Rangitikei River

Gravel Report

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Executive Summary

This study examines the gravel resources in the Rangitikei River based on the analysis of a combination of river cross section data and interpolated data from a digital elevation model.

The Rangitikei was divided into two separate reaches, defined by the timing of river surveys. The lower reach relates to the area of river from the mouth to benchmark 32.48 km and the upper reach relates to the area of the river upstream of benchmark 32.91 km to Rewa (benchmark 63.55 km).

The analysis of this report shows that the gravel volume has fluctuated along the Rangitikei River, with an overall trend of aggradation. The complex morphology of the Rangitikei River affects the ability to directly correlate an increase in gravel volume with deposition of gravel in the active channel. River alignment has affected the gravel volume change along the Rangitikei River due to marked increases in sinuosity, associated widening of bends, and formation of large vegetated gravel bars.

Degradation of the gravel resource has occurred between Bulls Bridge and Kakariki Bridge, though the dynamic morphology of the river affects the ability to attribute this degradation to gravel extraction only.

Mean bed level has also fluctuated along the Rangitikei River, there is a consistent relationship between mean bed level and gravel volume; a fall in either measure encounters a fall in the other, and vice versa. This relationship is not consistent along the entire length of the Rangitikei River due to erosional forces being focused on the berm rather than the bed.

It is recommended that annual gravel extraction rates be increased in parts of the Rangitikei River. One Plan Reach One (mouth to benchmark 15.45 km) currently has an allocable volume of 100,000 cubic metres per annum, this could increase to 130,000 cubic metres per annum due to significant aggradation of gravel. One Plan Reach Two (benchmark 15.45 km to Rewa) currently has an allocable volume of 30,000 cubic metres per annum. This reach includes the degradation zone, between Bulls Bridge and Kakariki Bridge, where the current rate of extraction is sustainable and no further change is recommended. However, between the One Plan Reach One/ Two boundary and Bulls Bridge it is recommended that a further 50,000 cubic metres per annum could be extracted from this 7 km reach. Upstream of Kakariki Bridge (from benchmark 40.01 km) annual extraction could increase to 100,000 cubic metres per annum to encourage extraction away from the degradation zone.

These recommendations have been conservative in increasing the gravel extraction volumes due to the uncertainty of the gravel resource and the dynamic nature of the morphology of the Rangitikei River. The river system as a whole may be effected by interrupting the supply of gravel to the downstream reaches.

CONTENTS

Rangitikei River Gravel Report

1 Introduction

This gravel report examines the gravel resources in the Rangitikei River from Rewa to the mouth. It covers the 63 km reach of the river that is in the Rangitikei River Scheme.

Figure 1 below shows the location of the study reach.

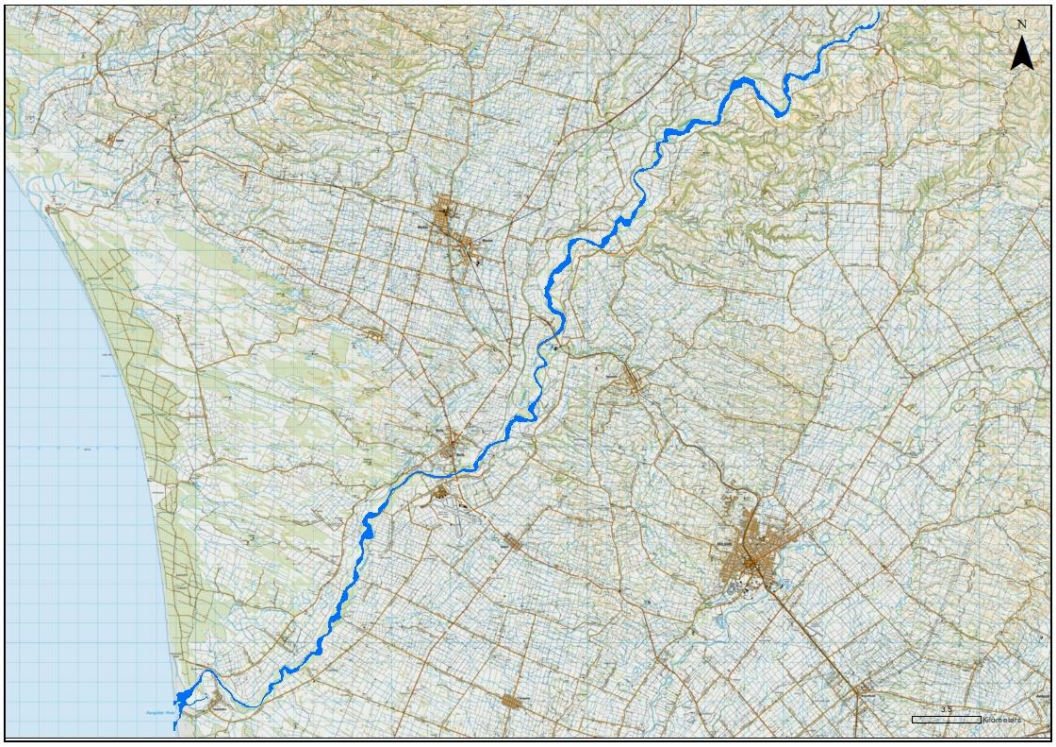


Figure 1: Rangitikei River Location Map

2 Background

The Rangitikei River catchment area is 4,144 km^2. The Rangitikei River Scheme provides erosion protection from Rewa to the sea, with the lower reaches providing flood protection to ~2,000 ha.

Figure 2 below shows the Rangitikei River catchment.

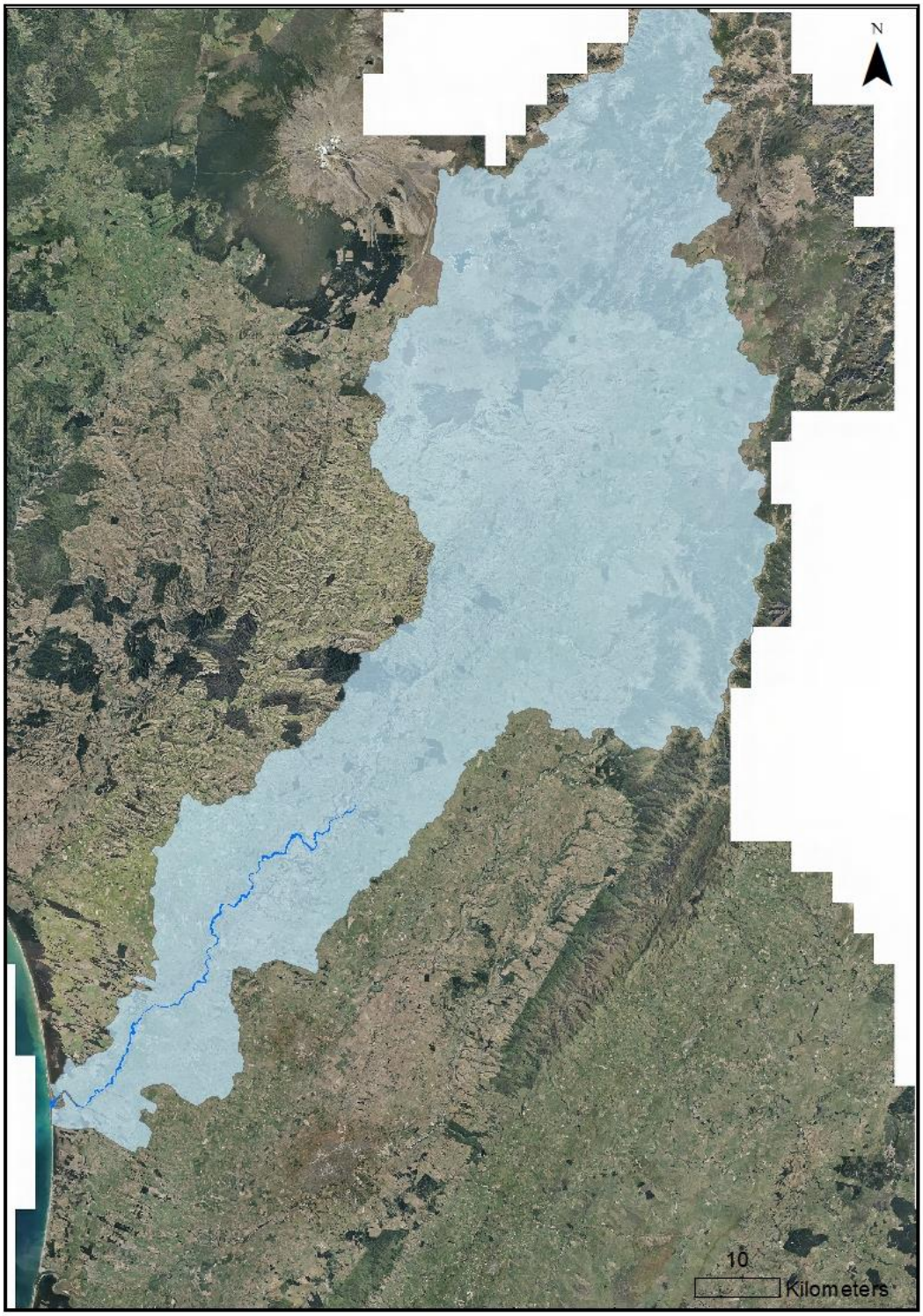


Figure 2: Rangitikei River Catchment

The Rangitikei River can be categorised into three parts:

(1) The lower reach, below Bulls (benchmark 22.33 km) is characterised by its wide floodplain, deposition of gravel, and the wide, shallow, multi-channel form. This reach has been stopbanked along the true Right Bank.
(2) From Bulls to above the Kakariki Bridge (benchmark 32.48 km) the river migrates within an entrenched terrace system and the significant floodplain.
(3) Above the Kakariki Bridge the terrace system is more complex which confines the river, and imposes control over the form of the river (Williams, 2018).

2.1 2010 Scheme Review

The 2010 Scheme Review concluded the following:

- The Rangitikei River continues to generally aggrade (apart from fluctuations near the river mouth) in the lower 15 km and degrade from that point to Rewa.
- Generally, between 15 km and Kakariki there is 'naturally' no increase in bed volume and that reach cannot be extracted without inevitable bed degradation. There are two apparent areas of deposition at Bulls and Kakariki; but this may be due to the bed there recovering from extraction due to infilling in subsequent floods, which deprives gravel to the reaches downstream.
- Since the previous survey in 1998, there has been a very serious drop in river bed volume and levels in the reach from Kakariki to Rewa, amounting to a loss of 2.4 million cubic metres of river bed.

2.2 2018 Scheme Review

The 2018 Scheme Review concluded the following:

- There are overall trends with substantial degradation of the river channel from the lower end of the alluvial plain (around 8 km) to above the Kakariki Bridge (around 35 km).
- The most recent survey indicates a deepening of the active channel area along the lower reaches (below about 15 km) due to the development of a narrower single channel along these reaches.
- Above the Kakariki Bridge, the mean bed level differences show the typical variations of a mobile gravel-bed river with a split channel form. There is, though, some degradation trend, which could arise from the channel management and confinement by farmland development.
- Since 2005, the sinuosity has markedly increased, with much wider bends extending well beyond the design fairway, and consequently with much larger bars that vegetation has now spread onto. The main channel has become progressively more entrenched, with an asymmetric shape around its bends. The bed material transport processes now gives rise to a downstream migration of the meanders, with sharper crossovers forming where rock works or dense vegetation holds the bank line.
- The river alignment and channel form from the Bulls Bridge downstream has remained essentially the same over the photographic record, but with some entrenchment and isolation of a berm area on the left side at the downstream end of this reach.

3 Cross Section Survey Data

The results of this study are based on the analysis of cross section survey data for years 2004 and 2009 and a combination of cross section survey data and LiDAR information (Light Detection and Ranging) for 2017.

LiDAR is a remote sensing method that uses light in the form of a pulsed laser to measure ranges to the earth's surface, and from the data obtained a Digital Elevation Model (DEM), was derived. However, LiDAR is unable to penetrate water and therefore; it was only used for sediment outside of the wetted channel. This data was combined with that obtained from physical surveys of the wetted channel. This combined dataset has been used for analysis in this study.

Figure 3 below illustrates the combination of LiDAR information and cross section survey information for analysis of the 2017 data in this report.

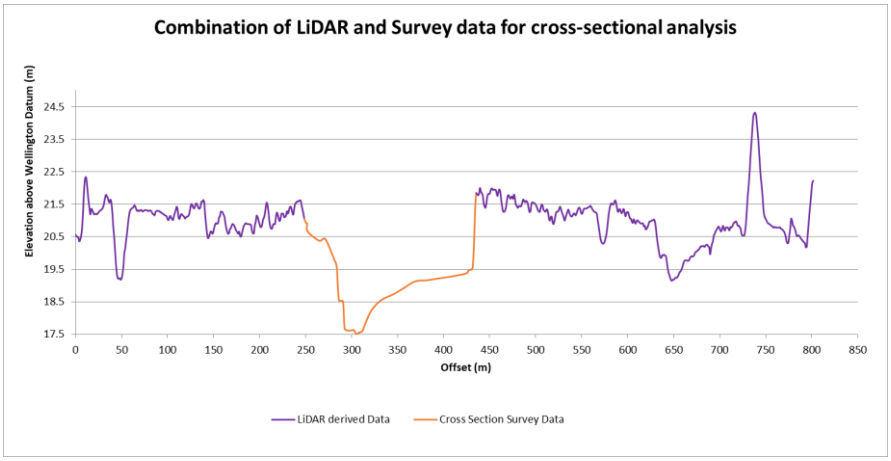


Figure 3: Combination of LiDAR and Cross Section Survey Data

The study reach was surveyed from the mouth to the 32.12 km benchmark in 2004 and from the 32.91 km benchmark to Rewa (63.55 km benchmark) in 2009.

Graphical representations of these surveyed cross sections are contained in Appendix E.

4 Cross Section Survey Data Analysis

To determine the change in the gravel resource of the Rangitikei River the change in volume of gravel has been calculated. The mean bed elevation has also been assessed in this study to help understand how the morphology of the river has changed over time.

For the purpose of this study, the active channel is defined as the area that includes the riverbed and gravel beaches normally located above the water level.

Analysis of the change in gravel volume and mean bed elevation will identify any trends of aggradation or degradation that may be occurring to the gravel resource of the Rangitikei River.

4.1 Gravel Volumes in the Rangitikei River

Individual analysis of each cross section was carried out to calculate the volume of gravel in the active channel of the Rangitikei River. HILLTOP software was used to calculate the area beneath the active channel at each cross section. These cross sectional areas were then integrated over half the distance to the adjacent upstream and downstream cross section to obtain a volume. These volumes have then been compared with those calculated from different surveys to see how the volume of gravel in the active channel has changed over time.

While this volume would include all material, and not just the gravel, between the riverbed and the assumed datum level, it is reasonable to assume that any change between surveys will be primarily due to the movement of gravel on the bed of the river and any gravel extraction.

A full set of results detailing the assumed extents of the active channel and the calculated gravel volumes can be seen in Appendix B.

4.2 Mean Bed Elevation of the Rangitikei River

The surveyed river cross section profiles were plotted using the over plot function on Manager. A visual inspection of the cross sections produced by Manager was carried out to determine the extents of the active channel at each cross section location. HILLTOP software was used to calculate the mean bed elevation for each cross section survey date (2004, 2009, and 2017).

A full set of results detailing the assumed extents of the active channel and the calculated mean bed levels can be seen in Appendix C.

5 Results

5.1 Mean Bed Elevation

As discussed in Section 3 of this report, the lower half of the study reach was surveyed in 2004 and the upper half of the study reach was surveyed in 2009.

Figure 4 overleaf shows the change of mean bed elevation of the active channel from 2004-2017. This demonstrates the variability of the channel at any given point along the river, as the channel migrates and changes form (William, 2018). The bed level fluctuations above Kakariki Bridge (benchmark 32.48 km) illustrates the typical variations of a mobile gravel-bed river with a spilt channel form (Williams, 2018).

Figure 4 shows that the mean bed level along the Rangitikei River has fluctuated significantly. There are sections along the study reach experiencing obvious rising or falling of mean bed level, these reaches are as follows:

The lower 5.42 km (from the mouth to benchmark 5.42 km) shows an increase in mean bed level, upstream of this reach there is a clear decline in mean bed level up to benchmark 16.75 km. Between benchmarks 16.75 km and 23.58 km (Bulls Bridge) there is an evident increase in mean bed level, this aggradation ends at the Bulls Bridge where there is a 16 km reach experiencing a fall in mean bed level (Bulls Bridge to upstream of Kakariki Bridge at benchmark 39.25 km). Upstream of Kakariki Bridge there is an increase in mean bed level, for ~10 km (to benchmark 48.5 km). Between benchmarks 48.5 km and 53.82 km there is a large decline in mean bed level, upstream of this reach there is a 10 km reach of increasing mean bed level (benchmark 53.82 km to 63.5 km) to Rewa.

Overall, the mean bed level has degraded along the entire study reach, though it is obvious from Figure 4 this decline is not evenly spread along the entire study reach. Between 2004 and 2017, the reach below Kakariki Bridge saw the mean bed level drop by an average of 0.29 m. The upper part of study reach saw fluctuations in the mean bed level of the river with some parts rising and others falling. Whilst there were some significant fluctuations in mean bed level in this reach (+/- 1.5 m) the average change was only a fall of 0.09 m between 2009 and 2017.

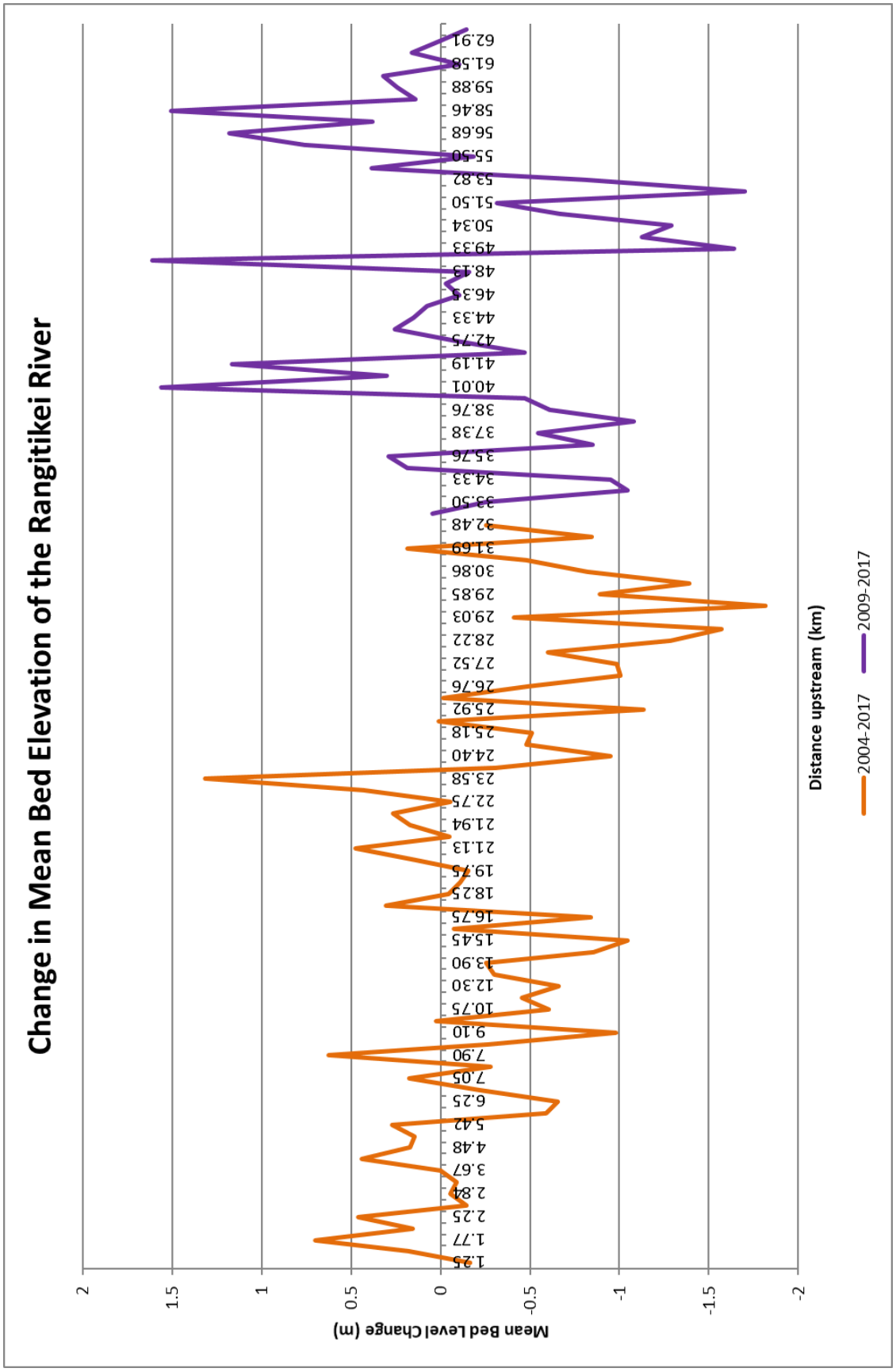


Figure 4: Mean Bed Elevation Change 2004, 2009, 2017

Between 2004 and 2017, there is a concentration of mean bed level decline between Bulls Bridge and Kakariki Bridge (benchmarks 22.33 km and 32.48 km). Mean bed level in this reach declined on average by 0.54 m, equating to 0.04 m per year of bed degradation. This concentration of bed degradation can be attributed to large channel shifts due to the surrounding terrace system and floodplain, and gravel extraction contributing to channel entrenchment.

Inspection of 2005 and 2016 aerial imagery shows that there were marked channel changes in this reach. The channel eroded ~100 m of the true Right Bank at benchmark 24.4 km resulting in ~1 m of bed degradation, at benchmark 25.92 km the river has migrated closer to the true Left Bank resulting in ~170 m of berm developing vegetation growth; causing concentration of flow on the riverbed, ultimately leading to entrenchment of the channel. Some reaches of the river have not experienced significant channel movement; therefore mean bed elevation has declined simply due to erosion of the riverbed. This erosion may be due to natural river processes that could be exacerbated by interventions in the river. For example, a number of bank protection assets are within this ~8 km reach of the river which cause the energy of the flow to be concentrated on the river bed rather than the bank.

Williams' Rangitikei Scheme Review (2018) has indicated that the lower section of the study reach (below 15 km) has experienced deepening of the active channel (decline in mean bed elevation) due to the development of a narrower single channel. This is demonstrated between the 8.21 km and 16.75 km benchmarks.

The decline in mean bed level between 2009 and 2017 in the upper half of the study reach is not as concentrated as the lower reach. The benchmarks experiencing the largest decline in mean bed elevation do not show significant channel movement; instead, this decline is attributable to the erosive powers of the flow being concentrated on the riverbed rather than the bank, similar to the downstream reach discussed above.

Figure 4 shows a large decline in mean bed level between benchmarks 49.33 km and 52.44 km between 2009 and 2017. This is due to channel entrenchment because of a narrowing thalweg. At benchmark 52.44 km erosion of ~230 m of riverbank has occurred as the river has meandered toward the right bank causing entrenchment and armouring of the point bar.

Overall, the Rangitikei River is a meandering river that has large-scale gravel extraction along its entire reach and is in a transitional phase as a single, meandering channel is developing. Mean bed level will continue to fluctuate as the river continues to adjust to its changing form and management approaches.

5.2 Gravel Volume Change of Rangitikei River

As discussed, in Section 3 of this report, the lower half of the study reach was surveyed in 2004 and the upper half of the study reach was surveyed in 2009. Both of these reaches were re-surveyed in 2017 using a combination of physical surveys and LiDAR.

Figure 5 below shows the change in gravel volume in the lower half of the study reach between 2004 and 2017.

Gravel volume between 2004 and 2017 has fluctuated overtime, with an overall increase in volume. Net gain in gravel volume was 670,000 cubic metres in this time, which equates to ~51,000 cubic metres per year of gravel aggradation.

Significant degradation of the gravel resource has occurred in this reach, concentrated upstream of Bulls Bridge to Kakariki Bridge, benchmarks 23.58 km and 32.48 km respectively. Total gravel volume declined by 1.26 million cubic metres between Bulls Bridge and Kakariki Bridge, between 2004 and 2017, which equates to 96,700 cubic metres of annual degradation of the gravel volume. The decline in gravel volume is consistent with mean bed level degradation (0.04 m of decline per year), which is attributable to gravel extraction resulting in entrenchment and narrowing of the active channel.

As **Figure 4** and **Figure 5** show, the reach upstream of Bulls Bridge has seen a lowering of mean bed levels and a reduction in gravel volume, therefore the gravel resource has experienced degradation.

The reach downstream of Bulls Bridge has experienced an overall trend of aggradation in this study period. Gravel volume downstream of the Bulls Bridge aggraded by 1.93 million cubic metres between 2004 and 2017, this equates to 148,000 cubic metres of annual aggradation. Whilst this reach has seen a significant aggradation of the gravel resource in the Rangitikei River, the mean bed level has fluctuated throughout the reach with a negligible average change (-0.007 m per annum). Between benchmarks 5.83 km and 16.75 km there is significant lowering of the mean bed level even though the gravel volume has aggraded. As discussed earlier in this report, the lower reach of the Rangitikei River is deepening due to the development of a narrower single channel (Williams, 2018). The gravel volume is aggrading due to armouring of point bars, causing large stores of gravel to be immobile and continually aggrading on the beaches.

