard model to a TUFLOW model which can be used to assess flood risk management options in the future.
- Produce new district planning maps to help inform development planning in the Waikanae Catchment.
- Engage with KCDC about the elevated risk to Waikanae so land use planning and develop can be managed appropriately.
- Review options for the management of flood risk of Waikanae through an FMP Review.

It is envisaged that the flood hazard model upgrade will need to take place before a review of the flood risk management measures. However, engagement with KCDC on the elevated risk should take place as soon as possible.

The wider review of the flood and erosion risk management strategy (the FMP) should support Mana Whenua's aspirations for the awa, the principles of Te Mana o Te Wai and direction of flood and erosion risk management by considering options for allowing the river the space to undergo its natural processes where possible whilst protecting the Waikanae community.

7. References

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