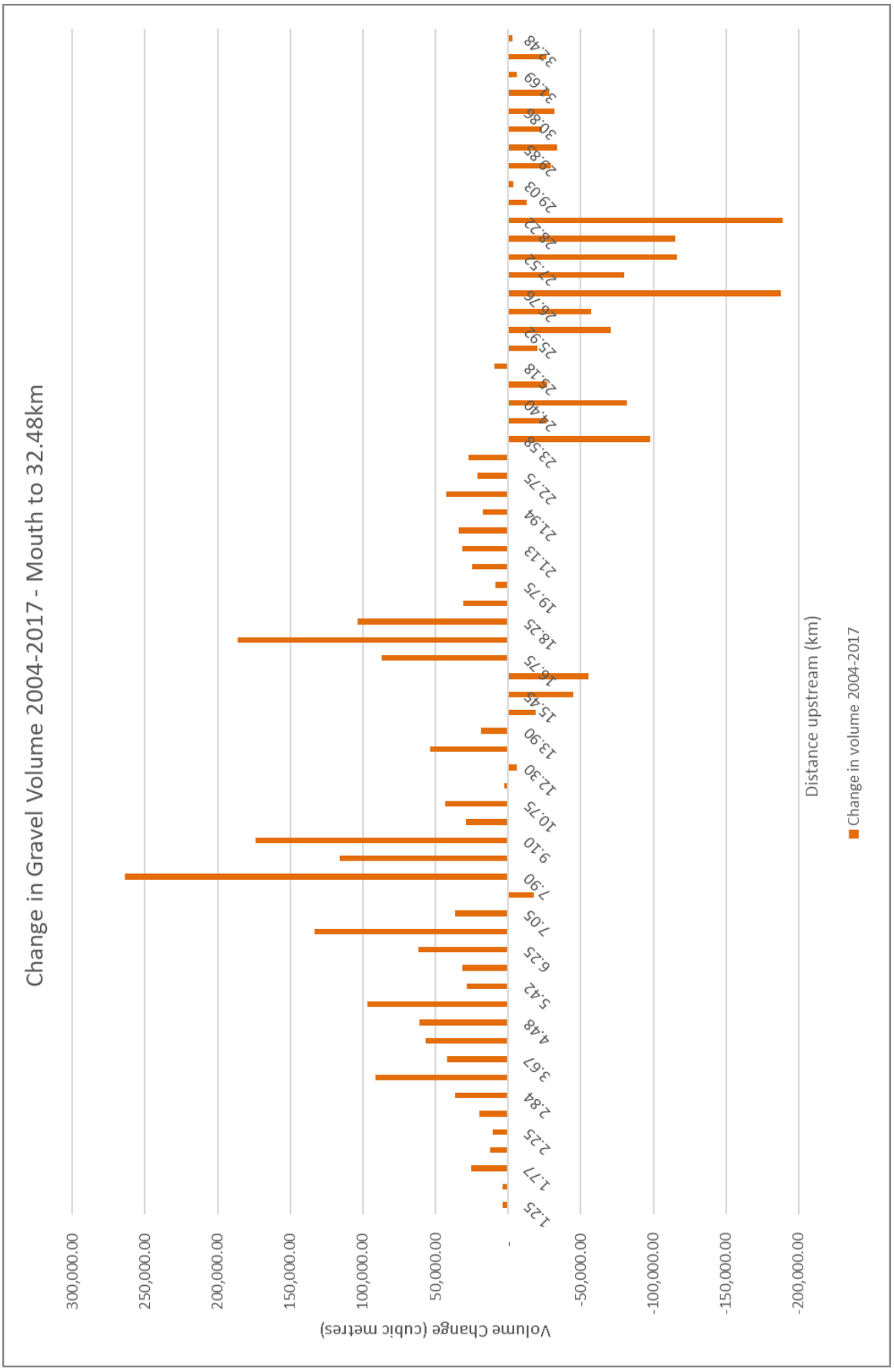


Figure 5: Gravel Volume Change between 2004 and 2017

Figure 6 overleaf shows the change in gravel volume in the upper half of the study reach from 2009 to 2017.

The figure shows that the gravel resource in this reach has fluctuated over this study period with a general trend of aggradation.

A net gain of 920,000 cubic metres occurred in this study period, equating to ~115,000 cubic metres per year. There has been a significant increase in volume between benchmarks 40.01 km and 42.75 km, and at individual benchmarks 48.50 km, and 57.69 km. Inspection of 2011 and 2016 aerial imagery has shown that this is due to marked shifts in the river channel.

Three cross sections have experienced a large decline in gravel volume between 2009 and 2017: 34.33 km, 45.08 km, and 58.46 km. At benchmark 34.33 km, this decline in gravel volume is due to widening of the channel resulting in the development of two shallow channels (see Figure 7 and Figure 8). At benchmark 58.46 km, the river channel has completely switched from the true Left Bank to its current path on the true Right Bank. At benchmark 45.08 km, the channel has eroded the riverbank as it has shifted.

The overall trend from 2009 to 2017 is aggradation with relatively few cross sections experiencing a decrease in gravel volume.

Gravel volume across the entire study reach has aggraded between 2004, 2009 and 2017. The significant channel shifts along the Rangitikei River are attributable to the complex terrace system above Bulls, as discussed in Williams' Scheme Review (2018). There is a main channel, though it does migrate and spilt, that is deeper and can migrate rapidly within the riverbed, which has contributed to the wider meandering form, causing some fluctuations in the gravel resource. This reach of the river is more complex than that downstream; the river is more confined by the natural terraces and high bluffs, and the river is slightly steeper causing the river's form to be more changeable (Williams, 2018). Thus, the increase in gravel volume does not correlate directly with deposition of gravel. As the channel meanders through natural terraces, there is fluctuations in gravel volume that could be attributable to the river channel shifting.

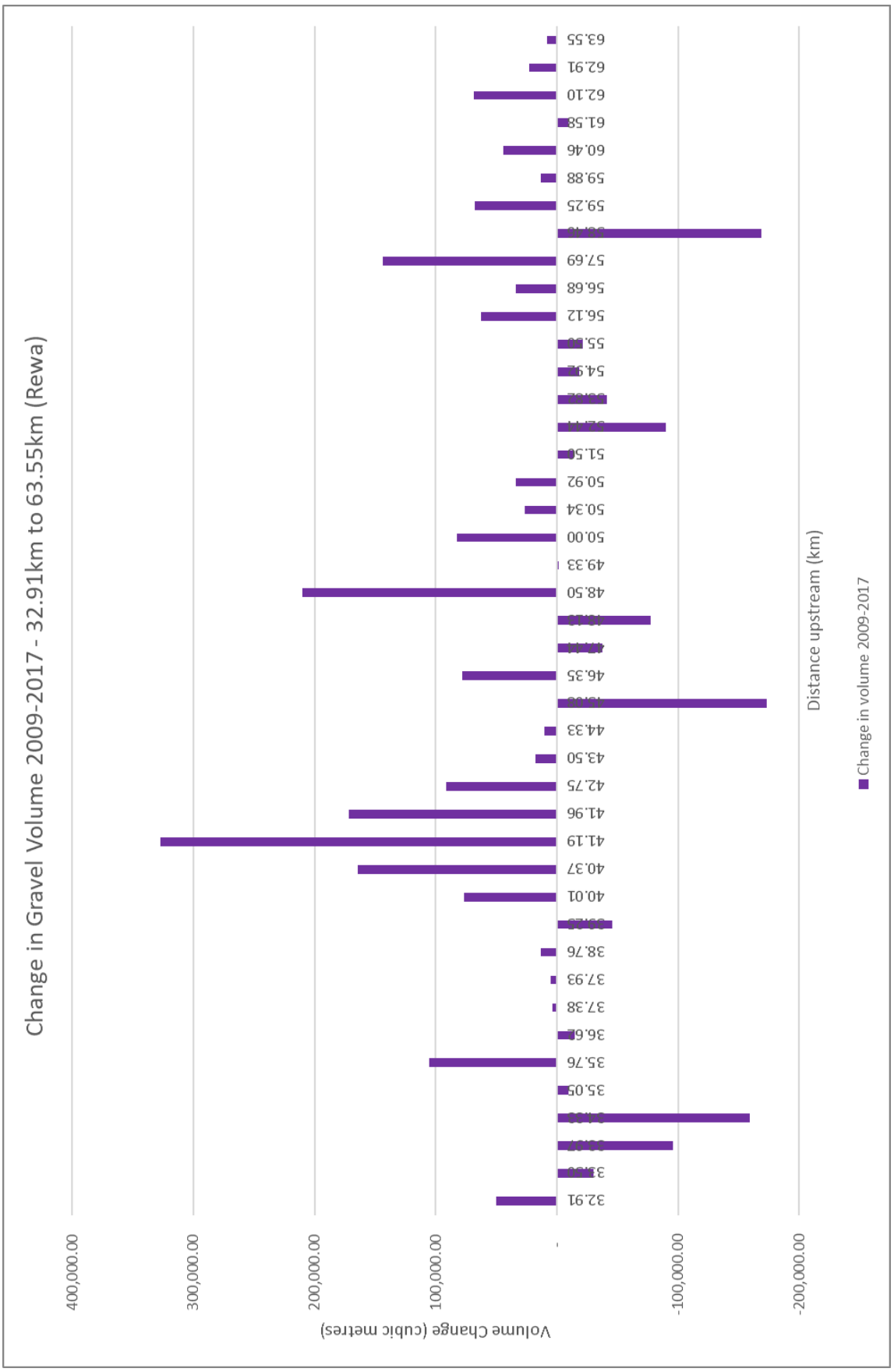


Figure 6: Gravel Volume change between 2009 and 2017

Figure 7 below illustrates the channel shifts common in the upper reach of this study.

Benchmark 34.33 km experienced marked channel change between the 2011 and 2016 aerial imagery shown in **Figure 7**, and the cross section survey data in **Figure 8**. Benchmark 34.33 km experienced a large decline in gravel volume due to widening of the active channel and the development of multiple channels between 2011 and 2016. It is obvious from both the aerial imagery and cross section data, shown in Figures 7 and 8, that there is significant erosion on the true Left Bank causing the overall decline in gravel volume. Mean bed level has declined while the main flow path has become shallower.

Figure 7: 2011 and 2016 Imagery showing channel alignment at benchmark 34.33km.

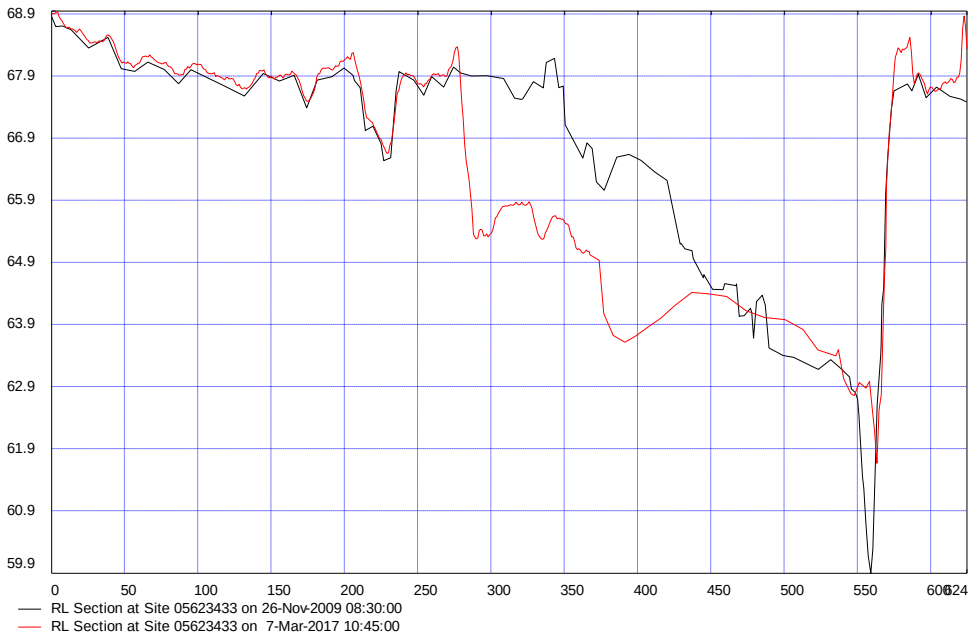


Figure 8: Cross Sectional Survey at Benchmark 34.33km

Figure 9 below is a combination of **Figure 5** and **Figure 6**, showing the change in gravel volume across the entire study reach between the two study periods.

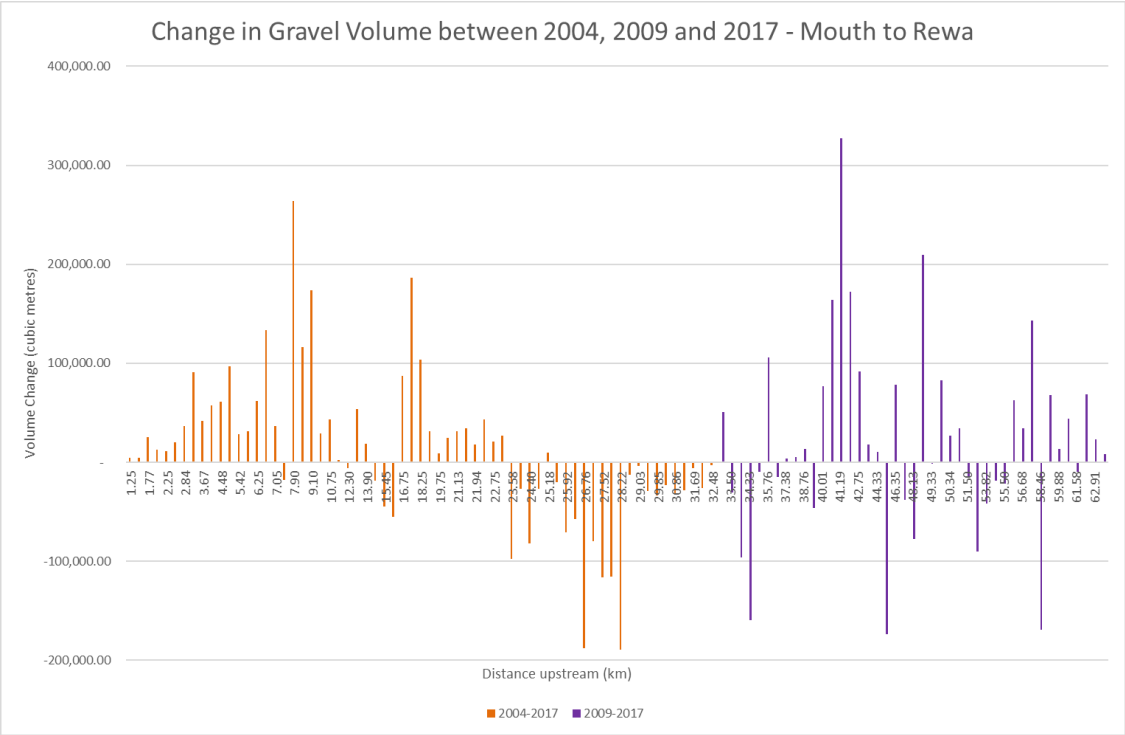


Figure 9: Gravel Volume Change between 2004, 2009 and 2017 for the entire study reach

The gravel volume analysis of the Rangitikei River is summarised below in Table 1.

Table 1: Overall Gravel Volume Change between 2004, 2009 and 2017

Study Period	Net Gain	Annual Volume
2004-2017	669,054 m^3	51,465 m^3
2009-2017	920,474 m^3	115,059 m^3

River alignment has affected the gravel volume change shown in

Table 1; since 2005 sinuosity has markedly increased and bends have become wider, consequently large bars have formed which vegetation has now spread onto (Williams, 2018). In addition, as sinuosity increases there is localised erosion causing further widening of the active channel and an associated change in the gravel resource.

5.3 Gravel Volume and Mean Bed Level Comparison

Figure 10 below shows the change in gravel volume and change in mean bed level. This graph illustrates that there is a relationship between mean bed level and gravel volume changes.

There is an evident relationship observed in Figure 10 where the mean bed level declines and there is an associated degradation of gravel volume and vice versa. However, this is not consistent along the entire length of the Rangitikei River because the river form changes as it flows out of the surrounding terrace system. This is evident in the lower reach of the river, which experienced a significant aggradation of gravel volume while the mean bed level declined.

As mentioned earlier in the report, this is due to the marked channel shifts, channel entrenchment due to narrowing of the channel and the development of a single channel as the river meanders through the floodplain below Bulls Bridge.

The reach below Bulls Bridge is also known as the depositional zone as the gradient of the river has changed, contributing to the increase in gravel volume.

Few benchmarks have experienced a decline in gravel volume and an increase in mean bed level, though it is apparent from the cross sectional survey data that this trend occurs where there has been erosion of the berms, but the bed level has increased. This is expected because the flow is concentrated on the berm rather than the bed, thus there is less erosion of the bed and an associated increase in mean bed level.

The remainder of the study reach has a consistent relationship between mean bed level and gravel volume changes.

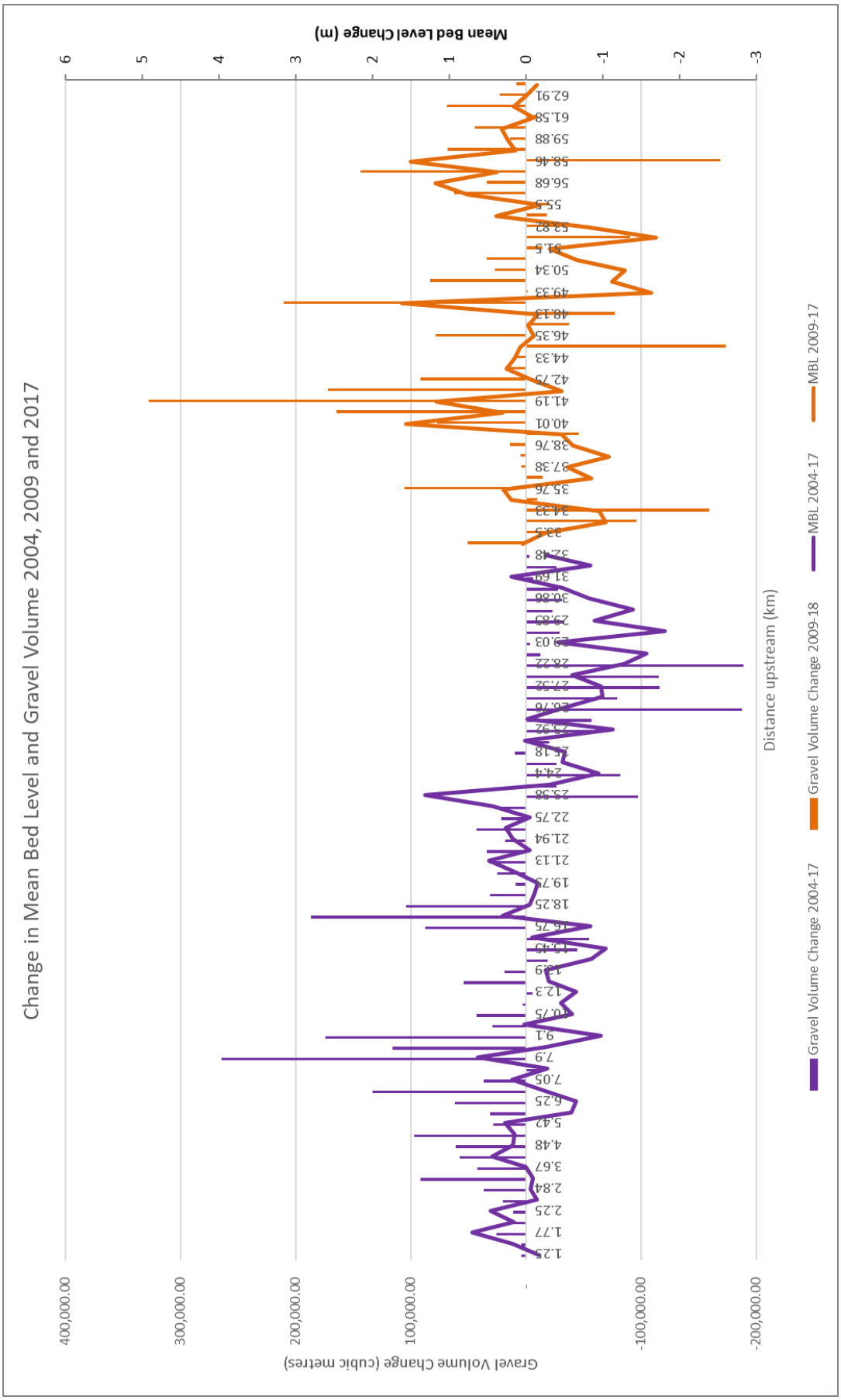


Figure 10: Gravel Volume Change and Mean Bed Level Change

6 Gravel Volume in Terms of One Plan Reaches

This study will be used to determine whether there is sufficient gravel in the Rangitikei River for sustainable gravel management.

The One Plan outlines annual allocable volumes for gravel extraction for four reaches along the Rangitikei River, outlined in **Table 2**, below.

Table 2: Long-term average annual allocable volumes of gravel (Table 17.1 in One Plan)

River or Reach	Volume (m^3)
Rangitikei River	
• Makahikatoa Stream to Mangarere Road bridge	15,000
• Mangarere Road bridge to Rewa	25,000
• Rewa to 7 km downstream of SH 1 bridge[2]	30,000
• 7 km downstream of SH 1 bridge to mouth[1]	100,000

[1] Referred to as Reach One
[2] Referred to as Reach Two

For the purposes of this gravel study, the latter two reaches have been analysed.

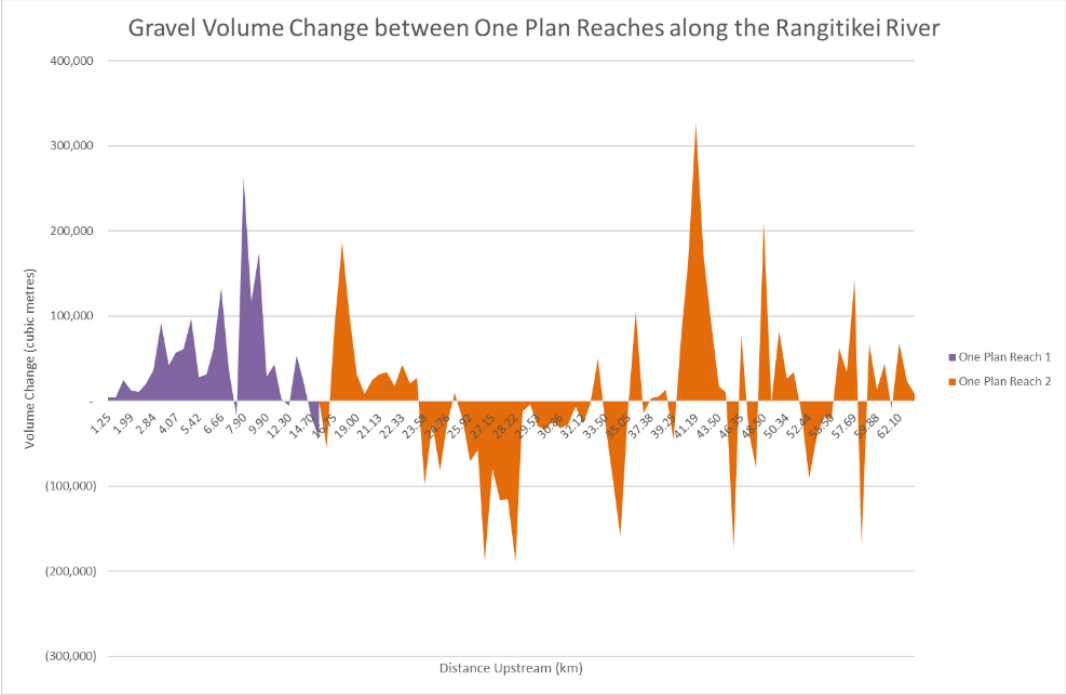


Figure 11: Gravel Volume Change between One Plan Reaches

Reach One covers the reach of the Rangitikei River from benchmark 15.45 km to the sea (mouth), with Reach Two spanning from the 63.55 km benchmark to the 15.45 km benchmark (7 km downstream of State Highway 1 Bridge).

Figure **11** above illustrates the change in gravel volume between the two One Plan reaches between 2004 and 2017 (note: this includes 2009 for the upper half of the study reach).

Reach One has aggraded by 1.37 million cubic metres over the study period, with Reach Two aggrading 224,000 cubic metres over the study period. Reach One has experienced

aggradation across the entire length of the reach; however throughout Reach Two there is an uneven distribution of aggradation and degradation. Gravel volume increases are concentrated in the upper section of Reach Two, where there is little gravel extraction due to accessibility issues and marked channel shifts, as discussed in Section 5.2 of this report.

There are little instances of gravel volume decline in Reach One, though there is a concentration of degradation in Reach Two between Bulls Bridge and Kakariki Bridge, as discussed earlier in the report.

Annually, the aggradation experienced in these reaches equates to ~105,000 cubic metres in Reach One and ~30,000 cubic metres of aggradation in Reach Two.

7 Gravel Extraction

Historically gravel has been extracted from the beaches of the Rangitikei River over a considerable time for various purposes. Records dating back to 1993 have been used for this study. Care should be taken with these figures as they include extraction from the active channel and longer-term high beach deposits.

2.7 million cubic metres of gravel have been extracted from the Rangitikei River between 1993 and 2017, equating to 113,000 cubic metres per year.

Annual gravel extraction over the study period (2004-2017) was 126,000 cubic metres.
Full details of the gravel extraction records can be seen in Appendix D.

Figure 12 below shows the reported gravel extraction volumes for each year between 1993 and 2017.

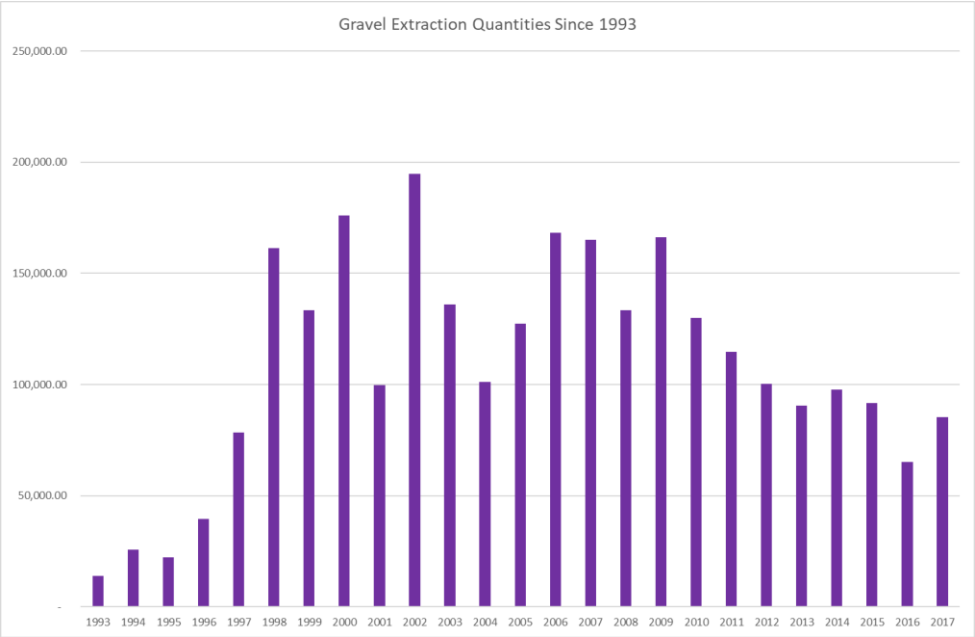


Figure 12: Gravel Extraction Quantities between 1993 and 2017

It is evident from **Figure 12**, that gravel extraction has increased since the 1990s though overall there has been a decline since 2010, following the last review of the Rangitikei River Scheme.

7.1 Gravel Extraction in terms of One Plan Reaches

Volumes of gravel extraction along the Rangitikei River have been divided into the reaches outlined in the One Plan (see Section 5.4), and are displayed in **Table 3** below, and graphically in **Figure 13**.

Table 3: Gravel Extraction Quantities divided into One Plan reaches between 1993 and 2017

Year	One Plan Reaches				
	Reach One	Reach Two	Mangarere Road Bridge to Rewa	Makahikatoa Stream to Mangarere Road Bridge	Total Per Year
1993	234.00	-	2,956.00	10,515.00	13,705.00
1994	9,532.00	50.00	515.00	15,605.00	25,702.00
1995	1,500.00	50.00	2,460.00	18,097.00	22,107.00
1996	20,400.00	100.00	3,982.00	15,093.00	39,575.00
1997	32,351.00	21,982.00	7,232.00	16,801.00	78,366.00
1998	36,914.00	99,087.00	16,333.00	8,892.00	161,226.00
1999	24,533.00	67,939.00	31,297.00	9,715.00	133,484.00
2000	70,118.00	95,041.00	2,751.00	8,243.00	176,153.00
2001	31,923.00	49,882.00	7,519.00	10,315.00	99,639.00
2002	42,835.00	136,559.00	9,906.00	5,400.00	194,700.00
2003	19,480.00	98,810.00	8,680.00	9,010.00	135,980.00
2004	23,549.00	53,757.00	997.00	22,820.00	101,123.00
2005	10,302.00	110,326.00	4,450.00	2,400.00	127,478.00
2006	61,754.00	91,086.00	8,755.00	6,660.00	168,255.00
2007	40,119.00	107,783.00	9,000.00	8,283.00	165,185.00
2008	35,103.00	78,290.00	16,260.00	3,759.00	133,412.00
2009	25,098.00	119,636.00	18,160.00	3,450.00	166,344.00
2010	22,289.00	86,921.00	16,830.00	4,030.00	130,070.00
2011	30,907.00	71,822.00	7,005.00	4,900.00	114,634.00
2012	26,223.00	53,780.00	16,544.00	3,816.00	100,363.00
2013	28,759.00	46,833.00	11,131.00	3,760.00	90,483.00
2014	27,002.00	56,000.00	11,408.00	3,145.00	97,555.00
2015	36,067.00	43,536.50	3,178.00	8,860.00	91,641.50
2016	23,302.00	29,226.00	10,075.00	2,500.00	65,103.00
2017	36,537.00	29,900.00	12,049.00	6,700.00	85,186.00
Totals:	**716,831.00**	**1,548,396.50**	**239,473.00**	**212,769.00**	**2,717,469.50**

Figure 13 below graphically displays the data in Table 3, gravel extraction from each of the One Plan reaches between 1993 and 2017.

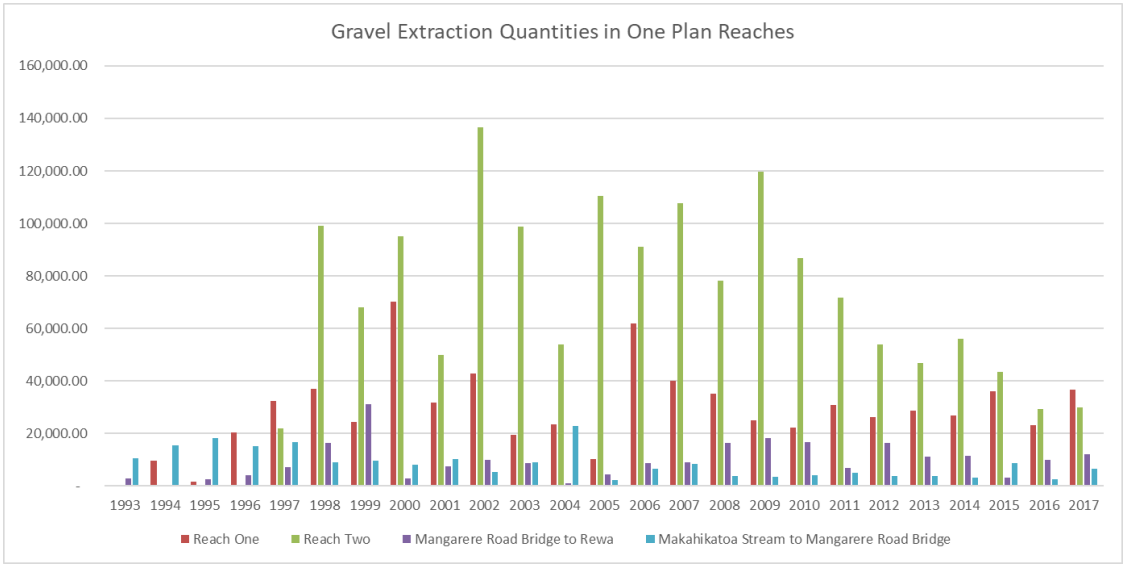


Figure 13: Gravel Extraction Quantities between 1993 and 2017, divided into One Plan reaches.

8 Overall Change in the Gravel Resource

Gravel volume, as discussed in this report, is the volume of gravel beneath the active channel, which does not include human disturbance of gravel such as gravel extraction.

Observed volumetric changes combined with recorded gravel extraction volumes provide an estimate of the gravel supply rate in the Rangitikei River. Net gravel volume approximates the pre-extraction condition of the gravel resource of the Rangitikei River.

Combining gravel extraction quantities in **Table 3** and gravel volumes from Appendix B, net gravel volume change in Reach One between 2004 and 2017 was ~1.8 million cubic metres, equating to 138,000 cubic metres per year of aggradation. Net gravel volume change in Reach Two between 2004 and 2017 (between benchmarks 15.45 km and 32.12 km) was ~282,000 cubic metres, equating to 22,000 cubic metres per annum of aggradation. Between 2009 and 2017 (upstream of benchmark 32.91 km) net gravel volume was 1.5 million cubic metres, equating to 182,000 per annum of aggradation in the gravel resource.

Table 4 below summarises the Net Gravel Volumes between 2004 and 2017 for Reach One and Reach Two.

Table 4: Net Gravel Volume between One Plan reaches

	2004-2017			2009-2017
	One Plan Reach 1:	One Plan Reach 2 (benchmark 15.45km to 32.12km)	One Plan Reach 2 (benchmark 15.45km to Bulls Bridge	One Plan Reach 2 (benchmark 32.91km to 63.55km)
Total Volume change:	1,365,933.00	- 696,878.50	512,597.00	920,474.50
Volume extracted:	427,011.00	978,896.50	357,211.50	537,654.50
Net Gravel Volume:	1,792,944.00	282,018.00	869,808.50	1,458,129.00
Net Volume per annum:	137,918.77	21,693.69	66,908.35	182,266.13

Table 4 illustrates the inferred gravel supply rate of the Rangitikei River is significantly high. The One Plan annual allocated volumes are substantially lower than the net gravel volume, notably in Reach Two, however the gravel extraction is not evenly spread across this reach. The gravel extraction in Reach Two is concentrated between Bulls Bridge and Kakariki Bridge, which is contributing to degradation of the gravel resource in this area.

Based on Table 3 and Figures 4 through to 6, gravel extraction rates in Reach One could be modified to increase the allocable volume to 130,000 cubic metres per annum. This would alleviate the pressures of excess gravel in the channel in this reach. Re-assessment of the gravel resource would be required in 5 years using LiDAR comparisons, rather than a combination of cross-sectional survey data and LiDAR.

There is evidence from this report that would allow some modification to Reach Two. Between 15.45 km and Bulls Bridge (7 km reach) a slight increase in annual allocable volume of approximately 50,000 cubic metres per annum is recommended, gravel volume has increased in this reach while mean bed level has made negligible change. Current rates of extraction are sustainable between Bulls Bridge and Kakariki Bridge (between benchmarks 23.58 km and 39.25 km). Whilst mean bed level and gravel volume in this reach has declined the morphology in this reach is very dynamic, therefore the decline in the gravel resource cannot be fully attributed to gravel extraction. Therefore, it is not recommended to change the gravel extraction rate in this reach.

Upstream of Kakariki Bridge, from benchmark 40.01 km to 63.55 km (at Rewa) there could be an increase in the rates of gravel extraction. Between 2009 and 2017, annual aggradation in this reach was 137,400 cubic metres. Annual extraction rates could be increased to 100,000 cubic metres per annum to encourage extraction away from the degraded reach (Bulls Bridge to Kakariki Bridge) and remove some of the gravel that has built-up in this reach.

These recommendations of this report have been conservative in increasing the gravel extraction volumes due to the uncertainty of the gravel resource and the dynamic nature of the morphology of the Rangitikei River. The river system as a whole may also be effected by interrupting the supply of gravel to the downstream reaches.

The recommendations stated above are simplified in Figure 14, below. This figure shows the extents of reaches that are recommended to have an increase in allocable volume (in green). Reach One to increase to 130,000 cubic metres per annum, directly upstream of the Reach One\Two boundary to Bulls Bridge to increase to 50,000 cubic metres per annum, and upstream of Kakariki Bridge to Rewa to increase to 100,000 cubic metres per annum. Shown in red is the degradation zone where gravel extraction at its current rate is sustainable and an increase in allocable volume is not recommended.

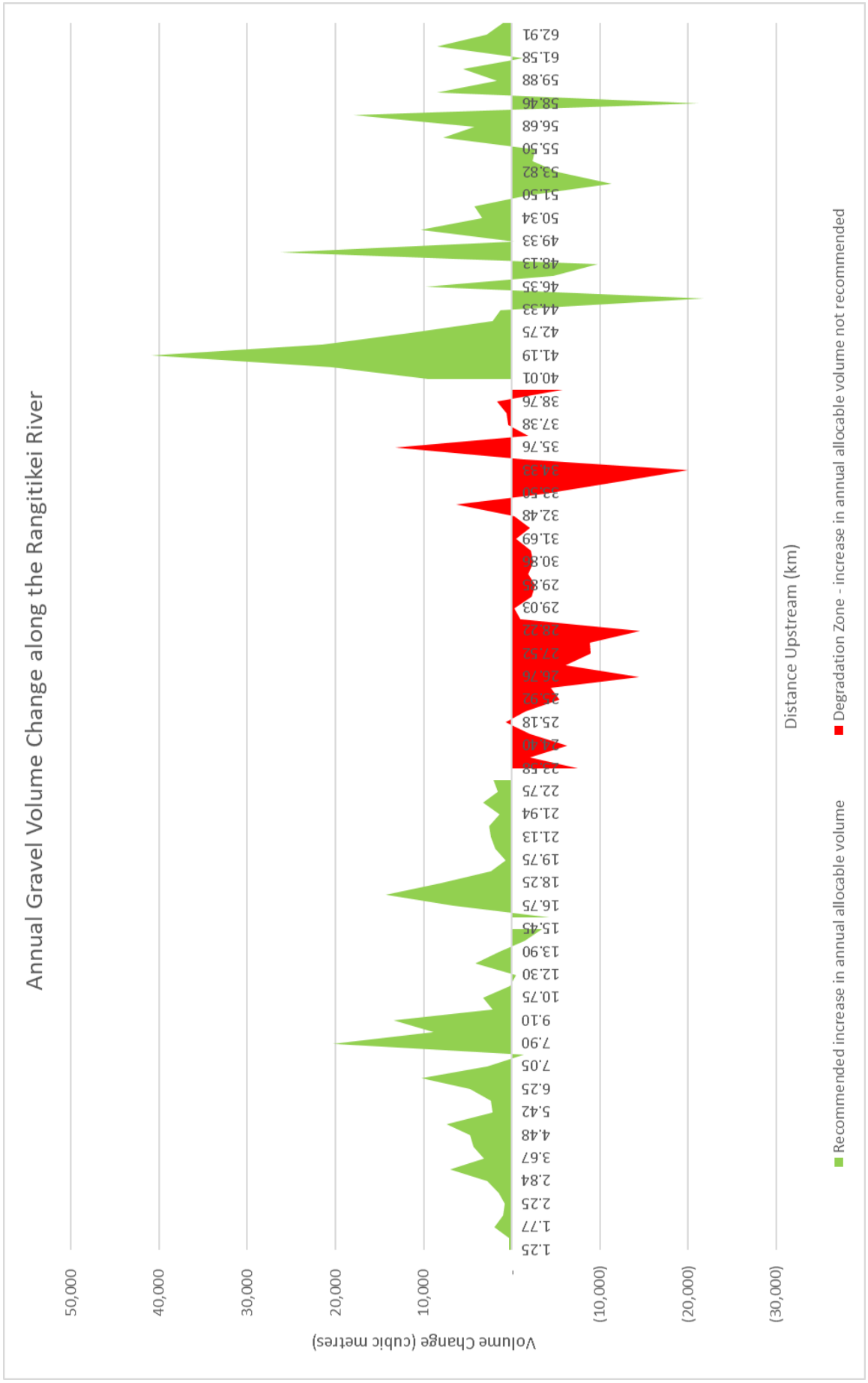


Figure 14: Annual gravel volume change along the Rangitikei River

9 Conclusions

The main findings to emerge from this gravel resource study of the Rangitikei River are:

- Mean bed level has declined across the entire study reach; 0.02 m average annual decline in the downstream reach and 0.01 m in the upstream reach.
- Mean bed level fluctuations experienced in the Rangitikei River between 2004 and 2017 can be partly attributed to typical variations of a mobile gravel-bed river, channel entrenchment due to the development of a narrower single channel, and concentrated gravel extraction.
- Between 2004 and 2017 the gravel volume in the downstream reach aggraded significantly; ~51,000 cubic metres per year.
- Between 2009 and 2017, the gravel volume in the upstream reach experienced aggradation of ~115,000 cubic metres per year.
- Aggradation is not consistent along the entire length of the downstream reach; there is a significant decline in gravel volume between Bulls Bridge and Kakariki Bridge ("degradation zone").
- The reach of the Rangitikei River between Bulls Bridge and Kakariki Bridge has been the most significantly affected by gravel extraction, however the morphology in this reach is very dynamic and the decline in the gravel resource cannot be fully attributed to gravel extraction.
- The reach between Bulls and Kakariki Bridge has experienced marked channel shifts which have contributed to the large fluctuations in both mean bed level and gravel volume, though the general trend along the entire study reach is as mean bed level declines, an associated decline in gravel volume occurs, and vice versa.
- In terms of the One Plan; Annually, Reach One has aggraded 105,000 cubic metres and Reach Two has aggraded 61,000 cubic metre.
- Annual gravel extraction was 113,000 cubic metres between 1993 and 2017, this increased to 126,000 cubic metres per year between 2004 and 2017.
- One Plan Reach One could increase annual gravel extraction by 30,000 cubic metres. Total average annual allocable volume would be 130,000 cubic metres.
- One Plan Reach Two could increase annual gravel extraction by 50,000 cubic metres per annum. This increase is only recommended to be extracted between the Reach One/ Two Boundary and Bulls Bridge, a 7 km reach of river.
- One Plan Reach Two has experienced significant degradation between Bulls Bridge and Kakariki Bridge, therefore an increase in gravel extraction rates is not sustainable.
- Upstream of Kakariki Bridge, from benchmark 40.01 km, annual extraction could increase to 100,000 cubic metres per annum to encourage extraction away from the degradation zone.

10 Appendices

10.1 Appendix A: Location of Cross Section

10.2 Appendix B: Analysis of Gravel Volume Beneath the Rangitikei River

	Area (m2)					VOLUME (m3)				
Distance Upstream (km)	2004	2009	2017	Change 2004-17	Change 2009-17	2004	2009	2017	Change 2004-17	Change 2009-17
1.25	610.4		639.6	29.2		85,456.00	-	89,544.00	4,088.00	
1.53	135.9		151.7	15.8		35,334.00	-	39,442.00	4,108.00	
1.77	1281.2		1391.1	109.9		294,676.00	-	319,953.00	25,277.00	
1.99	962.5		1015.5	53		231,000.00	-	243,720.00	12,720.00	
2.25	1201.3		1239.9	38.6		336,364.00	-	347,172.00	10,808.00	
2.55	1033.2		1100.8	67.6		304,794.00	-	324,736.00	19,942.00	
2.84	602.6		706.3	103.7		210,910.00	-	247,205.00	36,295.00	
3.25	2746.5		2966.5	220		1,139,797.50	-	1,231,097.50	91,300.00	
3.67	924.9		1026.9	102		379,209.00	-	421,029.00	41,820.00	
4.07	1080.8		1221.8	141		437,724.00	-	494,829.00	57,105.00	
4.48	1247.5		1398.5	151		505,237.50	-	566,392.50	61,155.00	
4.88	1238.6		1444.4	205.8		582,142.00	-	678,868.00	96,726.00	
5.42	460.9		521	60.1		218,927.50	-	247,475.00	28,547.50	
5.83	1345.5		1420.9	75.4		558,382.50	-	589,673.50	31,291.00	
6.25	3234.4		3382.9	148.5		1,342,276.00	-	1,403,903.50	61,627.50	
6.66	2218		2550.8	332.8		887,200.00	-	1,020,320.00	133,120.00	
7.05	826.1		936.3	110.2		272,613.00	-	308,979.00	36,366.00	
7.32	1691.1		1649	-42.1		718,717.50	-	700,825.00	- 17,892.50	
7.90	2789.6		3383.1	593.5		1,241,372.00	-	1,505,479.50	264,107.50	
8.21	1999.9		2193.1	193.2		1,199,940.00	-	1,315,860.00	115,920.00	
9.10	2482.3		2687.9	205.6		2,097,543.50	-	2,271,275.50	173,732.00	
9.90	2760.5		2795.4	34.9		2,277,412.50	-	2,306,205.00	28,792.50	
10.75	1630.5		1682.7	52.2		1,345,162.50	-	1,388,227.50	43,065.00	
11.55	2301.2		2304.5	3.3		1,783,430.00	-	1,785,987.50	2,557.50	
12.30	1847.8		1840.2	-7.6		1,432,045.00	-	1,426,155.00	- 5,890.00	
13.10	1907.7		1975.1	67.4		1,526,160.00	-	1,580,080.00	53,920.00	
13.90	2202.7		2226.1	23.4		1,762,160.00	-	1,780,880.00	18,720.00	
14.70	1136.9		1112.7	-24.2		881,097.50	-	862,342.50	- 18,755.00	
15.45	938.7		882.9	-55.8		750,960.00	-	706,320.00	- 44,640.00	
16.30	1768.1		1683.3	-84.8		1,149,265.00	-	1,094,145.00	- 55,120.00	
16.75	2352.4		2518.4	166		1,235,010.00	-	1,322,160.00	87,150.00	
17.35	1726.5		1974.8	248.3		1,294,875.00	-	1,481,100.00	186,225.00	
18.25	3436.9		3562.5	125.6		2,835,442.50	-	2,939,062.50	103,620.00	
19.00	1464.4		1505.9	41.5		1,098,300.00	-	1,129,425.00	31,125.00	
19.75	1662.4		1672.8	10.4		1,371,480.00	-	1,380,060.00	8,580.00	
20.65	1352.5		1388.6	36.1		933,225.00	-	958,134.00	24,909.00	
21.13	1238.8		1311.4	72.6		538,878.00	-	570,459.00	31,581.00	
21.52	1503.3		1587.4	84.1		608,836.50	-	642,897.00	34,060.50	
21.94	566.3		609.6	43.3		229,351.50	-	246,888.00	17,536.50	
22.33	2326.8		2432.8	106		942,354.00	-	985,284.00	42,930.00	
22.75	2184.2		2232.9	48.7		950,127.00	-	971,311.50	21,184.50	
23.20	350		415.4	65.4		145,250.00	-	172,391.00	27,141.00	
23.58	2314.2		2060.6	-253.6		890,967.00	-	793,331.00	- 97,636.00	
23.97	1605.6		1540.9	-64.7		658,296.00	-	631,769.00	- 26,527.00	
24.40	893.7		686.4	-207.3		353,011.50	-	271,128.00	- 81,883.50	
24.76	1164.6		1096.1	-68.5		454,194.00	-	427,479.00	- 26,715.00	
25.18	963.7		987.5	23.8		390,298.50	-	399,937.50	9,639.00	
25.57	563.9		509.5	-54.4		208,643.00	-	188,515.00	- 20,128.00	
25.92	992.4		806.5	-185.9		377,112.00	-	306,470.00	- 70,642.00	
26.33	1013.9		878	-135.9		425,838.00	-	368,760.00	- 57,078.00	
26.76	1868.9		1411	-457.9		766,249.00	-	578,510.00	- 187,739.00	
27.15	779.4		569.6	-209.8		296,172.00	-	216,448.00	- 79,724.00	
27.52	1254.7		911.9	-342.8		426,598.00	-	310,046.00	- 116,552.00	
27.83	1213.2		883.9	-329.3		424,620.00	-	309,365.00	- 115,255.00	
28.22	1593.5		1108.6	-484.9		621,465.00	-	432,354.00	- 189,111.00	
28.61	812.2		781.2	-31		328,941.00	-	316,386.00	- 12,555.00	
29.03	1348.5		1340.4	-8.1		620,310.00	-	616,584.00	- 3,726.00	
29.53	457.4		385.7	-71.7		187,534.00	-	158,137.00	- 29,397.00	
29.85	620.4		533.5	-86.9		241,956.00	-	208,065.00	- 33,891.00	
30.31	450.2		403.7	-46.5		227,351.00	-	203,868.50	- 23,482.50	
30.86	139.7		76.9	-62.8		70,548.50	-	38,834.50	- 31,714.00	
31.32	626.4		558.7	-67.7		259,956.00	-	231,860.50	- 28,095.50	
31.69	858.9		843.3	-15.6		343,560.00	-	337,320.00	- 6,240.00	
32.12	1004.2		937.5	-66.7		396,659.00	-	370,312.50	- 26,346.50	
32.48	630.2		622.6	-7.6		248,929.00	-	245,927.00	- 3,002.00	

	Area (m2)					VOLUME (m3)				
Distance Upstream (km)	2004	2009	2017	Change 2004-17	Change 2009-17	2004	2009	2017	Change 2004-17	Change 2009-17
32.91		1275.7	1374.4		98.7	-	650,607.00	700,944.00		50,337.00
33.5		844.4	786.9		-57.5	-	447,532.00	417,057.00		-30,475.00
33.97		1546	1314.9		-231.1	-	641,590.00	545,683.50		-95,906.50
34.33		1763.9	1468.7		-295.2	-	952,506.00	793,098.00		-159,408.00
35.05		687.9	674.1		-13.8	-	491,848.50	481,981.50		-9,867.00
35.76		1096.8	1231.3		134.5	-	860,988.00	966,570.50		105,582.50
36.62		1603.1	1584.6		-18.5	-	1,298,511.00	1,283,526.00		-14,985.00
37.38		896.7	902.3		5.6	-	587,338.50	591,006.50		3,668.00
37.93		1108.8	1115.8		7	-	765,072.00	769,902.00		4,830.00
38.76		952.9	973.2		20.3	-	628,914.00	642,312.00		13,398.00
39.25		371.4	297.8		-73.6	-	232,125.00	186,125.00		-46,000.00
40.01		1899.8	2036.6		136.8	-	1,063,888.00	1,140,496.00		76,608.00
40.37		597.7	875.7		278	-	352,643.00	516,663.00		164,020.00
41.19		1733.9	2145.6		411.7	-	1,378,450.50	1,705,752.00		327,301.50
41.96		650.7	871		220.3	-	507,546.00	679,380.00		171,834.00
42.75		401.9	520.5		118.6	-	309,463.00	400,785.00		91,322.00
43.5		203.1	225.3		22.2	-	160,449.00	177,987.00		17,538.00
44.33		135.3	148.1		12.8	-	106,887.00	116,999.00		10,112.00
45.08		813.5	641.6		-171.9	-	821,635.00	648,016.00		-173,619.00
46.35		586.2	652.5		66.3	-	691,716.00	769,950.00		78,234.00
47.44		1497	1454.4		-42.6	-	1,332,330.00	1,294,416.00		-37,914.00
48.13		1116.5	970		-146.5	-	591,745.00	514,100.00		-77,645.00
48.5		1317.3	1667		349.7	-	790,380.00	1,000,200.00		209,820.00
49.33		647.8	645.3		-2.5	-	485,850.00	483,975.00		-1,875.00
50		753.4	917.3		163.9	-	380,467.00	463,236.50		82,769.50
50.34		902.8	960.6		57.8	-	415,288.00	441,876.00		26,588.00
50.92		552.3	611		58.7	-	320,334.00	354,380.00		34,046.00
51.5		385.5	367.1		-18.4	-	292,980.00	278,996.00		-13,984.00
52.44		741.5	663.6		-77.9	-	860,140.00	769,776.00		-90,364.00
53.82		639.9	606.3		-33.6	-	793,476.00	751,812.00		-41,664.00
54.92		318.4	296.3		-22.1	-	267,456.00	248,892.00		-18,564.00
55.5		1086.6	1051.1		-35.5	-	651,960.00	630,660.00		-21,300.00
56.12		238.9	344.6		105.7	-	140,951.00	203,314.00		62,363.00
56.68		448.9	492.1		43.2	-	352,386.50	386,298.50		33,912.00
57.69		734	895.2		161.2	-	653,260.00	796,728.00		143,468.00
58.46		2908.3	2691.4		-216.9	-	2,268,474.00	2,099,292.00		-169,182.00
59.25		839.9	935.8		95.9	-	596,329.00	664,418.00		68,089.00
59.88		386.2	408.4		22.2	-	233,651.00	247,082.00		13,431.00
60.46		210.7	262.7		52	-	179,095.00	223,295.00		44,200.00
61.58		336	324		-12	-	275,520.00	265,680.00		-9,840.00
62.1		605.5	708.1		102.6	-	402,657.50	470,886.50		68,229.00
62.91		462.3	494		31.7	-	335,167.50	358,150.00		22,982.50
63.55		282.3	308.5		26.2	-	90,336.00	98,720.00		8,384.00

10.3 Appendix C: Analysis of Mean Bed Level Beneath the Rangitikei Rive

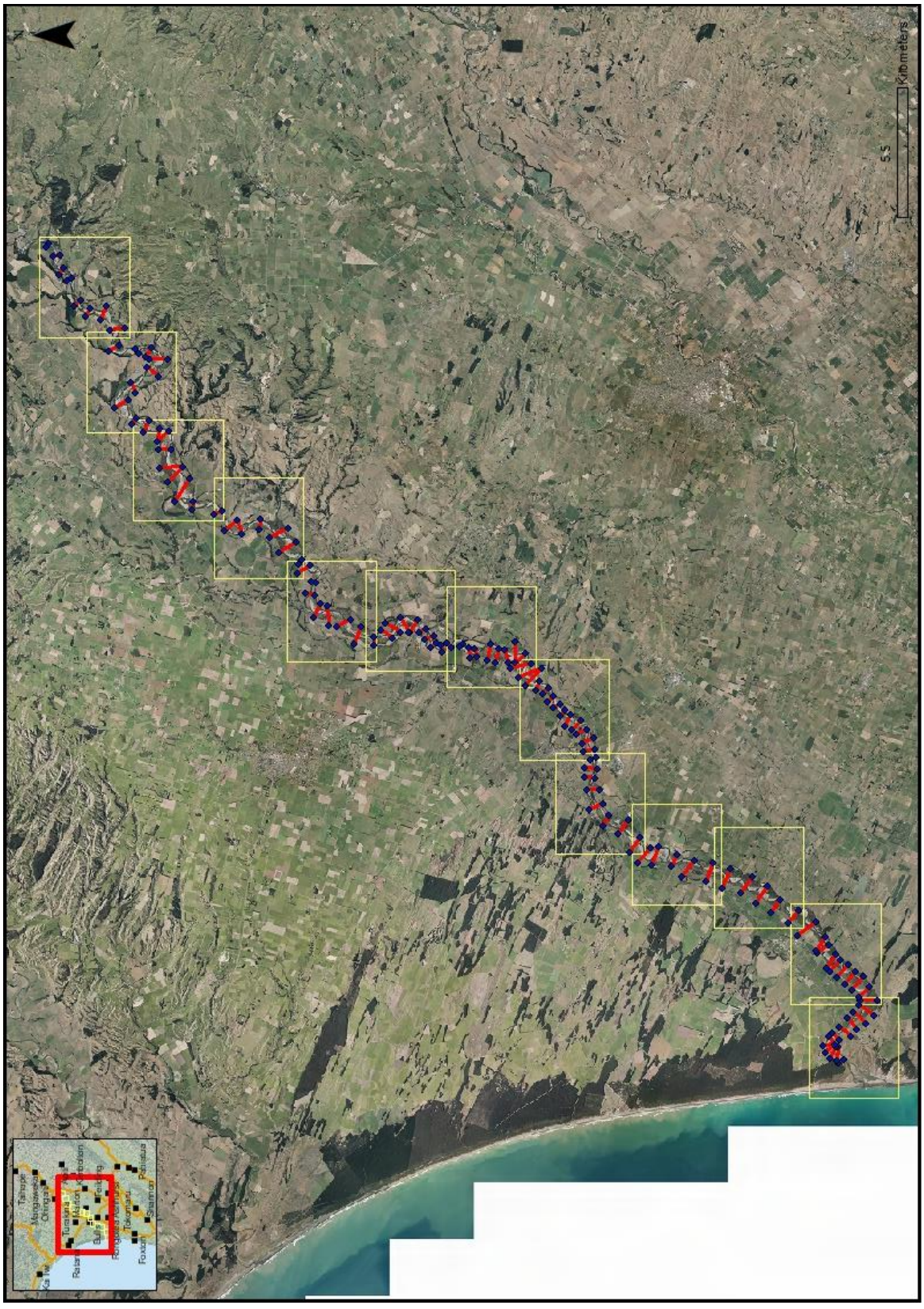
Distance Upstream (km)	Change 2004-17	Change 2009-17
1.25	-0.165	
1.53	0.181	
1.77	0.701	
1.99	0.154	
2.25	0.458	
2.55	-0.144	
2.84	-0.057	
3.25	-0.089	
3.67	0	
4.07	0.442	
4.48	0.168	
4.88	0.146	
5.42	0.272	
5.83	-0.591	
6.25	-0.657	
6.66	-0.216	
7.05	0.177	
7.32	-0.279	
7.9	0.625	
8.21	-0.268	
9.1	-0.98	
9.9	0.026	
10.75	-0.603	
11.55	-0.456	
12.3	-0.66	
13.1	-0.301	
13.9	-0.256	
14.7	-0.854	
15.45	-1.045	
16.3	-0.077	
16.75	-0.84	
17.35	0.306	
18.25	-0.047	
19	-0.112	
19.75	-0.154	
20.65	0.142	
21.13	0.477	
21.52	-0.051	
21.94	0.17	
22.33	0.266	
22.75	-0.054	
23.2	0.43	
23.58	1.314	
23.97	-0.311	
24.4	-0.95	
24.76	-0.482	
25.18	-0.511	
25.57	0.011	
25.92	-1.136	
26.33	-0.016	
26.76	-0.489	
27.15	-1.003	
27.52	-0.983	
27.83	-0.598	
28.22	-1.285	
28.61	-1.57	
29.03	-0.412	
29.53	-1.814	
29.85	-0.892	
30.31	-1.39	
30.86	-0.818	
31.32	-0.48	
31.69	0.184	
32.12	-0.846	
32.48	-0.254	

Distance Upstream (km)	Change 2004-17	Change 2009-17
32.91		0.047
33.5		-0.257
33.97		-1.045
34.33		-0.952
35.05		0.187
35.76		0.288
36.62		-0.852
37.38		-0.543
37.93		-1.082
38.76		-0.611
39.25		-0.468
40.01		1.563
40.37		0.302
41.19		1.167
41.96		-0.468
42.75		-0.087
43.5		0.256
44.33		0.152
45.08		0.075
46.35		-0.107
47.44		-0.028
48.13		-0.16
48.5		1.612
49.33		-1.639
50		-1.124
50.34		-1.29
50.92		-0.666
51.5		-0.314
52.44		-1.7
53.82		-0.812
54.92		0.387
55.5		-0.186
56.12		0.762
56.68		1.179
57.69		0.379
58.46		1.504
59.25		0.138
59.88		0.238
60.46		0.319
61.58		-0.107
62.1		0.162
62.91		0.006
63.55		-0.143

10.4 Appendix D: Gravel Extraction Record

	ONE PLAN REACHES					TOTAL EXTRACTION	
Year	Reach One	Reach Two	Mangarere Road Bridge to Rewa	Makahikatoa Stream to Mangarere Road Bridge	Total Per Year	Year	Extracted Quantity
1993	234.00	-	2,956.00	10,515.00	13,705.00	1993	13,705.00
1994	9,532.00	50.00	515.00	15,605.00	25,702.00	1994	25,702.00
1995	1,500.00	50.00	2,460.00	18,097.00	22,107.00	1995	22,107.00
1996	20,400.00	100.00	3,982.00	15,093.00	39,575.00	1996	39,575.00
1997	32,351.00	21,982.00	7,232.00	16,801.00	78,366.00	1997	78,366.00
1998	36,914.00	99,087.00	16,333.00	8,892.00	161,226.00	1998	161,226.00
1999	24,533.00	67,939.00	31,297.00	9,715.00	133,484.00	1999	133,484.00
2000	70,118.00	95,041.00	2,751.00	8,243.00	176,153.00	2000	176,153.00
2001	31,923.00	49,882.00	7,519.00	10,315.00	99,639.00	2001	99,639.00
2002	42,835.00	136,559.00	9,906.00	5,400.00	194,700.00	2002	194,700.00
2003	19,480.00	98,810.00	8,680.00	9,010.00	135,980.00	2003	135,980.00
2004	23,549.00	53,757.00	997.00	22,820.00	101,123.00	2004	101,123.00
2005	10,302.00	110,326.00	4,450.00	2,400.00	127,478.00	2005	127,478.00
2006	61,754.00	91,086.00	8,755.00	6,660.00	168,255.00	2006	168,255.00
2007	40,119.00	107,783.00	9,000.00	8,283.00	165,185.00	2007	165,185.00
2008	35,103.00	78,290.00	16,260.00	3,759.00	133,412.00	2008	133,412.00
2009	25,098.00	119,636.00	18,160.00	3,450.00	166,344.00	2009	166,344.00
2010	22,289.00	86,921.00	16,830.00	4,030.00	130,070.00	2010	130,070.00
2011	30,907.00	71,822.00	7,005.00	4,900.00	114,634.00	2011	114,634.00
2012	26,223.00	53,780.00	16,544.00	3,816.00	100,363.00	2012	100,363.00
2013	28,759.00	46,833.00	11,131.00	3,760.00	90,483.00	2013	90,483.00
2014	27,002.00	56,000.00	11,408.00	3,145.00	97,555.00	2014	97,555.00
2015	36,067.00	43,536.50	3,178.00	8,860.00	91,641.50	2015	91,641.50
2016	23,302.00	29,226.00	10,075.00	2,500.00	65,103.00	2016	65,103.00
2017	36,537.00	29,900.00	12,049.00	6,700.00	85,186.00	2017	85,186.00
Totals:	**716,831.00**	**1,548,396.50**	**239,473.00**	**212,769.00**	**2,717,469.50**		2,717,469.50

10.5 Appendix E: Surveyed Cross Sections

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2.55km
1.77km
2.84km
1.53km
1.45km
3.25km
3.87km
4.97km
4.89km
4.85km
5.42km
5.83km
6.22km
6.68km
Page 1 of 13
0.65
Kilometers


N
9.90km
9.10km
8.24km
7.60km
7.25km
7.05km
6.08km
6.22km
5.83km
5.42km
4.88km
4.49km
4.07km
3.67km
3.25km
Page 2 of 13
0.65
Kilometers


13.90km
13.10km
12.90km
11.55km
10.75km
9.90km
9.10km
N
Page 3 of 13
0.65
Kilometers


Bulls
18.25km
17.35km
16.30km
15.45km
14.70km
13.90km
13.10km
N
Page 4 of 13
0.65
Kilometers

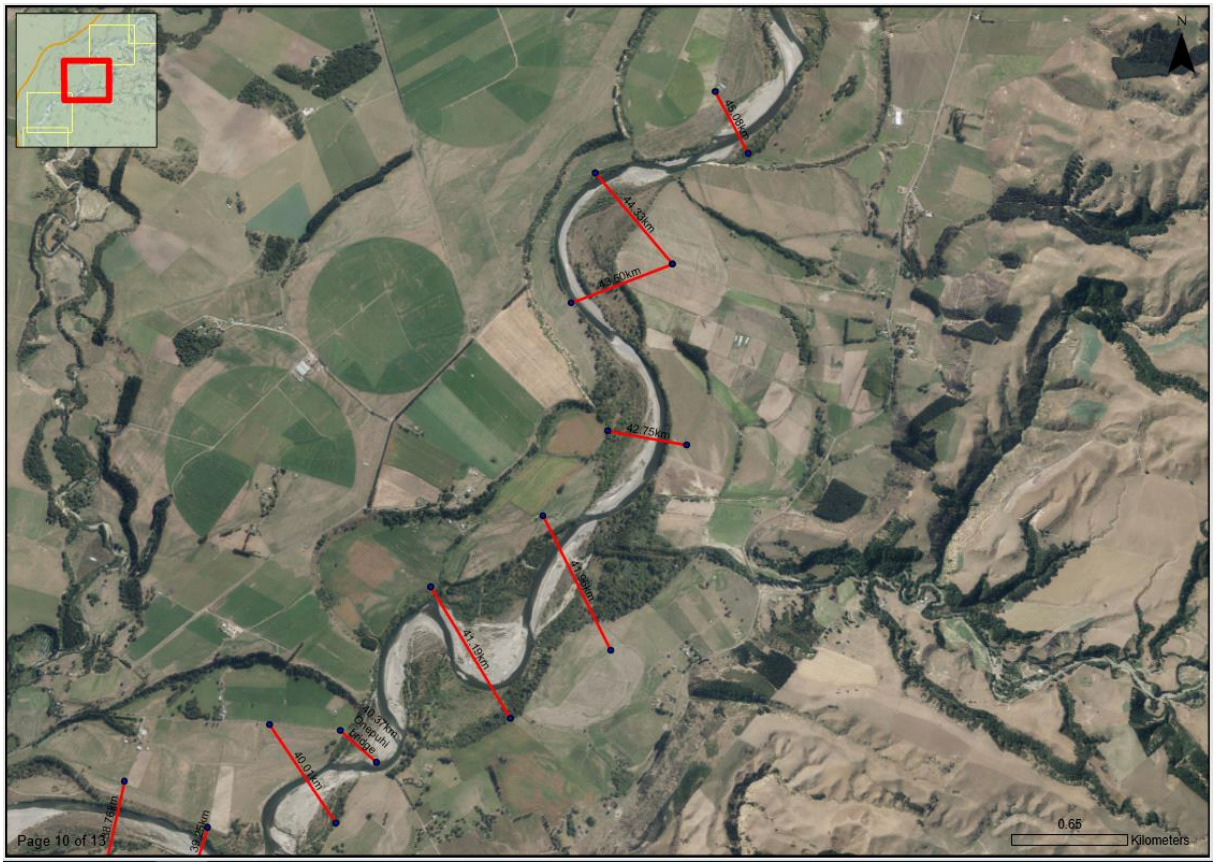

Bulls
Sanson
N
Page 5 of 13
0 0.65
Kilometers


Bulls
Sanson
N
27.83km
27.92km
27.54km
26.18km
26.33km
25.92km
25.57km
25.18km
24.75km
24.40km
23.97km
23.59km
Page 6 of 13
0 0.65
Kilometers


Halcombe
Bulls
N
31.32km
30.86km
29.95km
29.53km
29.03km
28.61km
28.22km
27.83km
27.52km
27.15km
26.74km
26.33km
25.92km
Page 7 of 13
0.65
Kilometers


Marton
Halcombe
Bulls
N
35.76km
35.05km
34.93km
34.37km
33.50km
32.81km
31.32km
30.65km
Page 8 of 13
0.65
Kilometers


Marton
Halcombe
N
41.19km
40.37km
Onepuhi
Landing
40.04km
39.78km
39.36km
37.93km
37.34km
36.78km
36.76km
35.05km
34.09km
Page 9 of 13
0.65
Kilometers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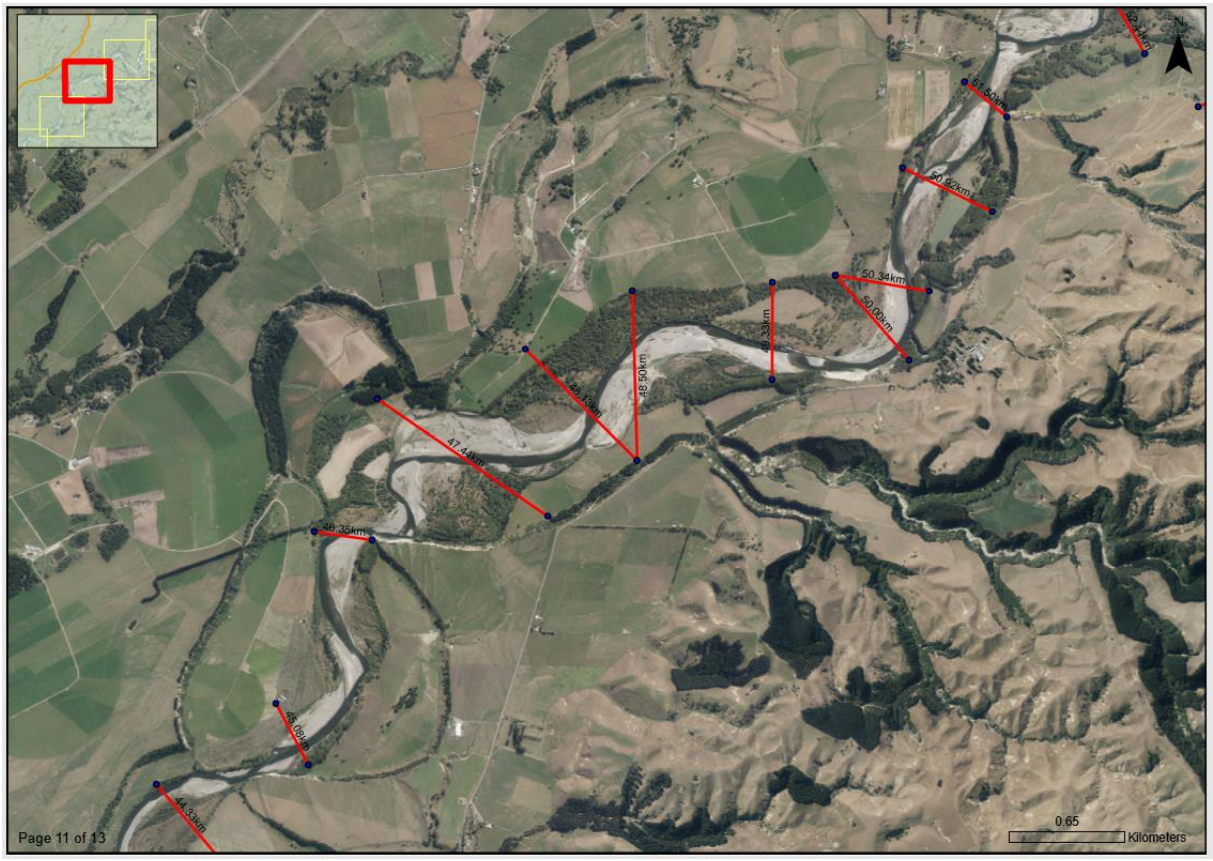
42.75km
41.19km
40.37km
Onepuhi
Landing
40.04km
Page 10 of 13
0.65
Kilometers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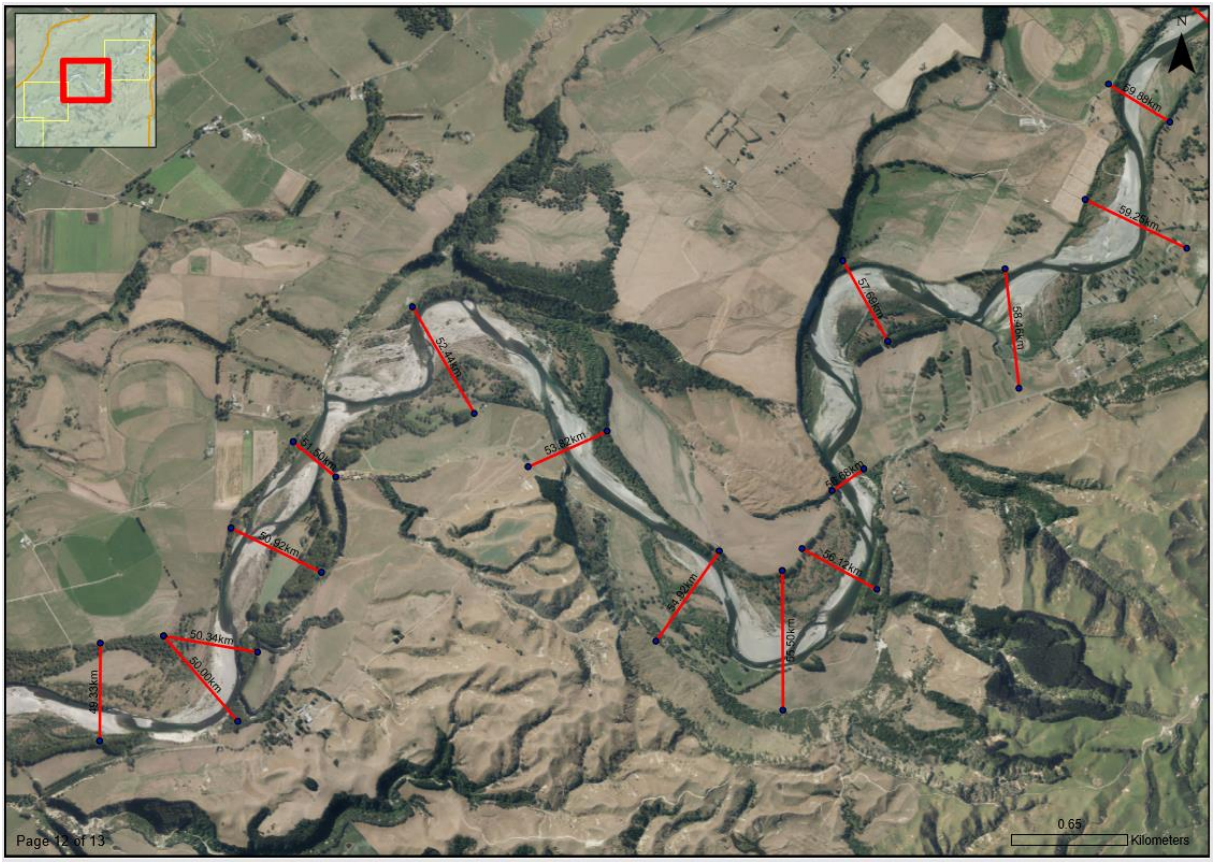
47.44km
46.35km
45.08km
44.33km
Page 11 of 13
0.65
Kilometers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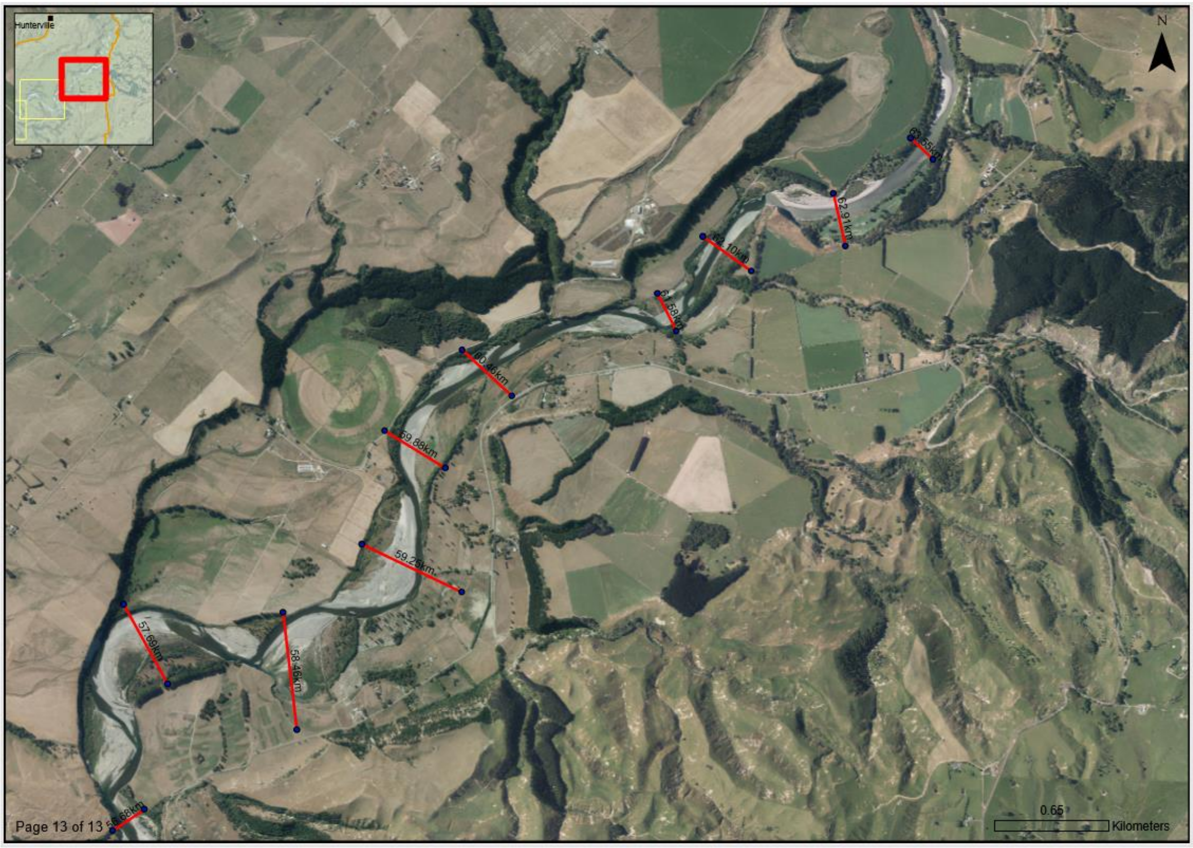
49.33km
54.80km
56.21km
Page 12 of 13
0.65
Kilometers


Hunterville
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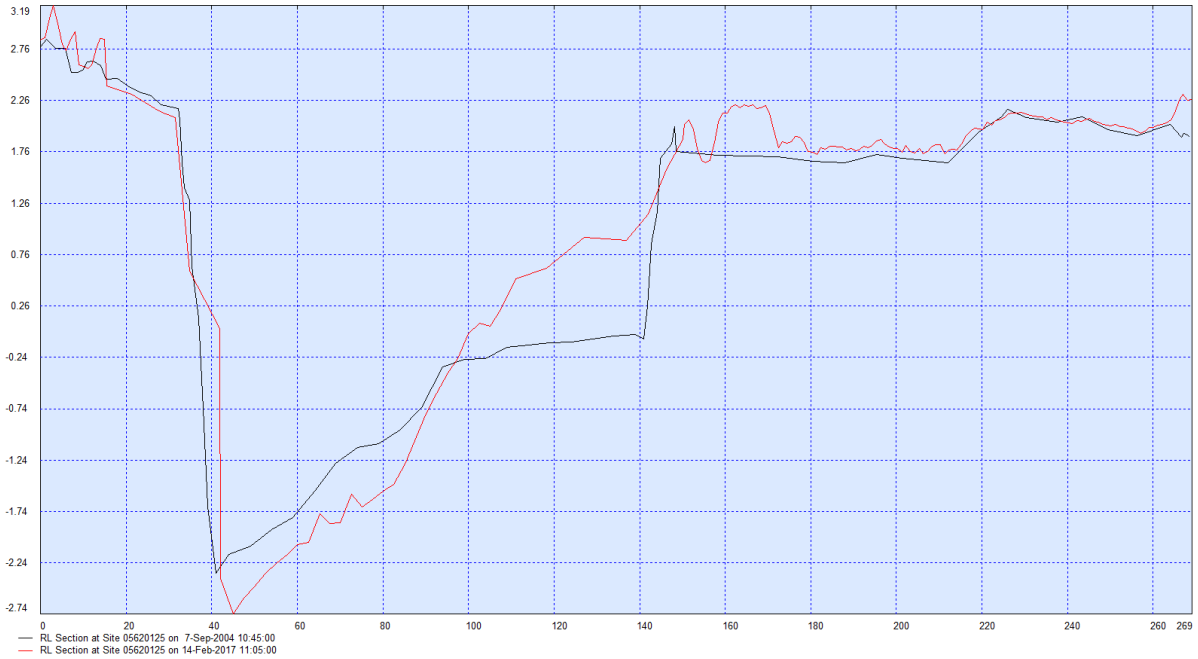
59.25km
57.69km
58.46km
Page 13 of 13
0.65
Kilometers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1.26
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40
60
80
100
120
140
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260
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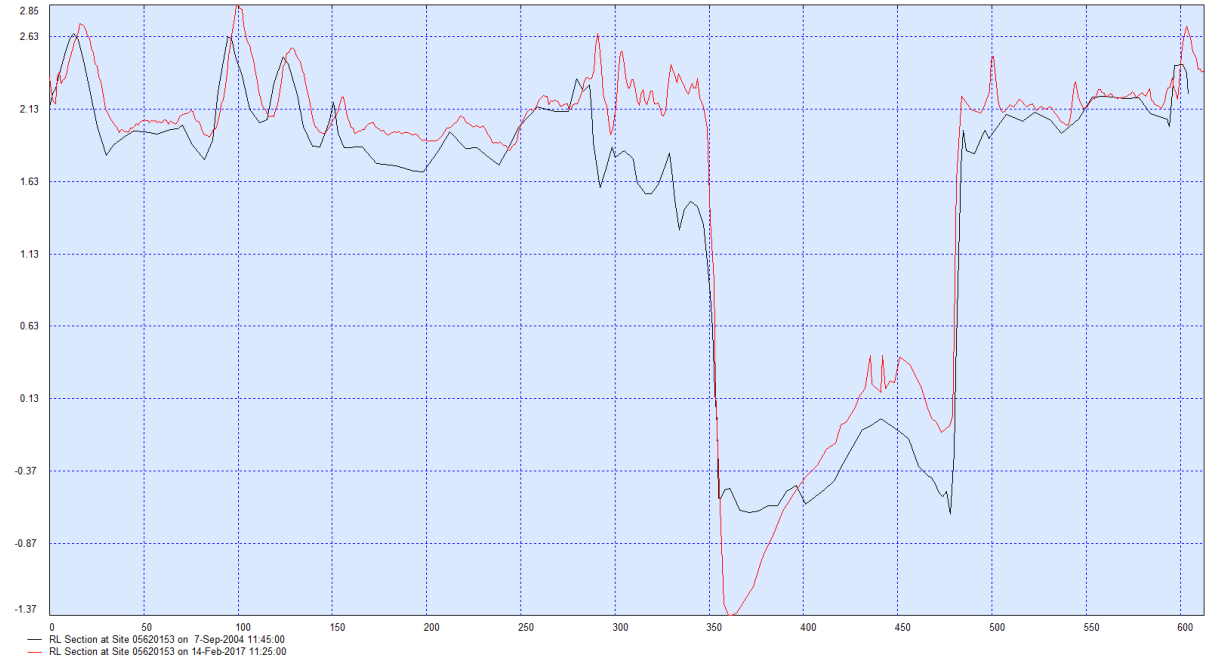
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100
150
200
250
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RL Section at Site 05620153 on 7-Sep-2004 11:45:00
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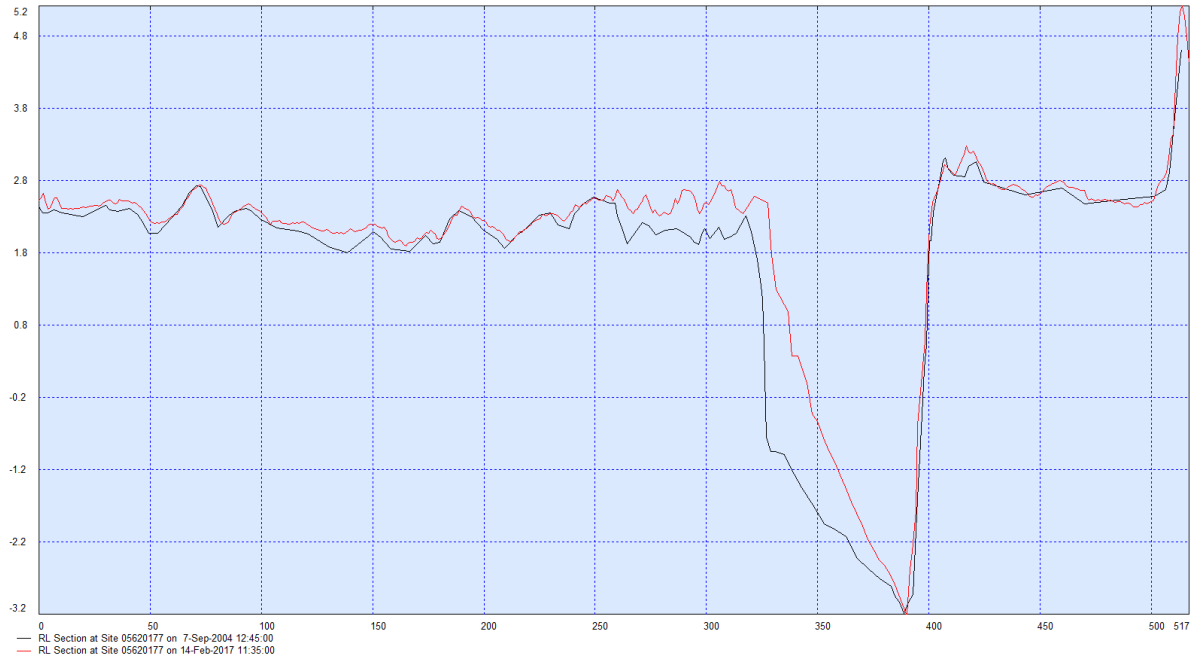
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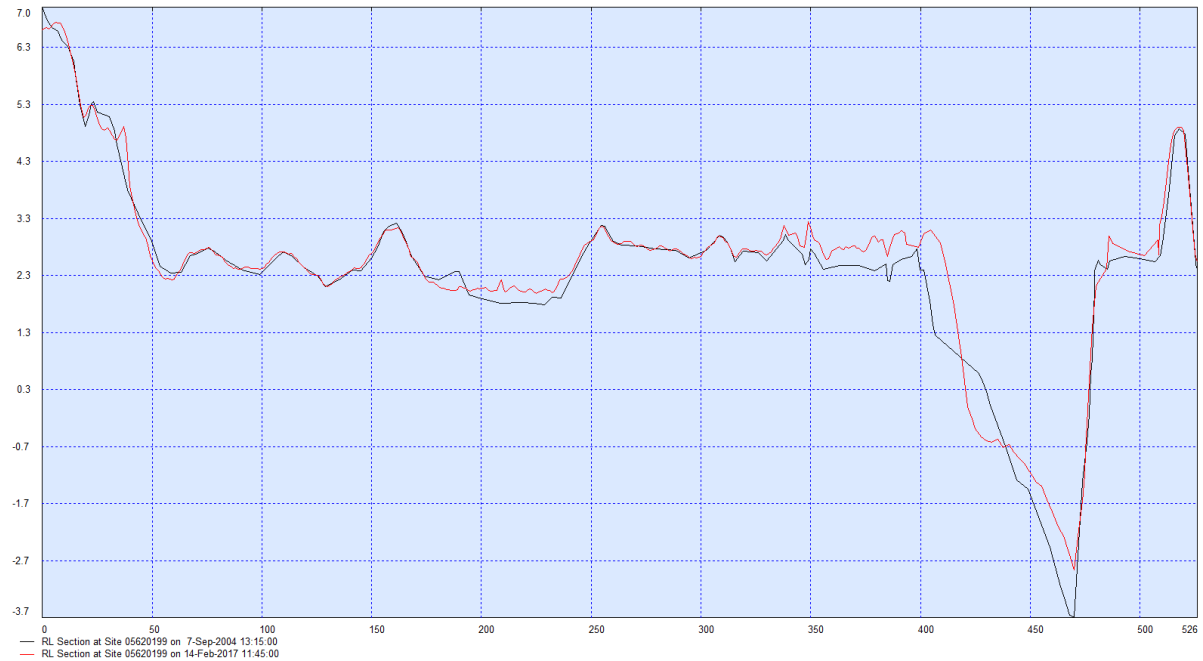
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-3.7
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100
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500
526
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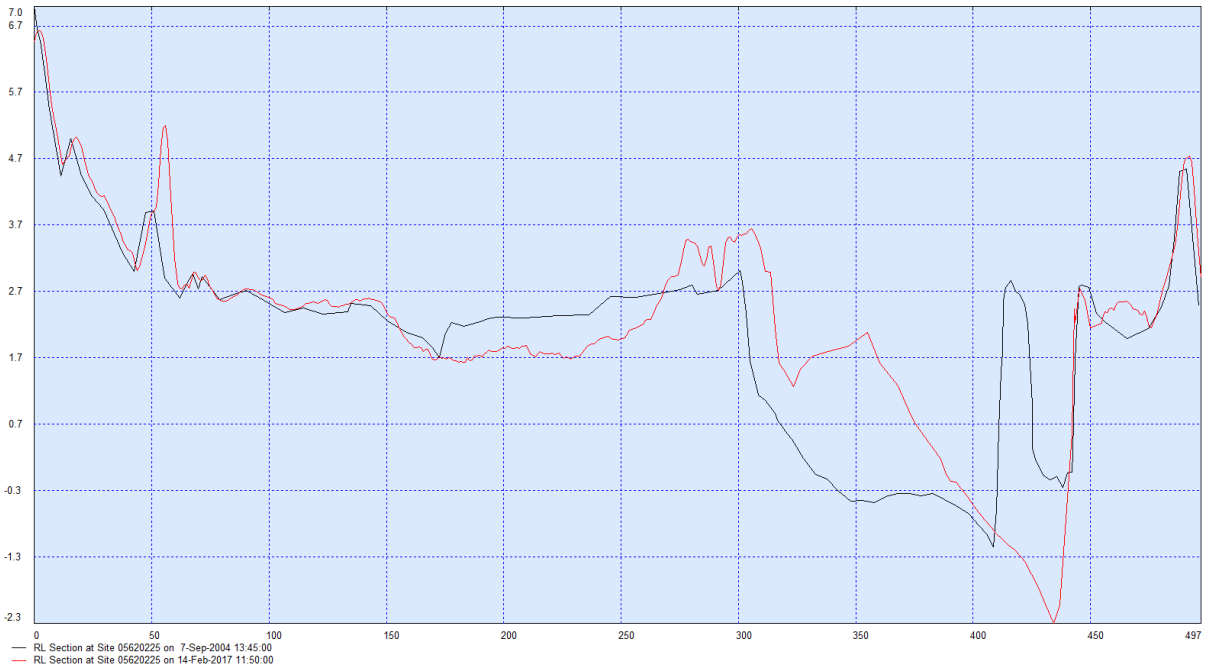
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2.7
1.7
0.7
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-2.3
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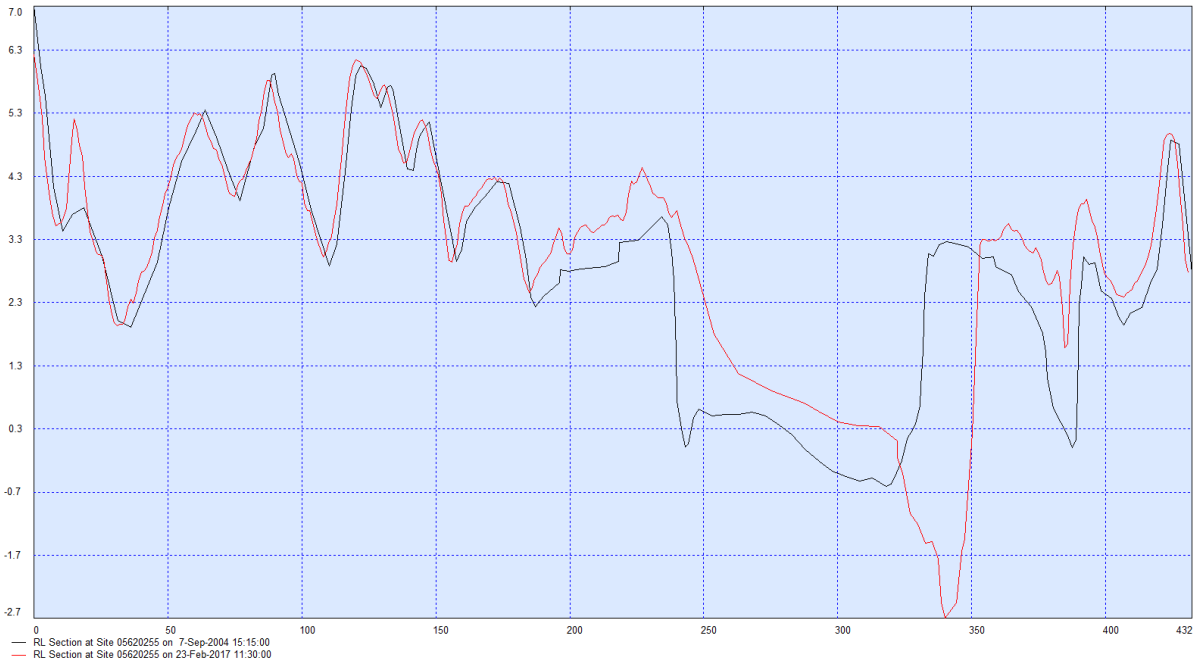
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0.3
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-1.7
-2.7
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100
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400
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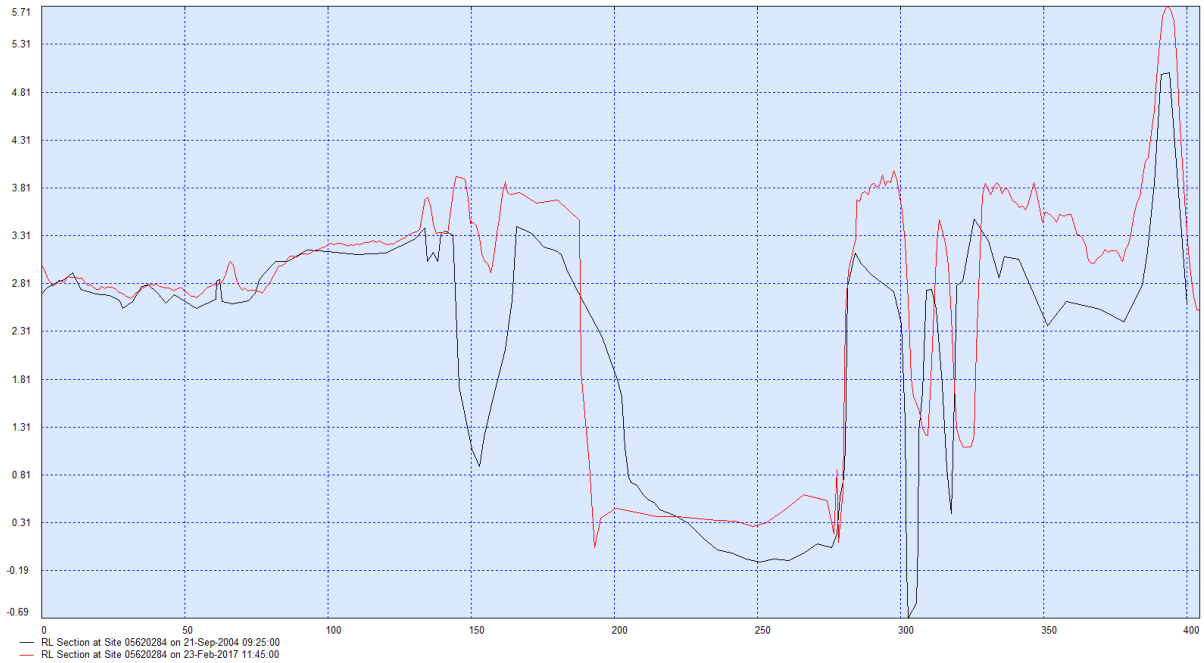
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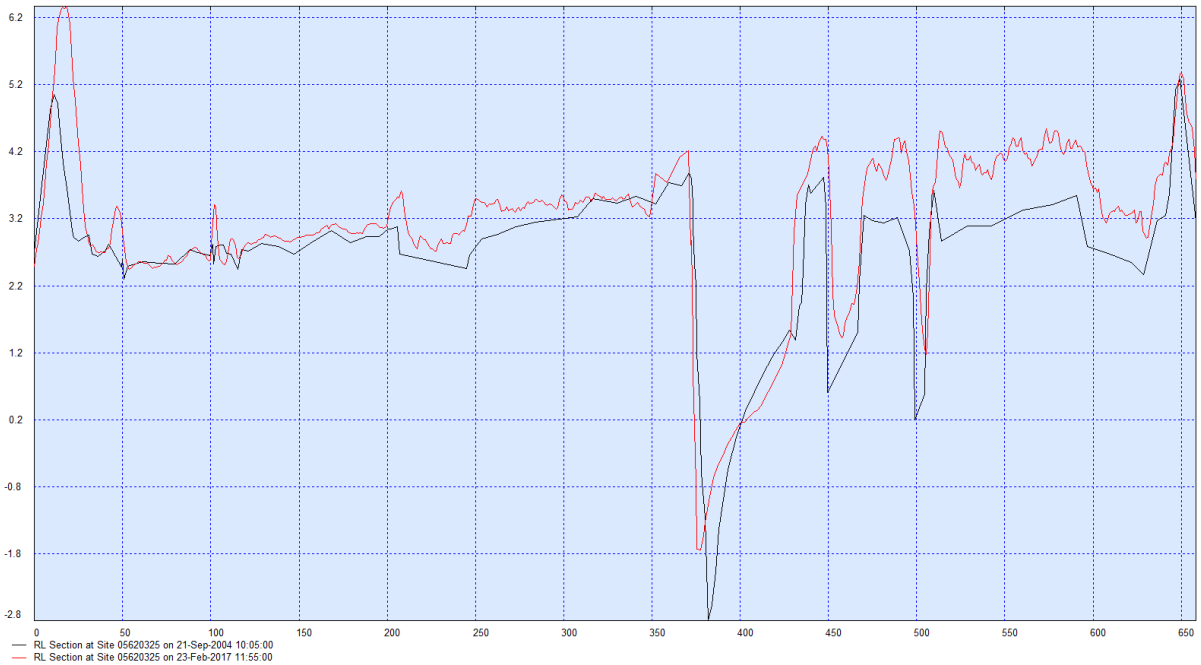
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2.2
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-1.8
-2.8
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300
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600
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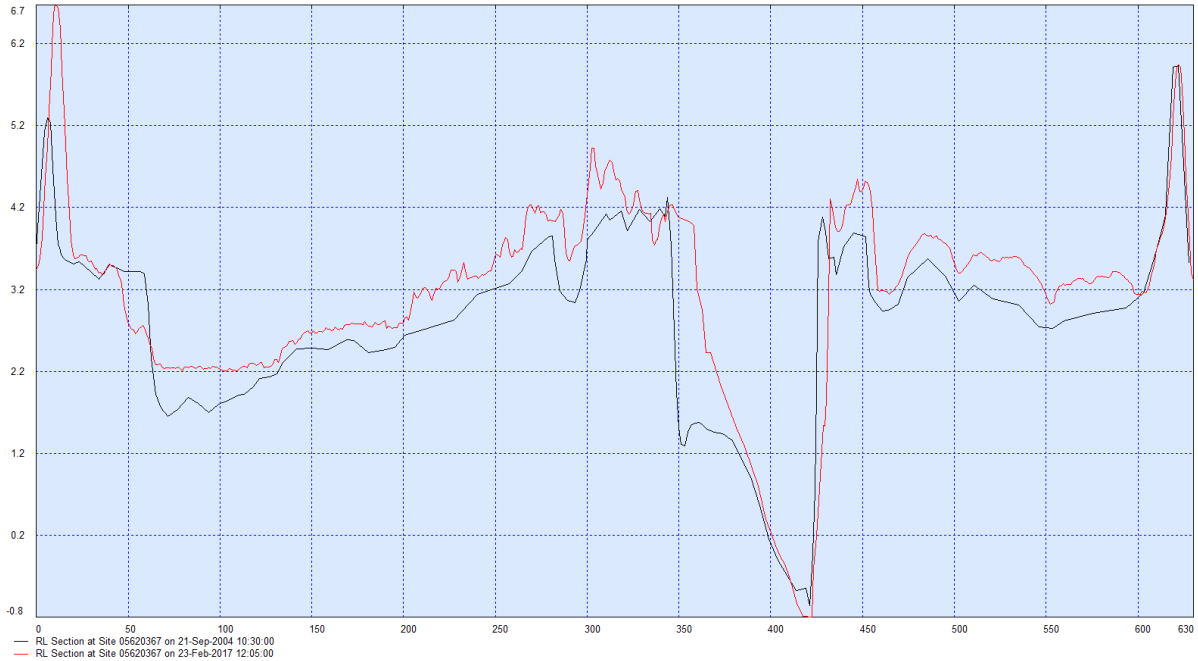
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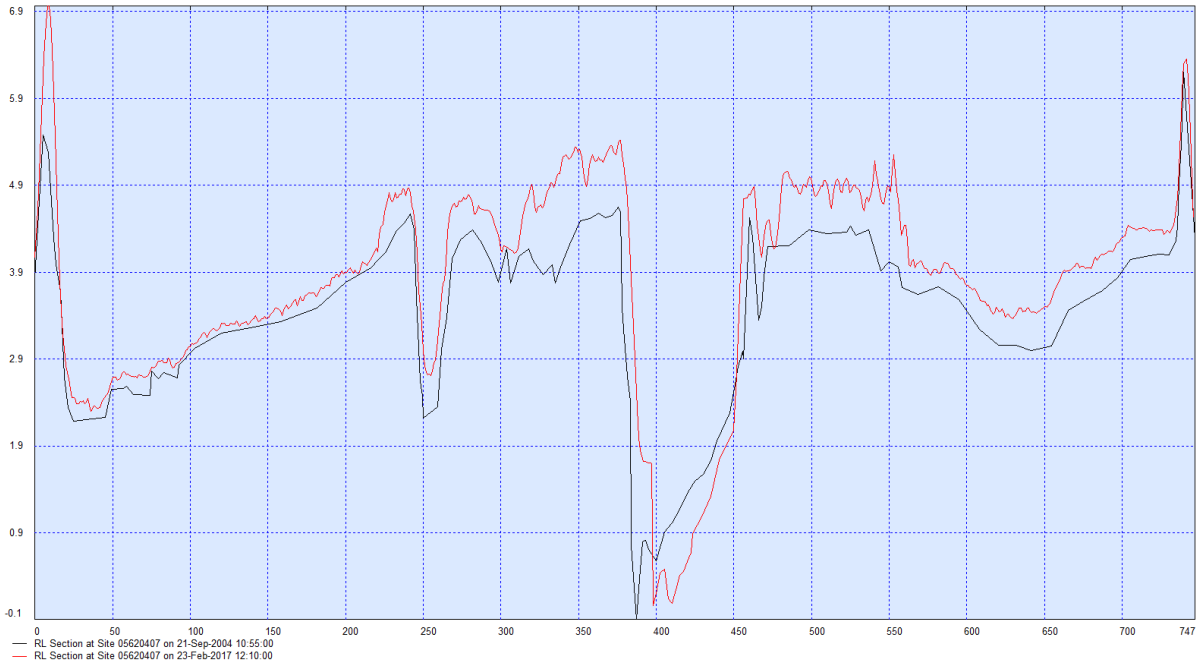
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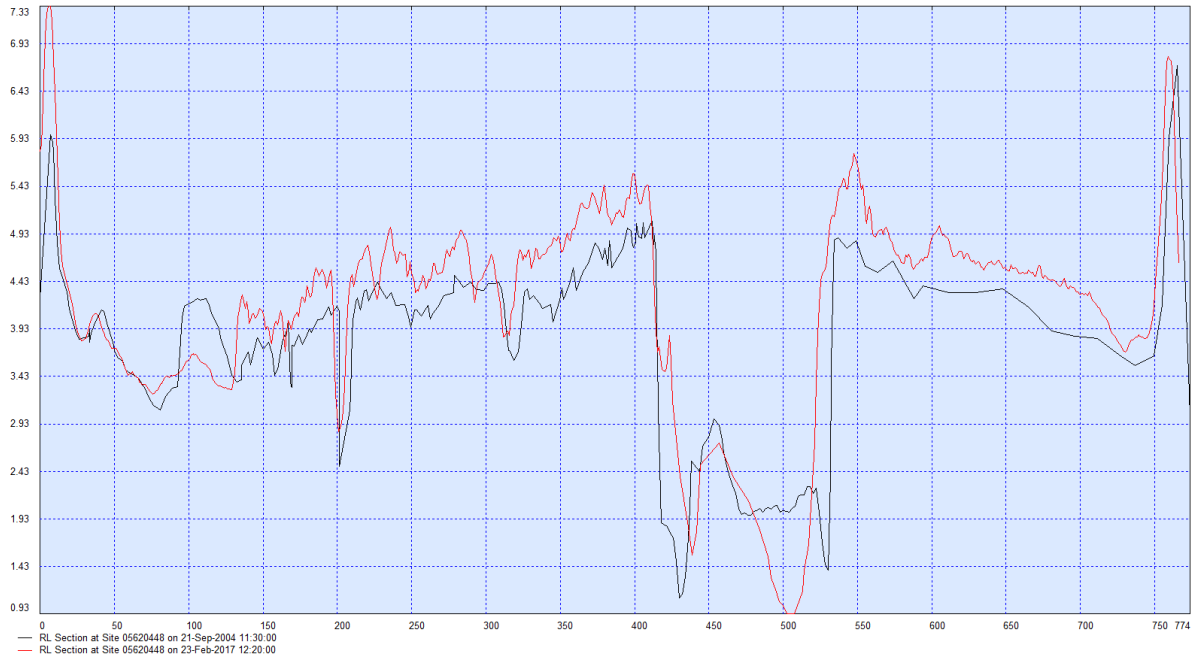
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0
50
100
150
200
250
300
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400
450
500
550
600
650
700
750
774
RL Section at Site 05620448 on 21-Sep-2004 11:30:00
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7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
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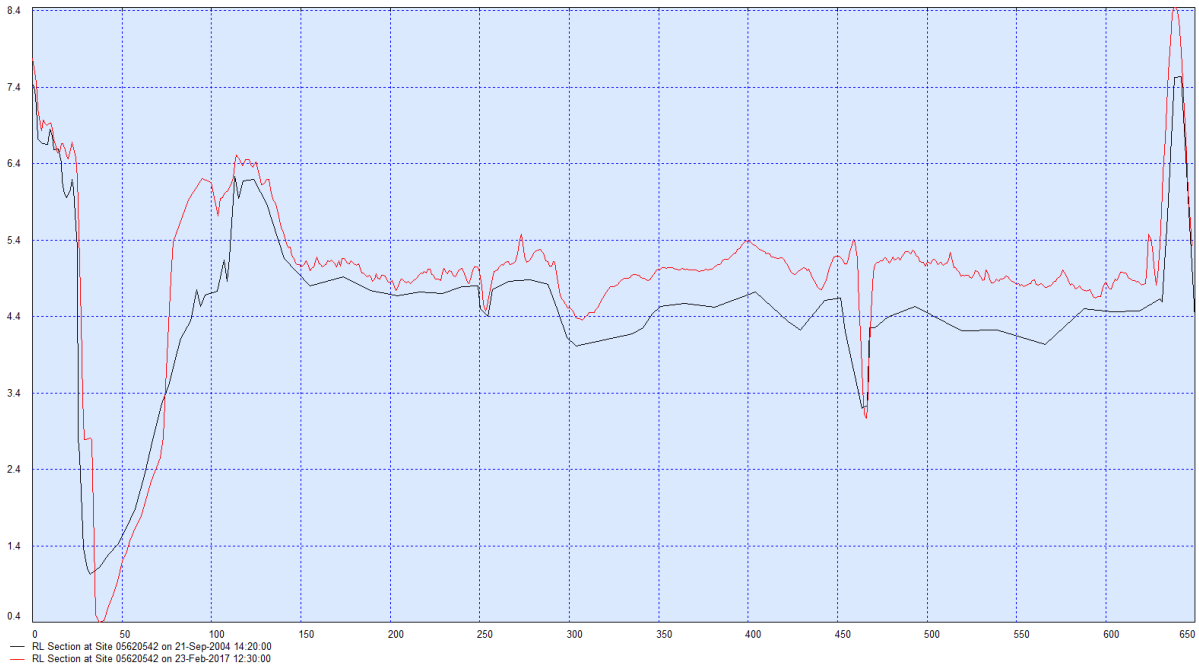
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300
350
400
450
500
550
600
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RL Section at Site 05620542 on 21-Sep-2004 14:20:00
RL Section at Site 05620542 on 23-Feb-2017 12:30:00


9.1
8.8
7.8
6.8
5.8
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3.8
2.8
1.8
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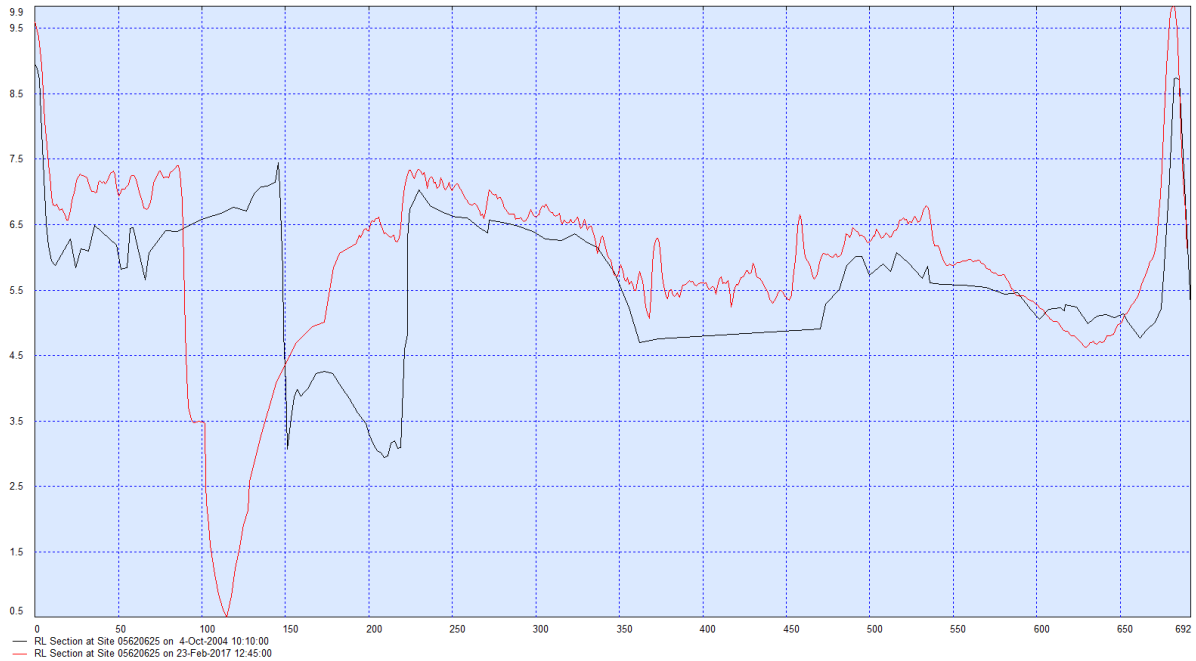
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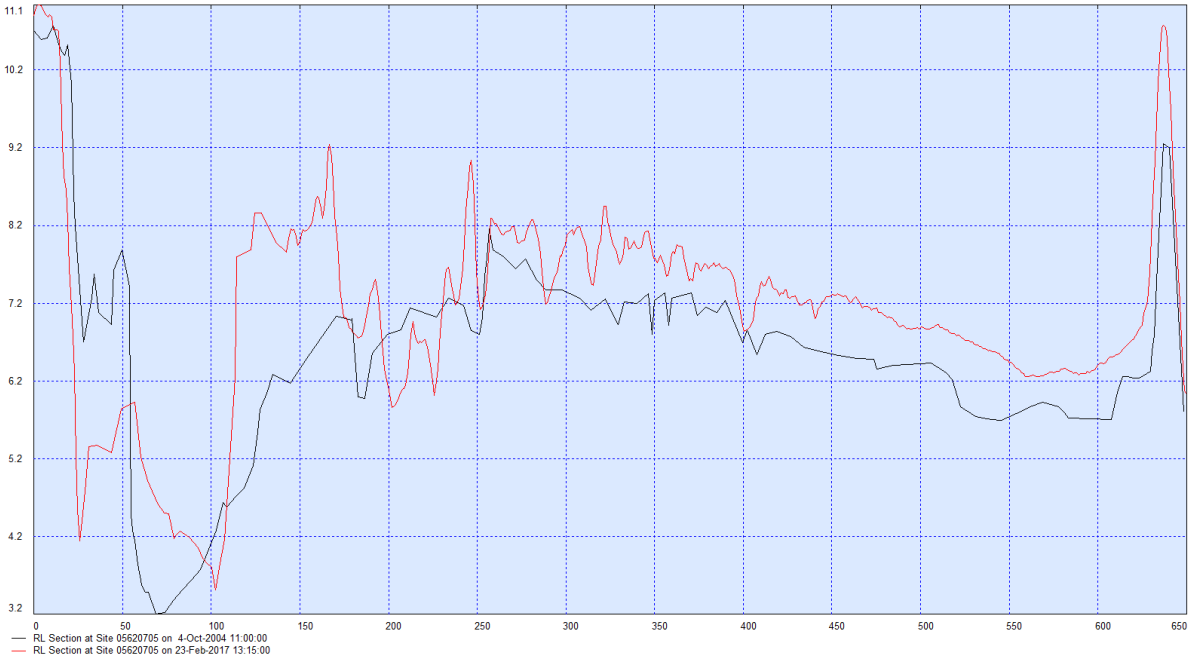
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400
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500
550
600
650
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RL Section at Site 05620705 on 23-Feb-2017 13:15:00


13.7
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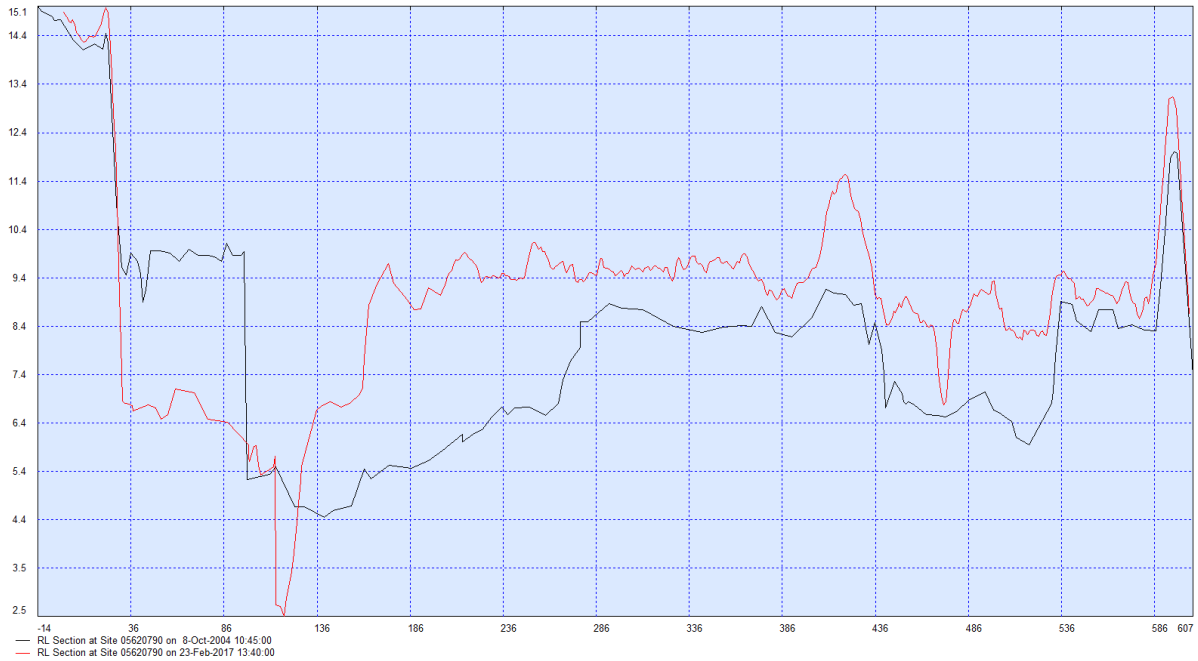
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386
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486
536
586
607
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549
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699
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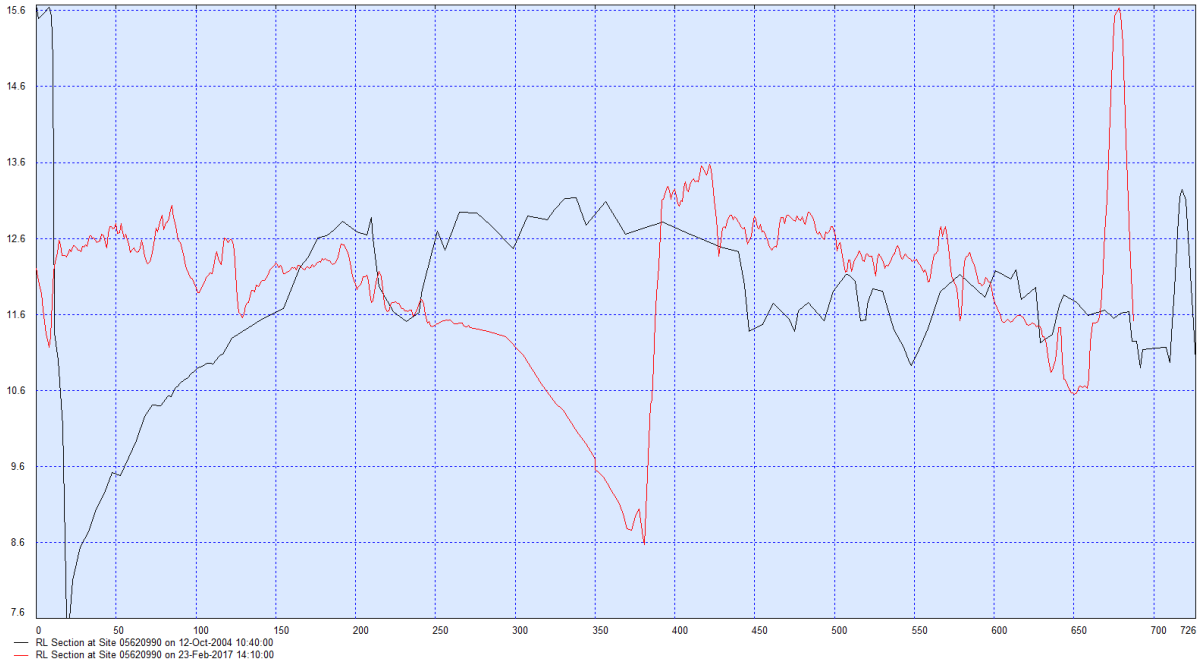
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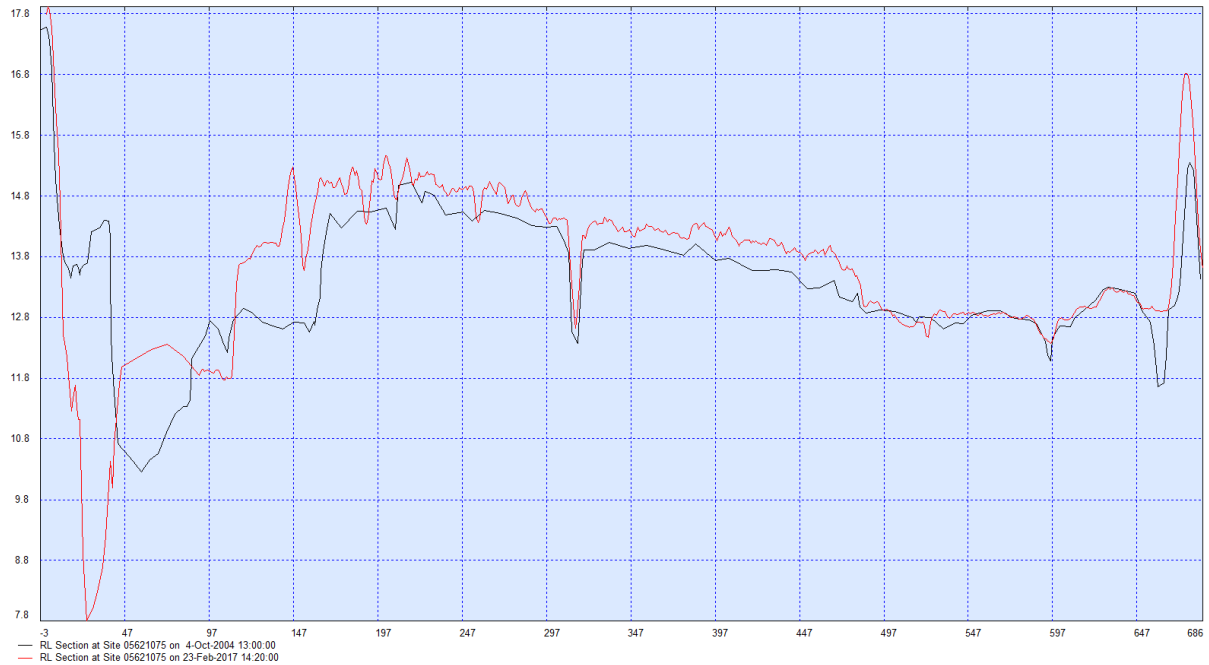
RL Section at Site 05620990 on 23-Feb-2017 14:10:00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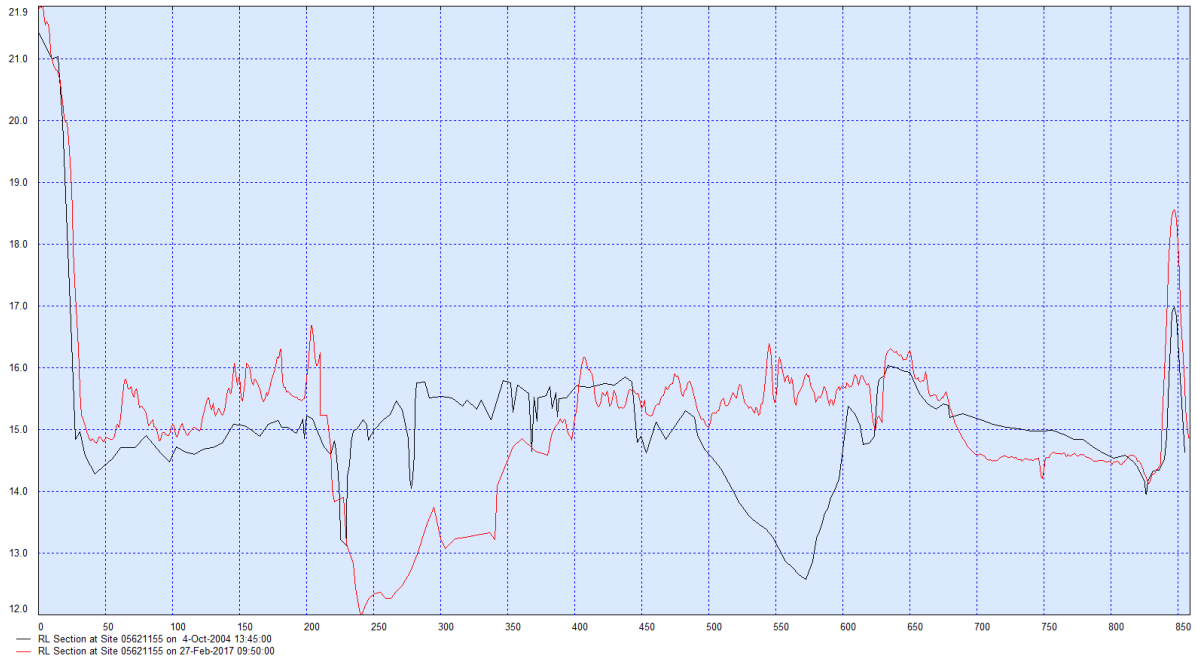
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RL Section at Site 05621155 on 4-Oct-2004 13:45:00
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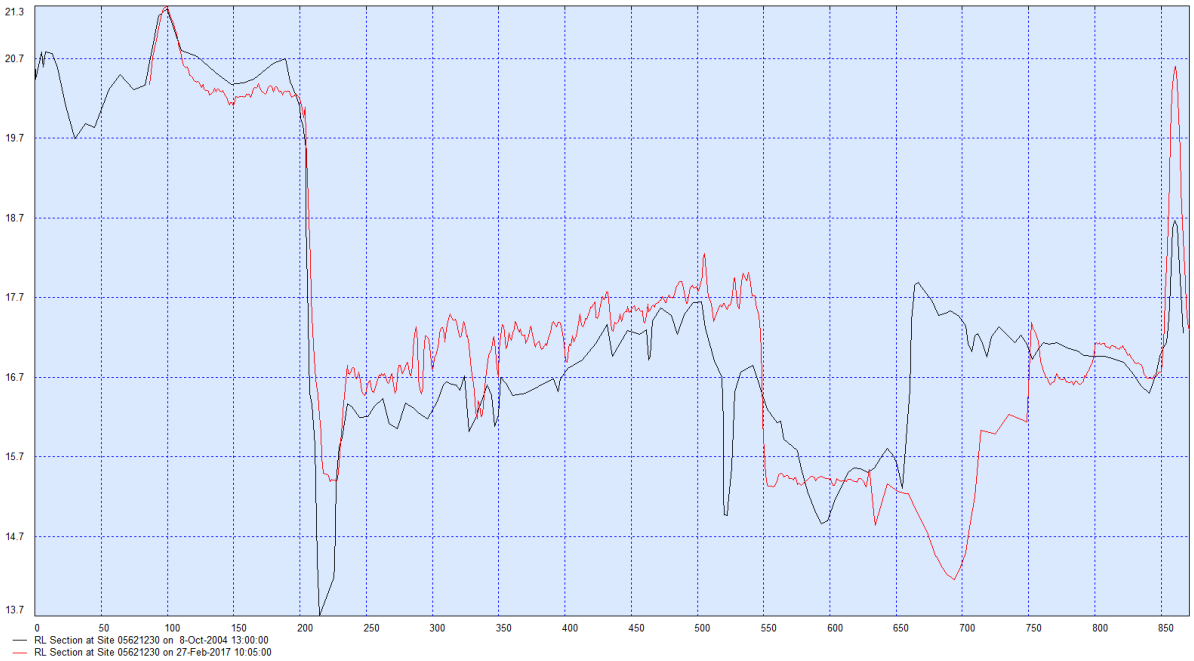
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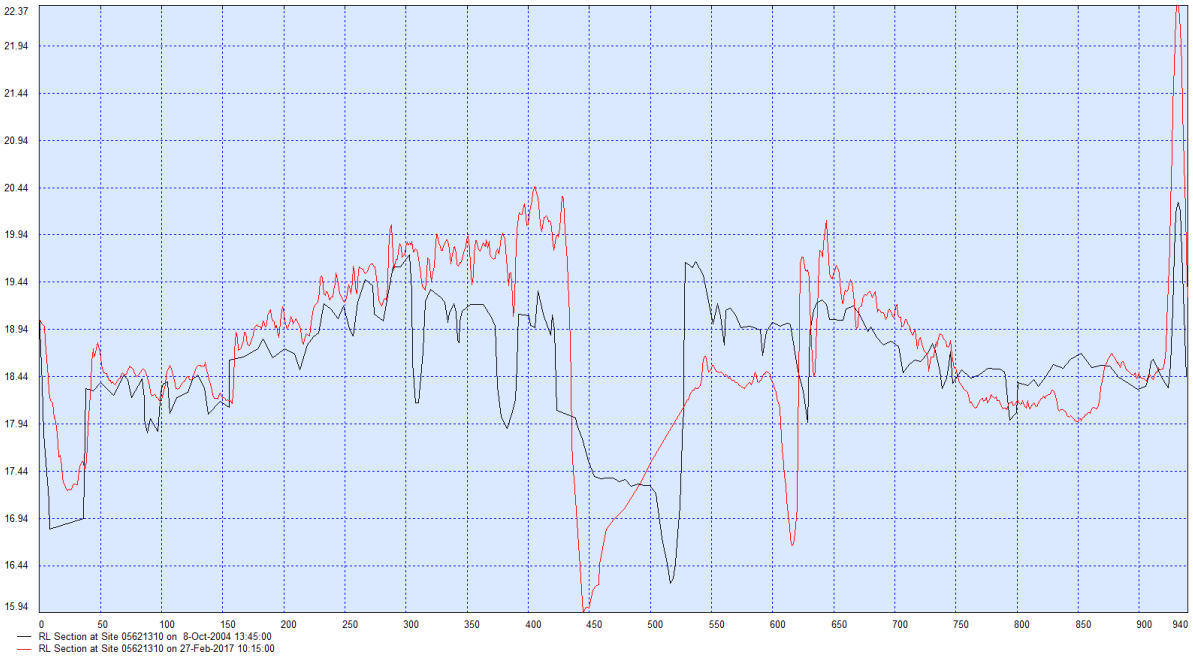
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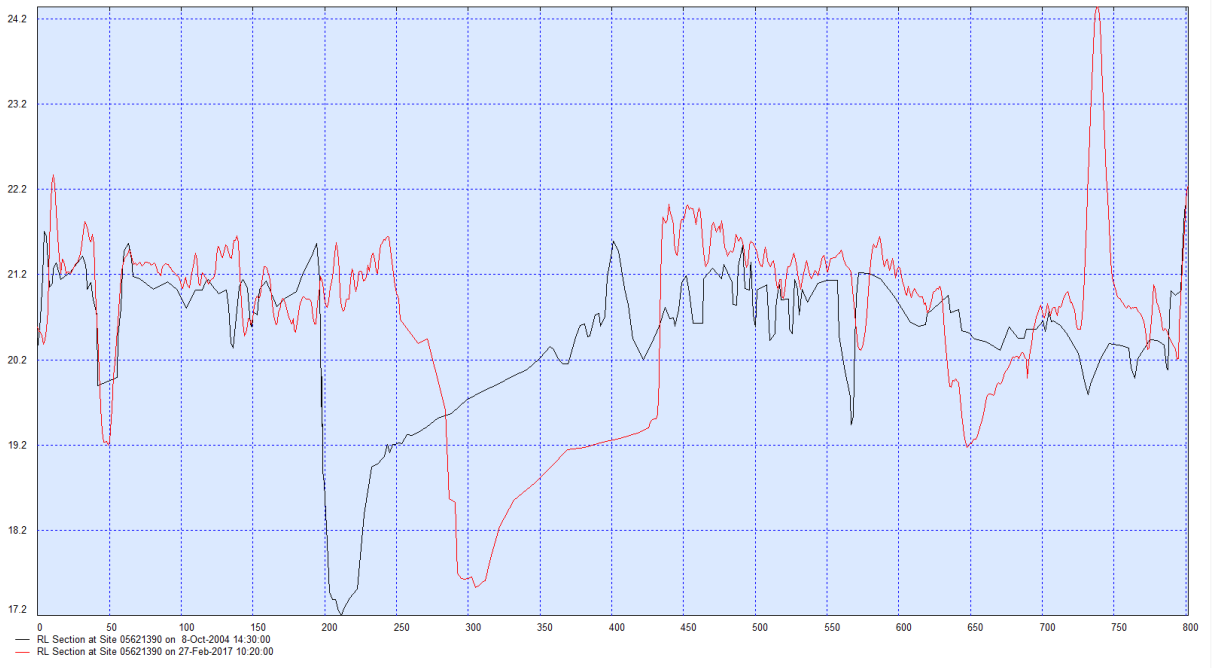
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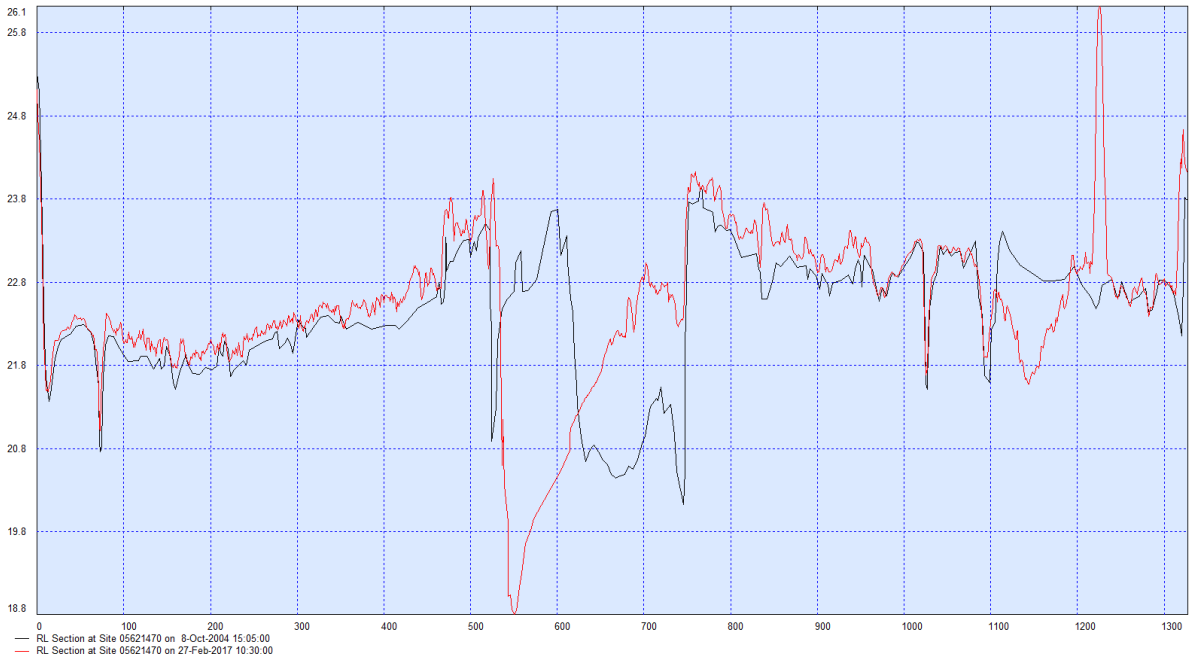
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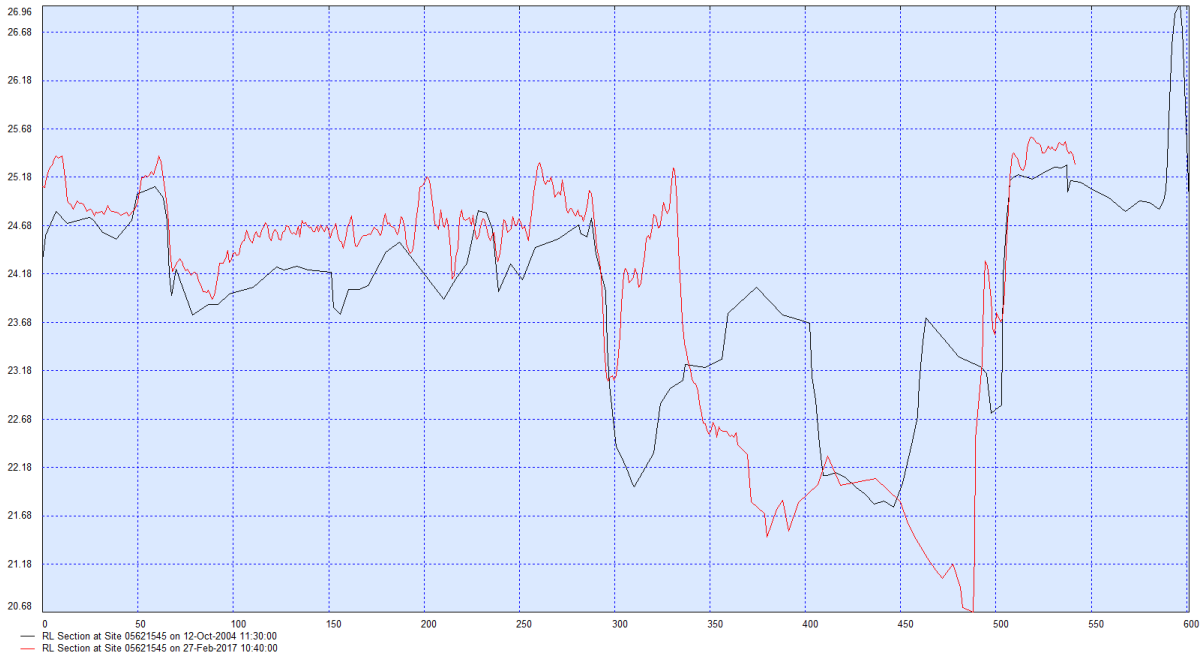
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RL Section at Site 05621545 on 12-Oct-2004 11:30:00
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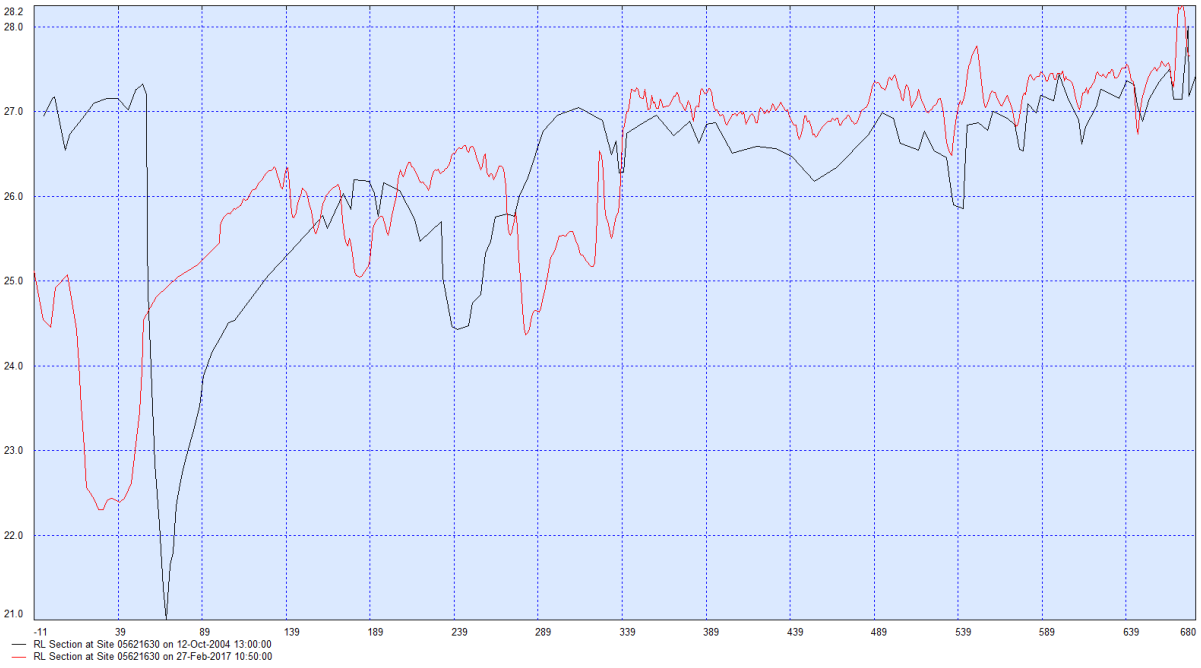
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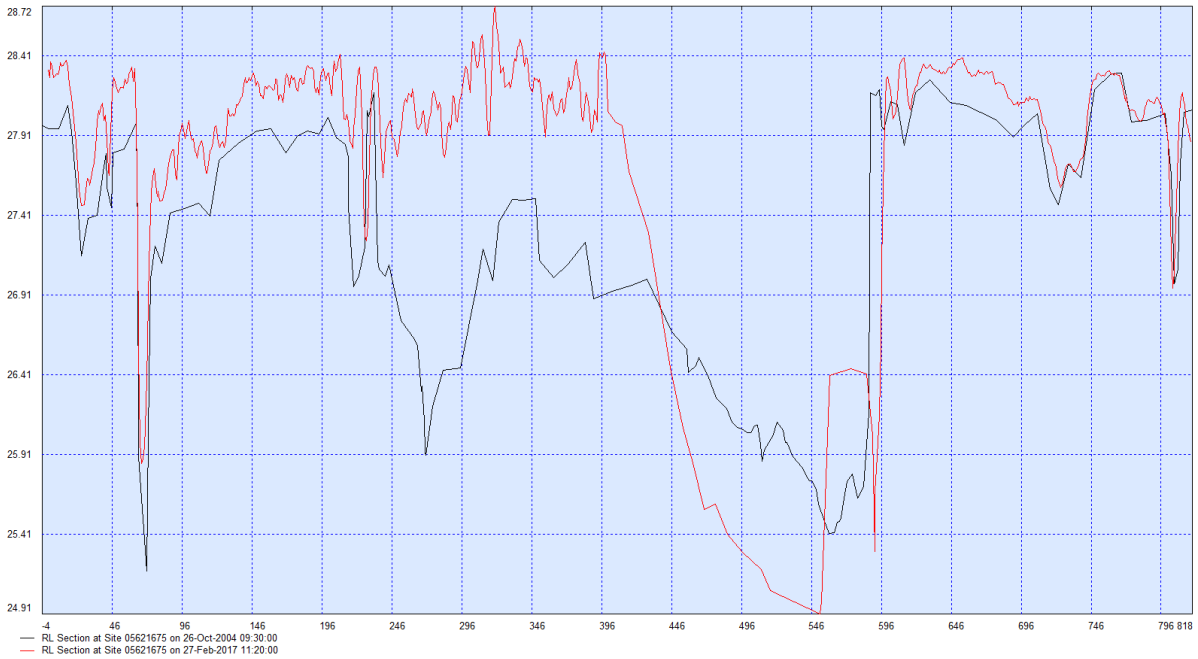
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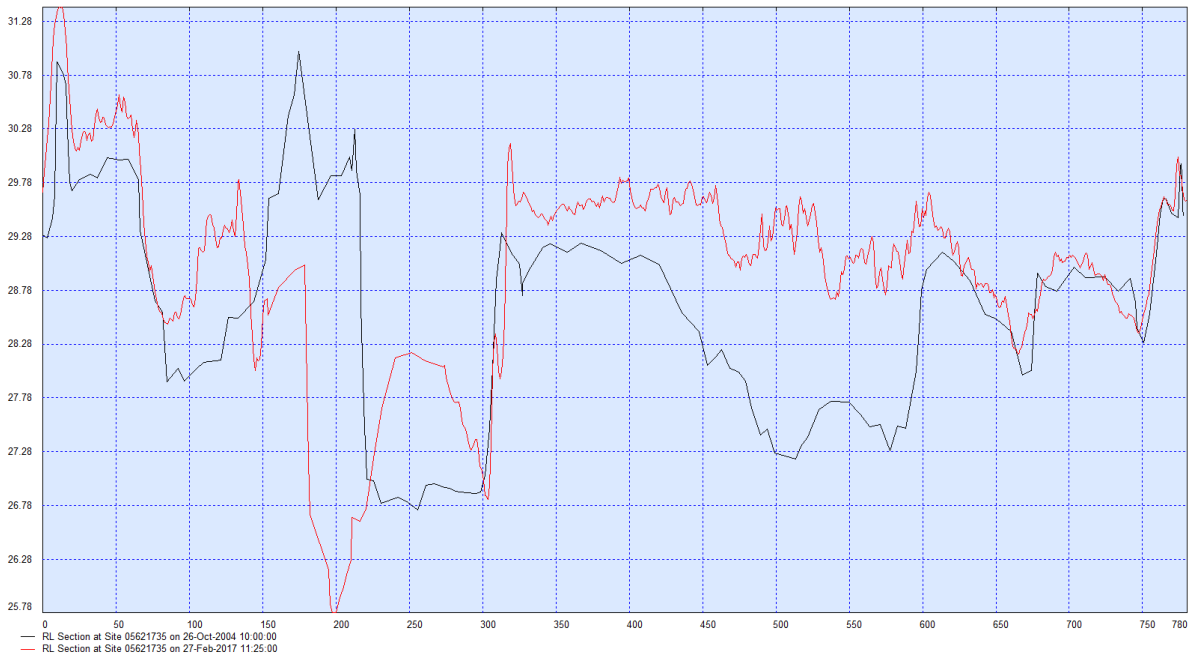
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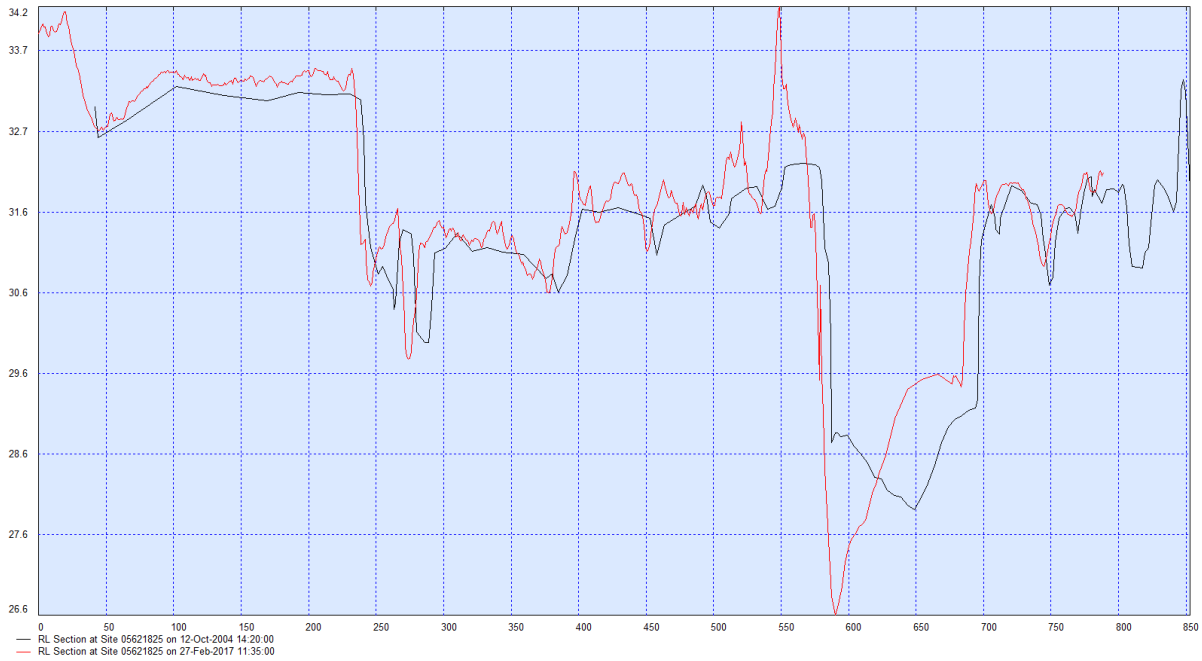
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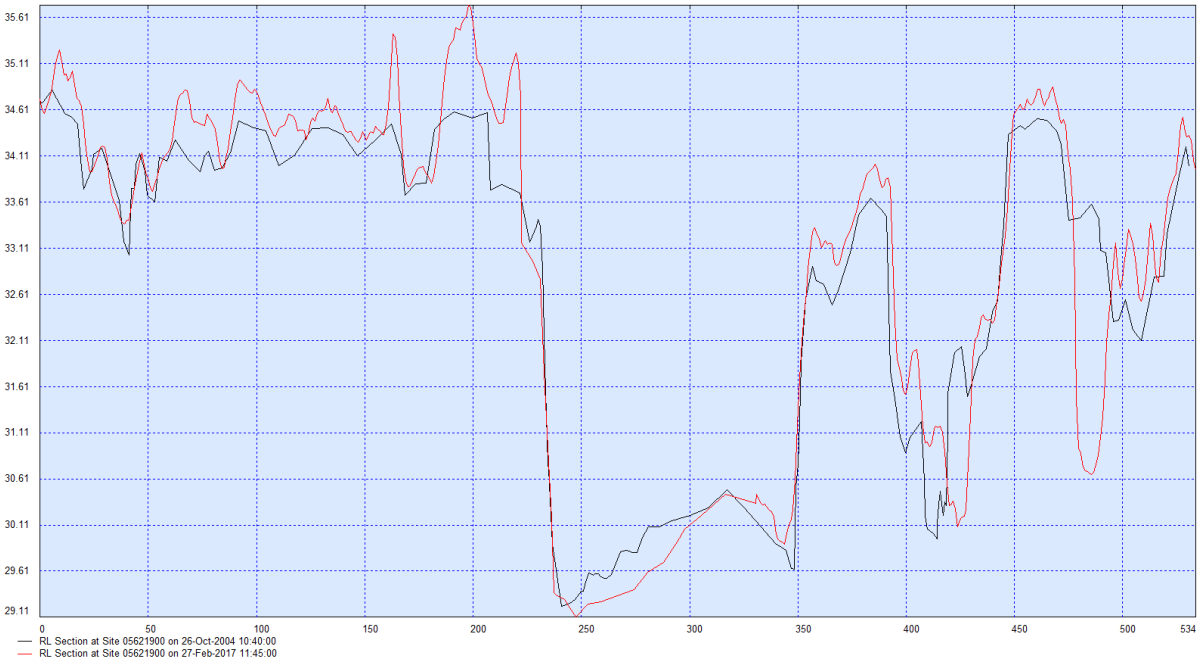
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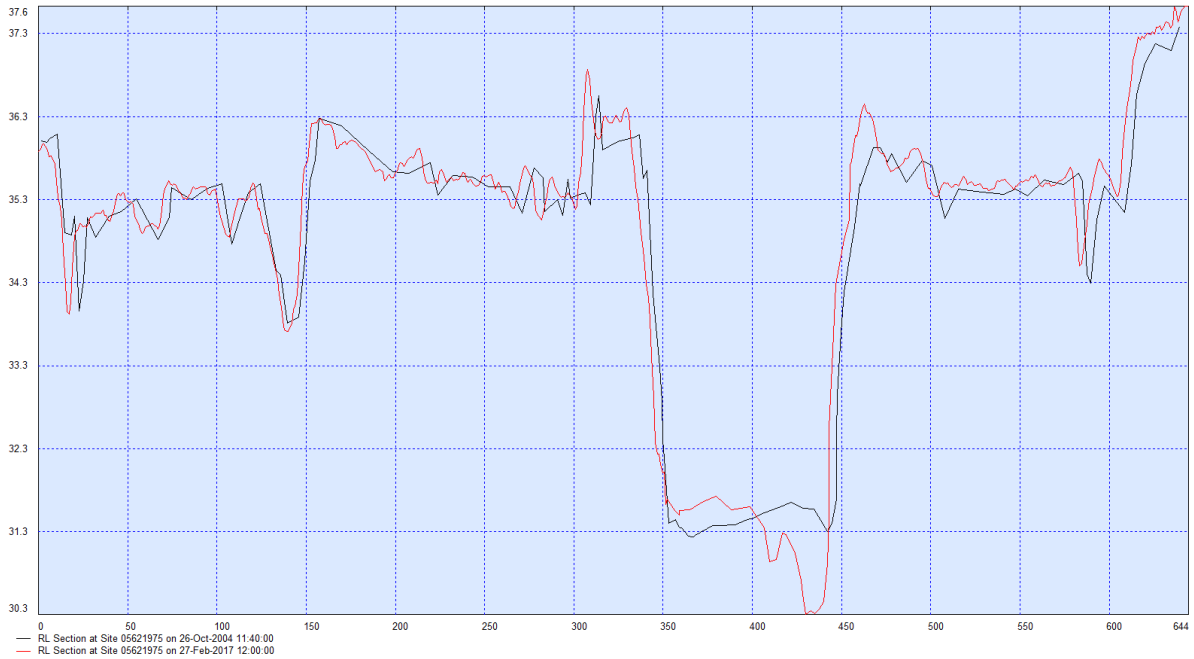
RL Section at Site 05621900 on 27-Feb-2017 11:45:00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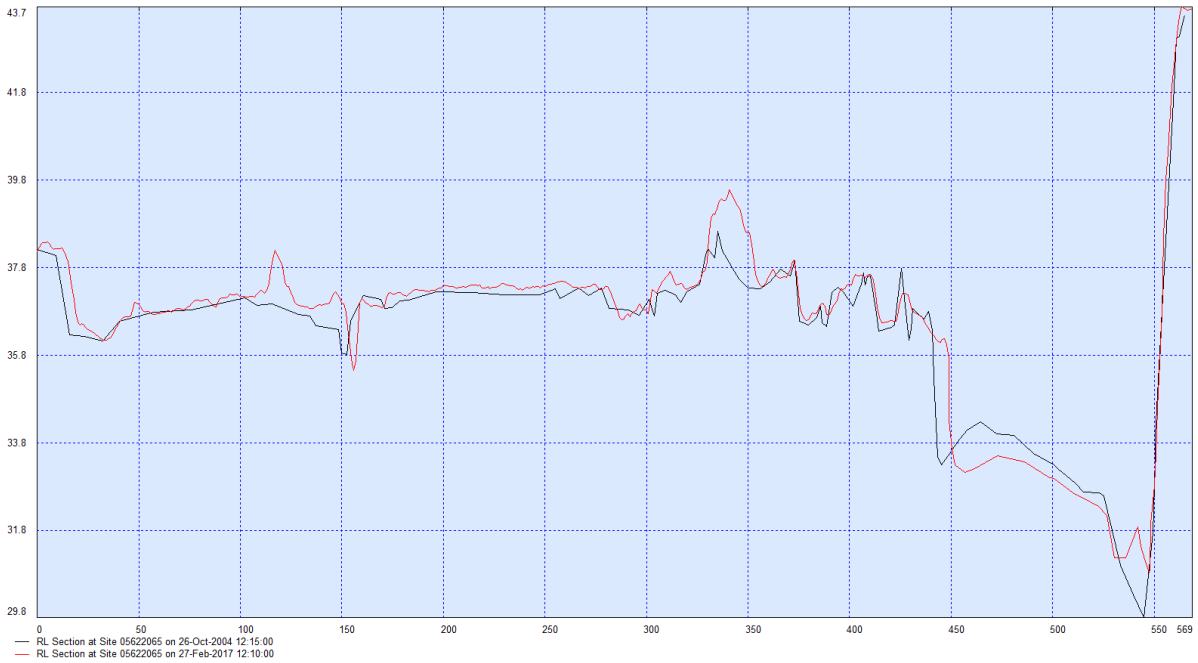
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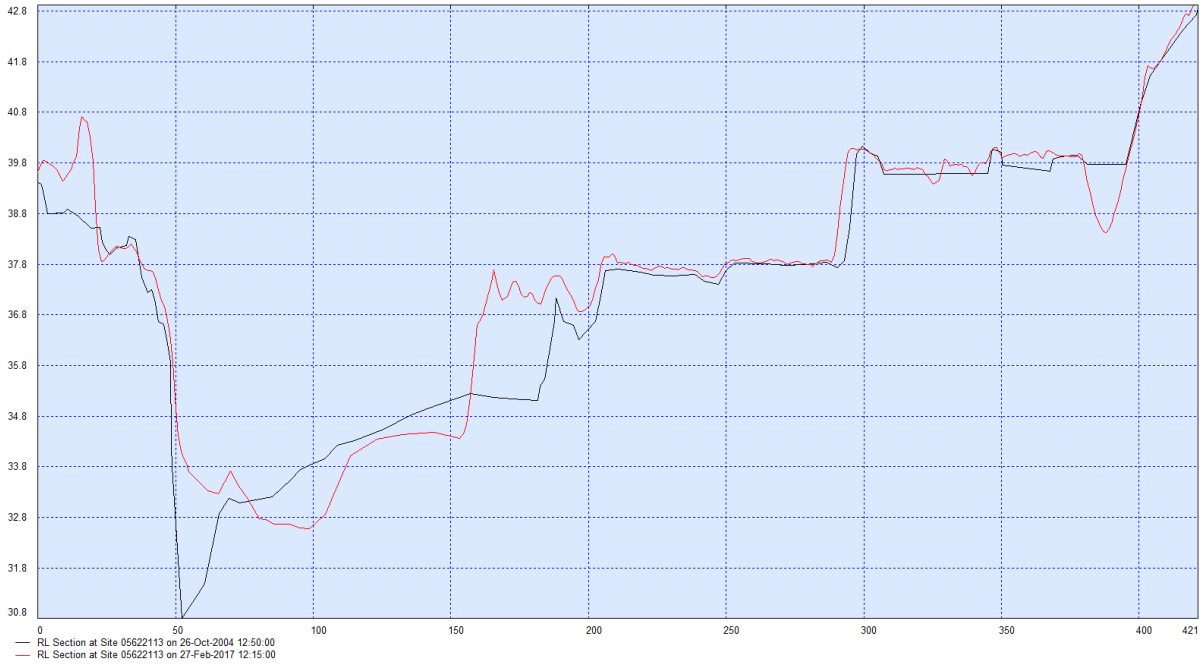
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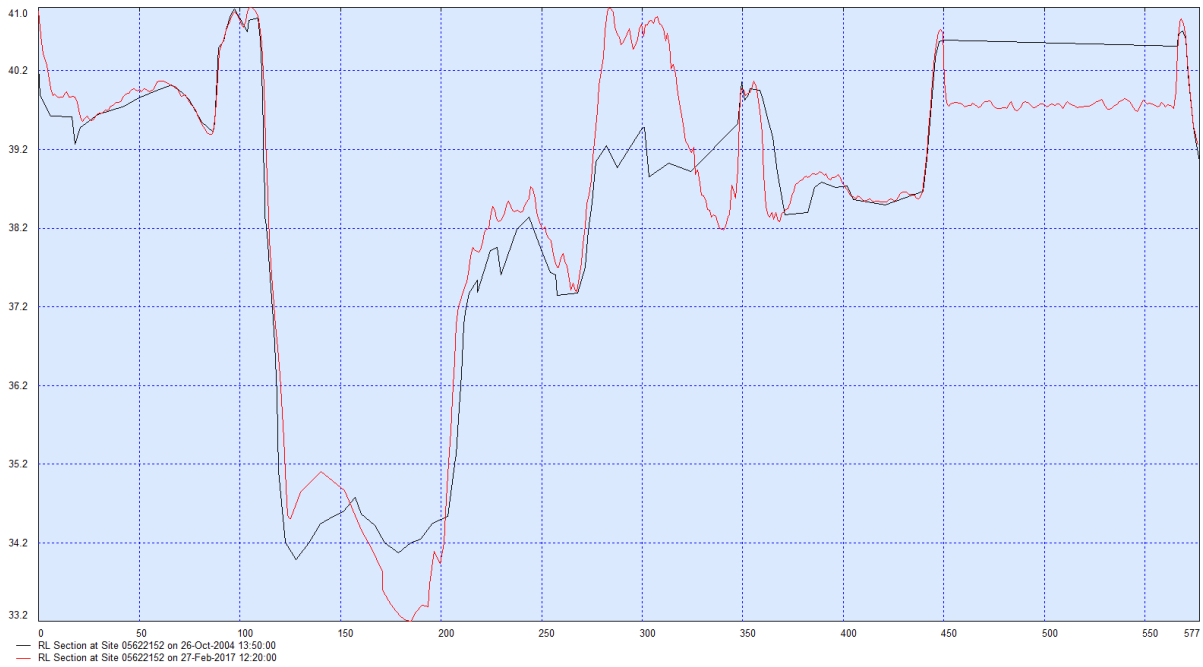
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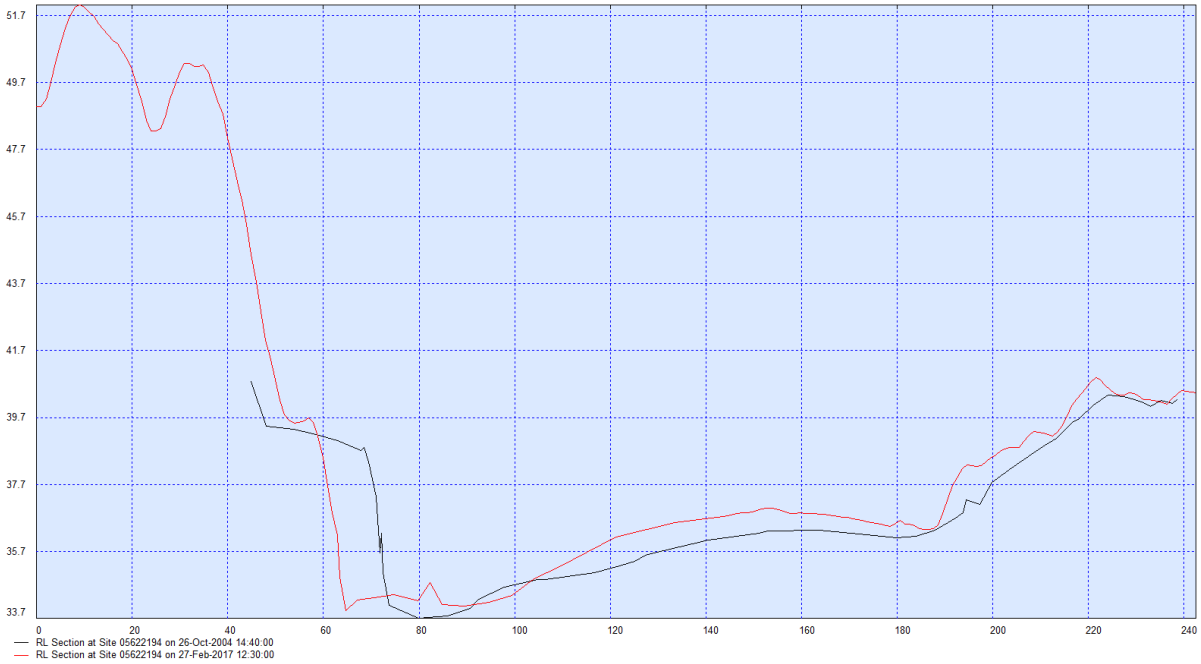
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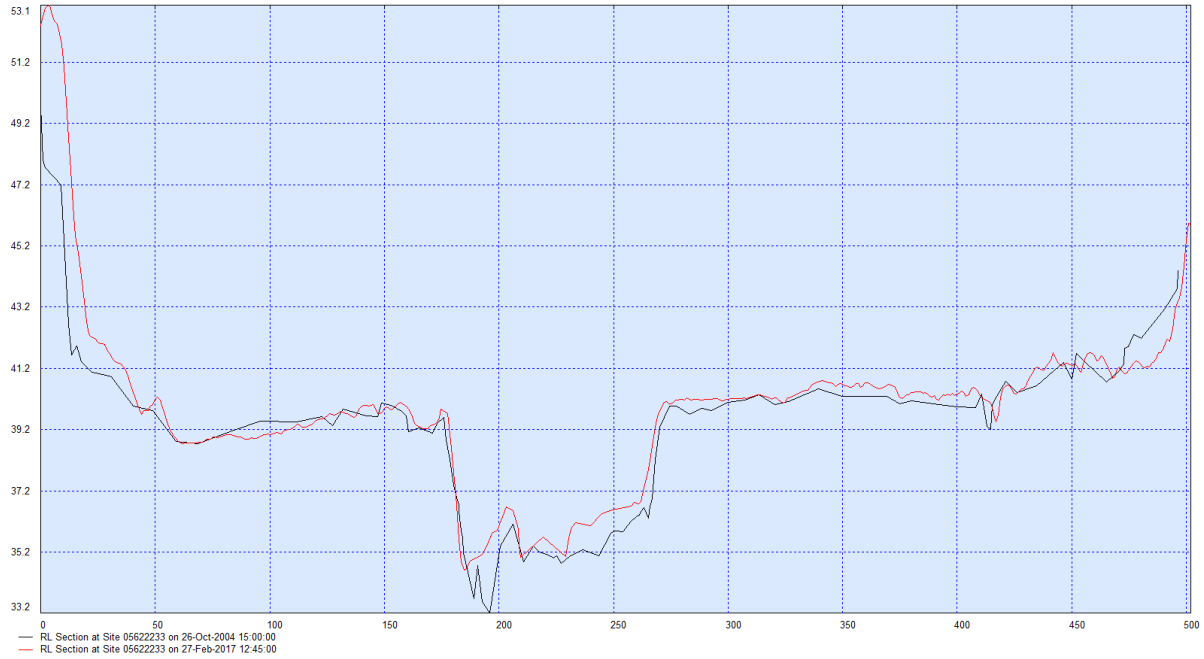
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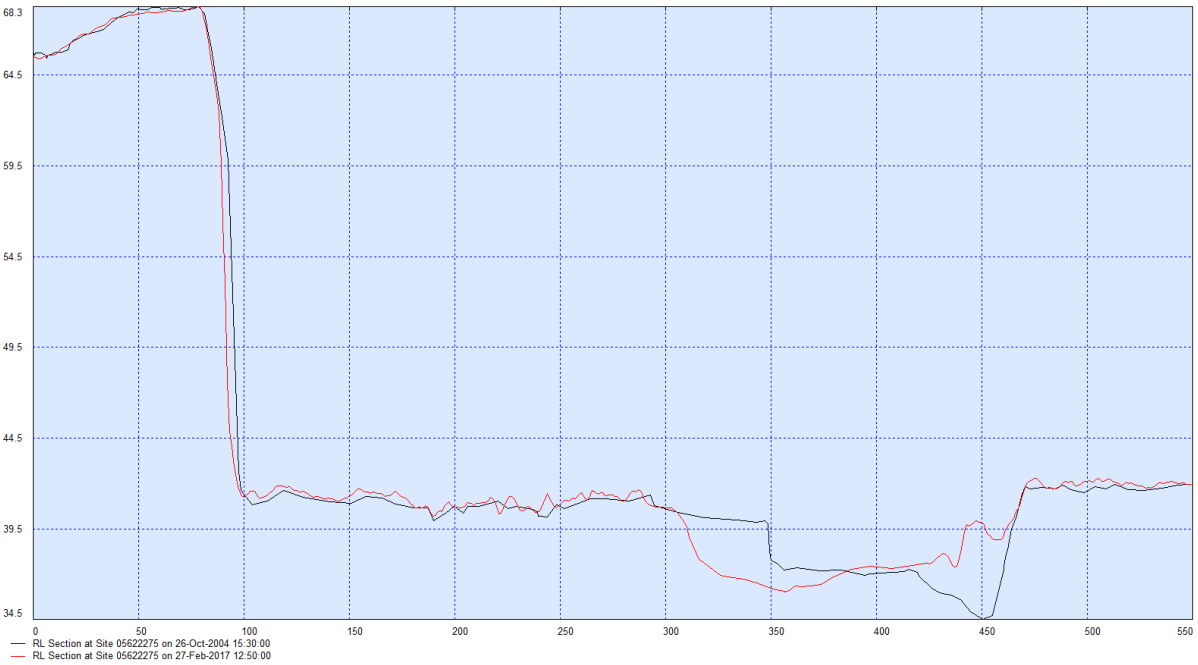
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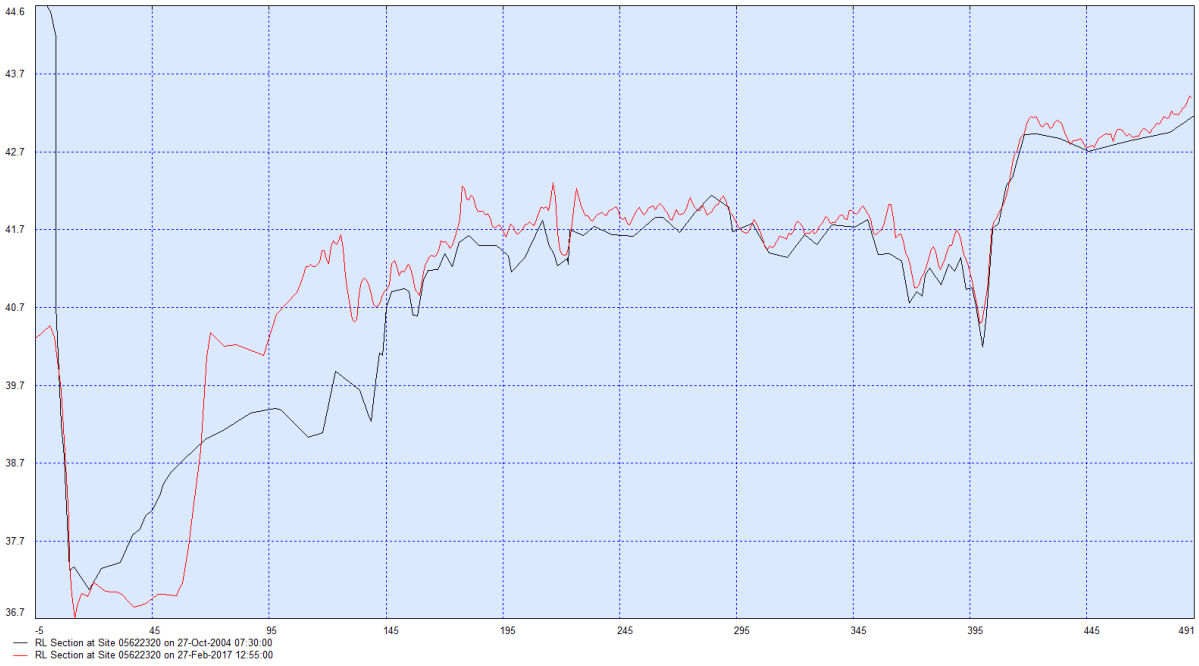
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RL Section at Site 05622320 on 27-Feb-2017 12:55:00


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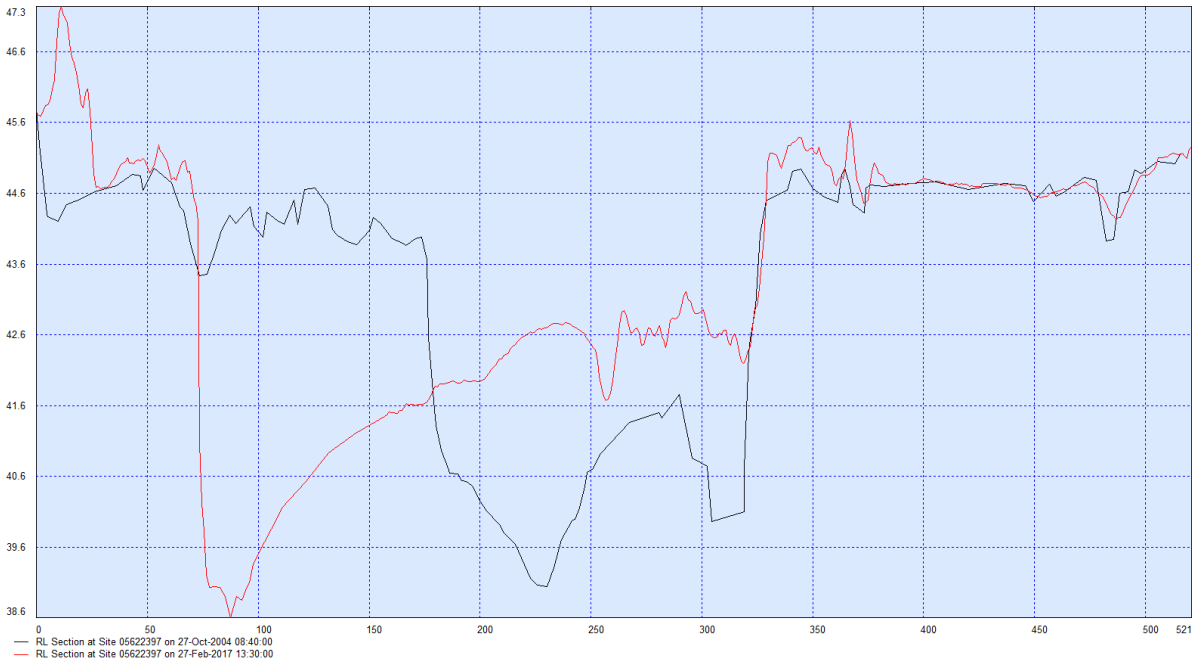
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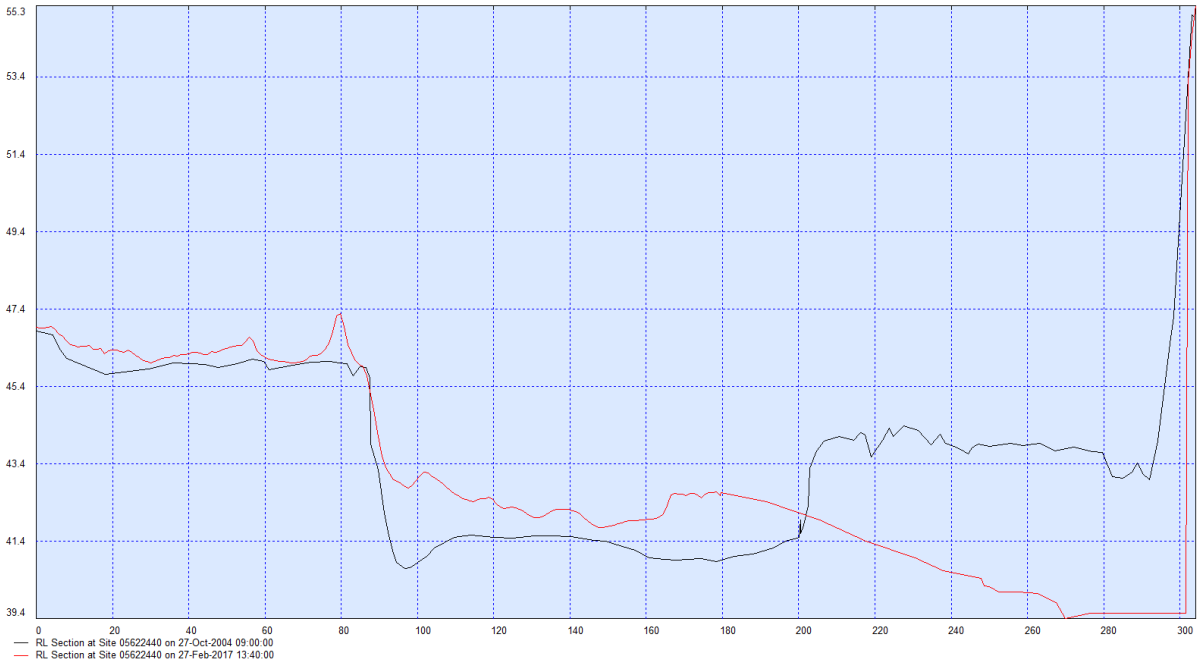
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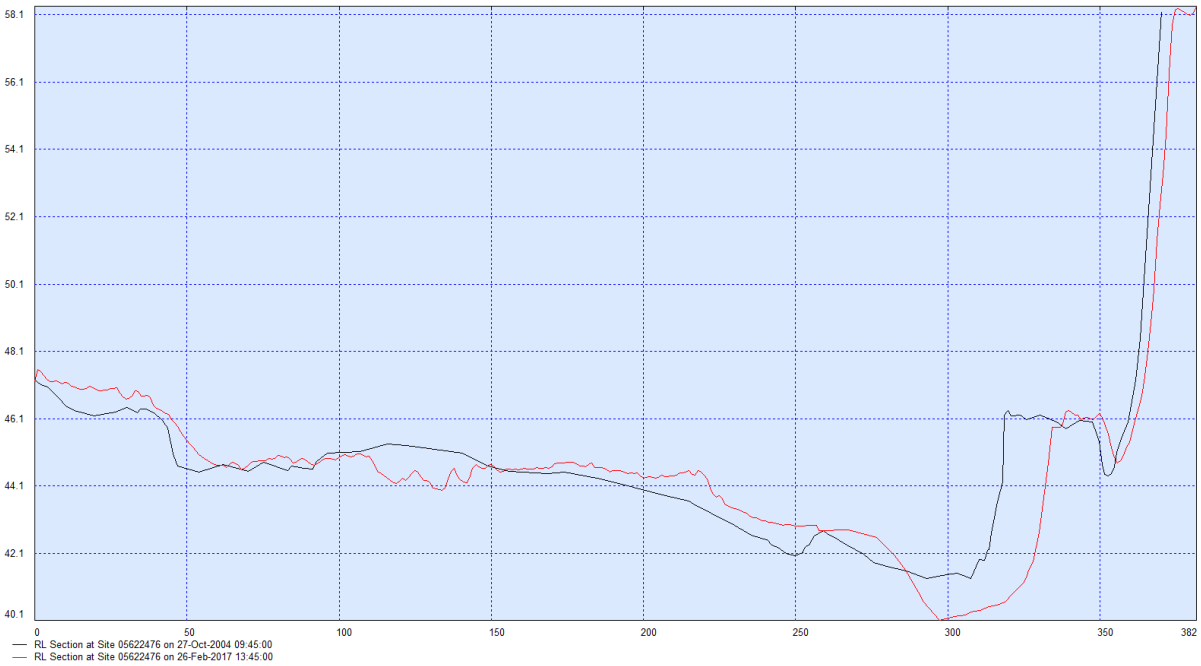
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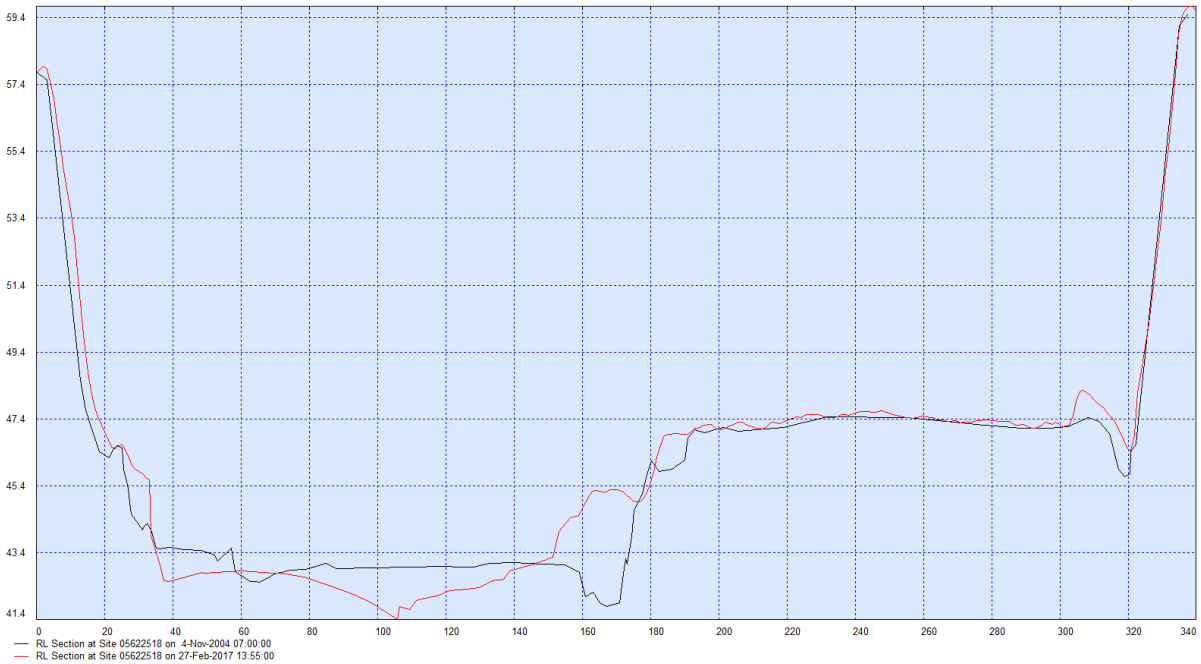
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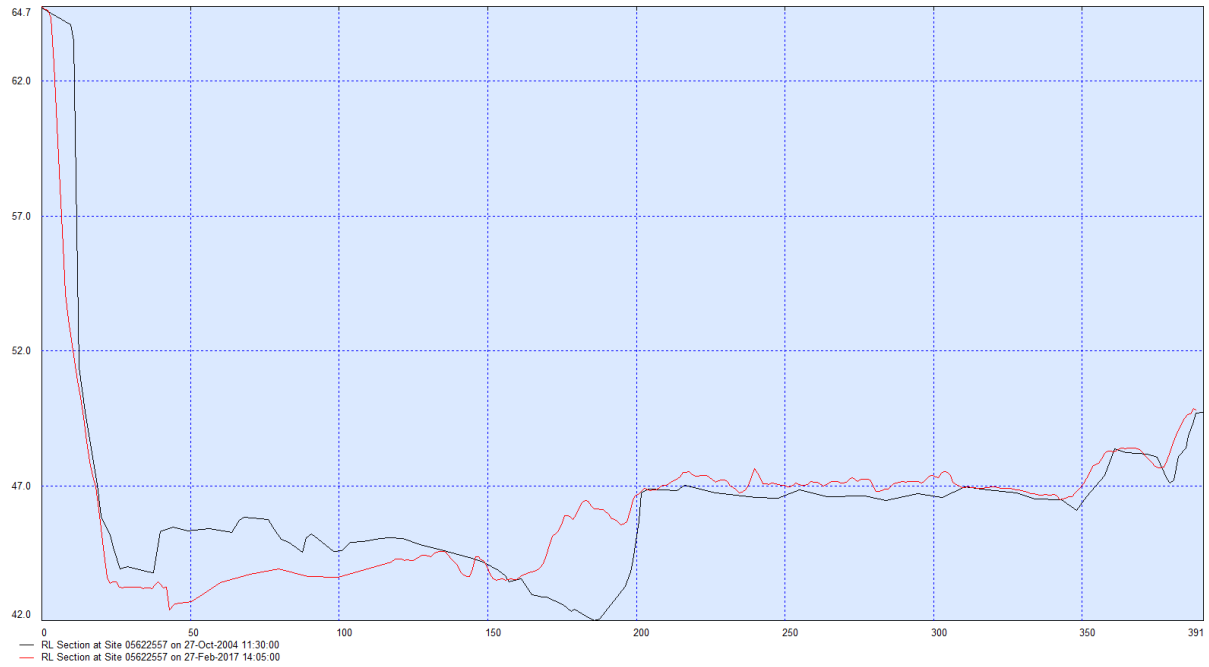
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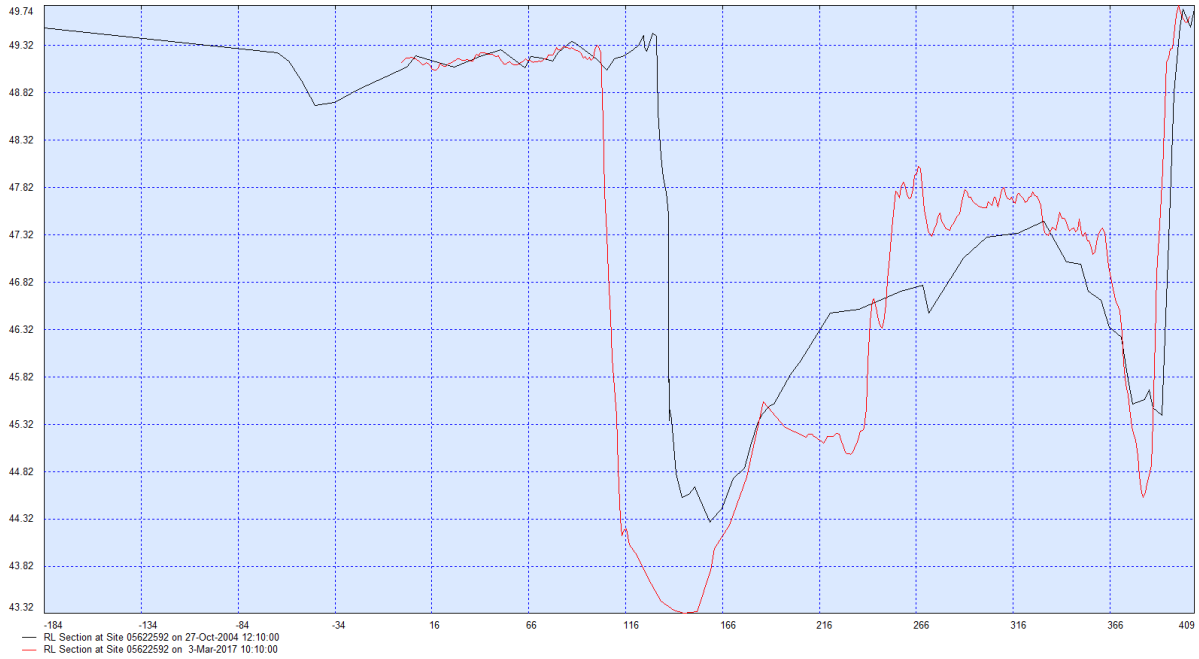
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RL Section at Site 05622592 on 27-Oct-2004 12:10:00
RL Section at Site 05622592 on 3-Mar-2017 10:10:00


51.5
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49.1
48.1
47.1
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45.1
44.1
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RL Section at Site 05622633 on 4-Nov-2004 07:30:00
RL Section at Site 05622633 on 3-Mar-2017 10:15:00


52.0
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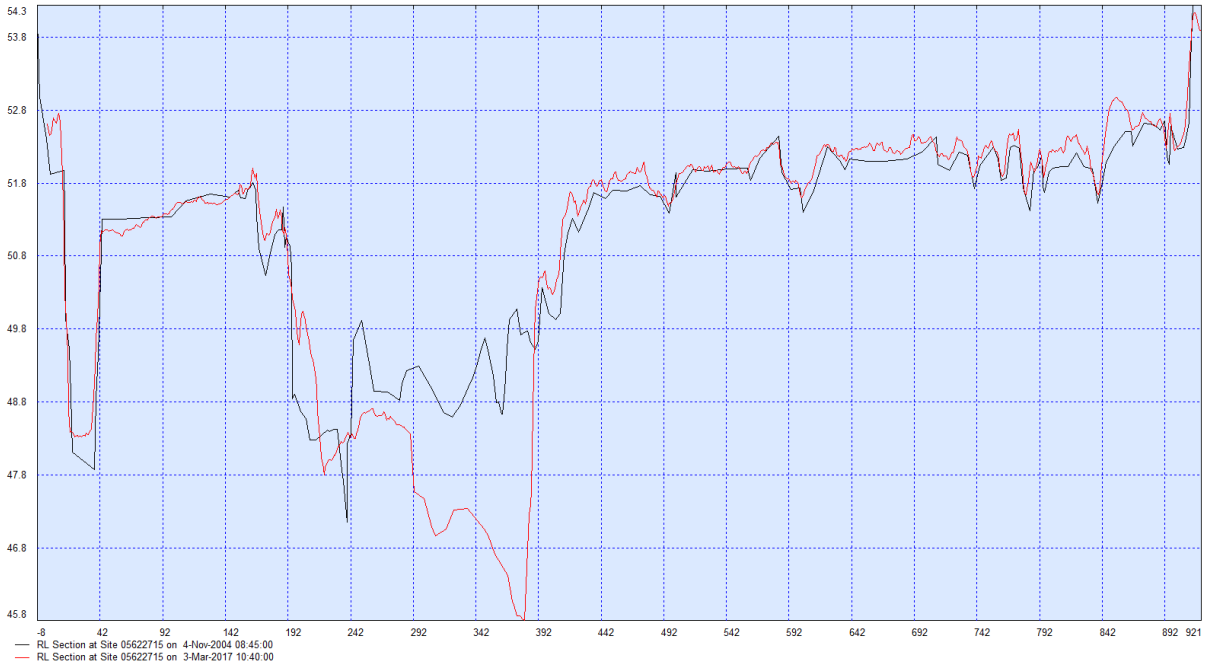
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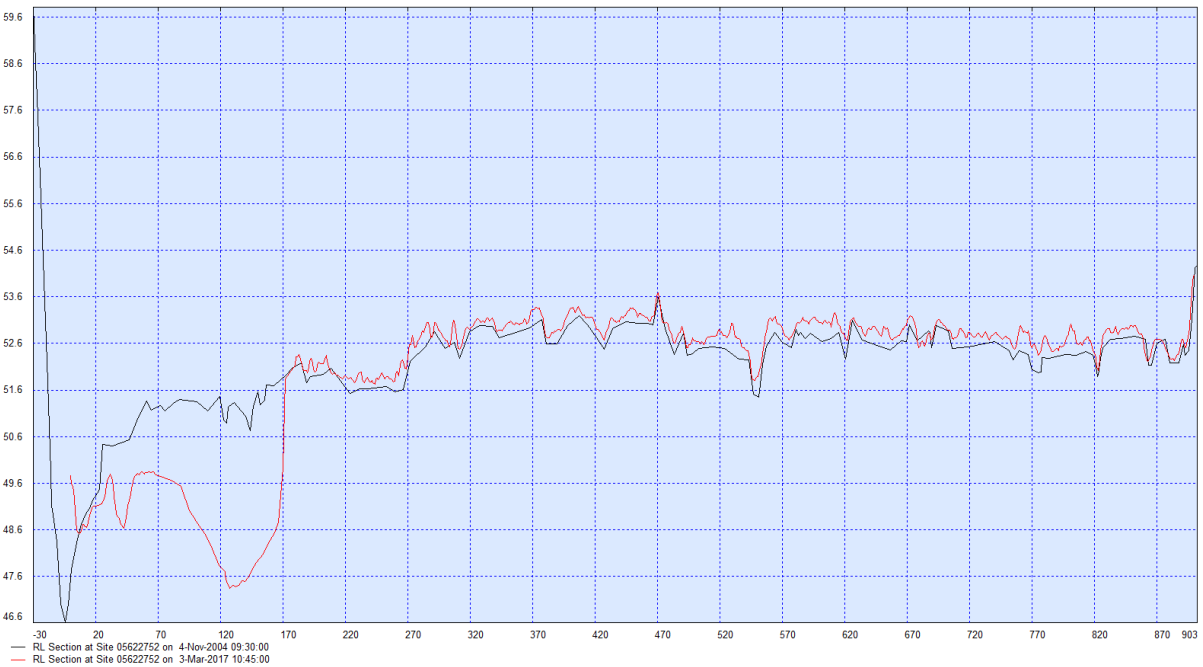
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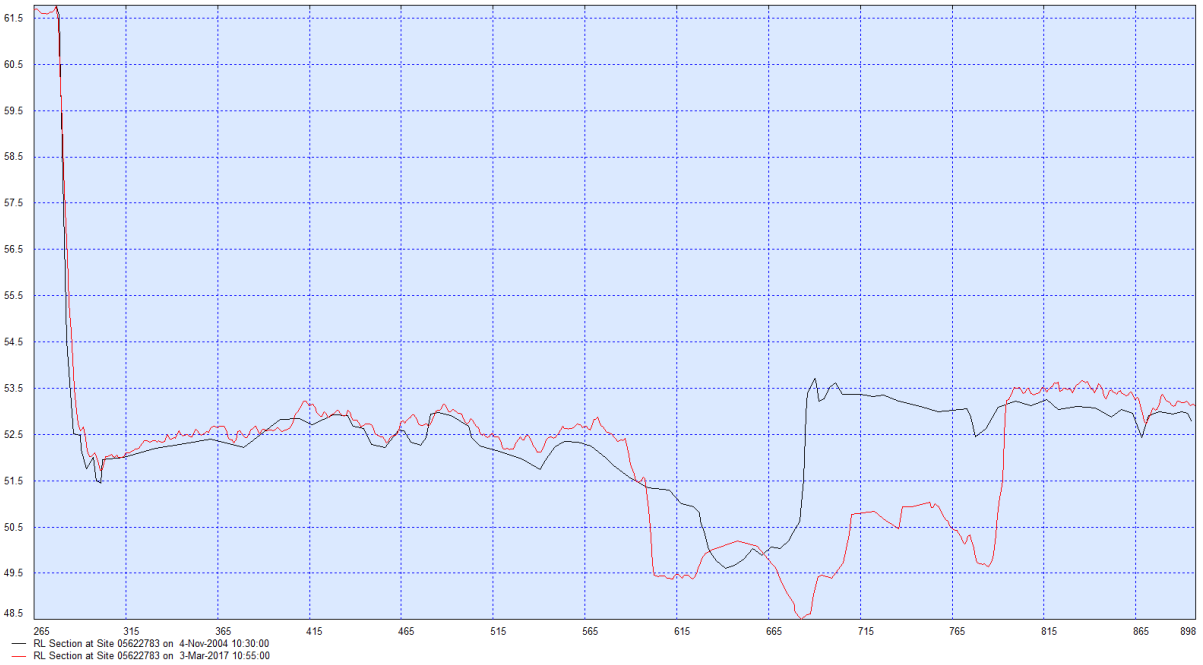
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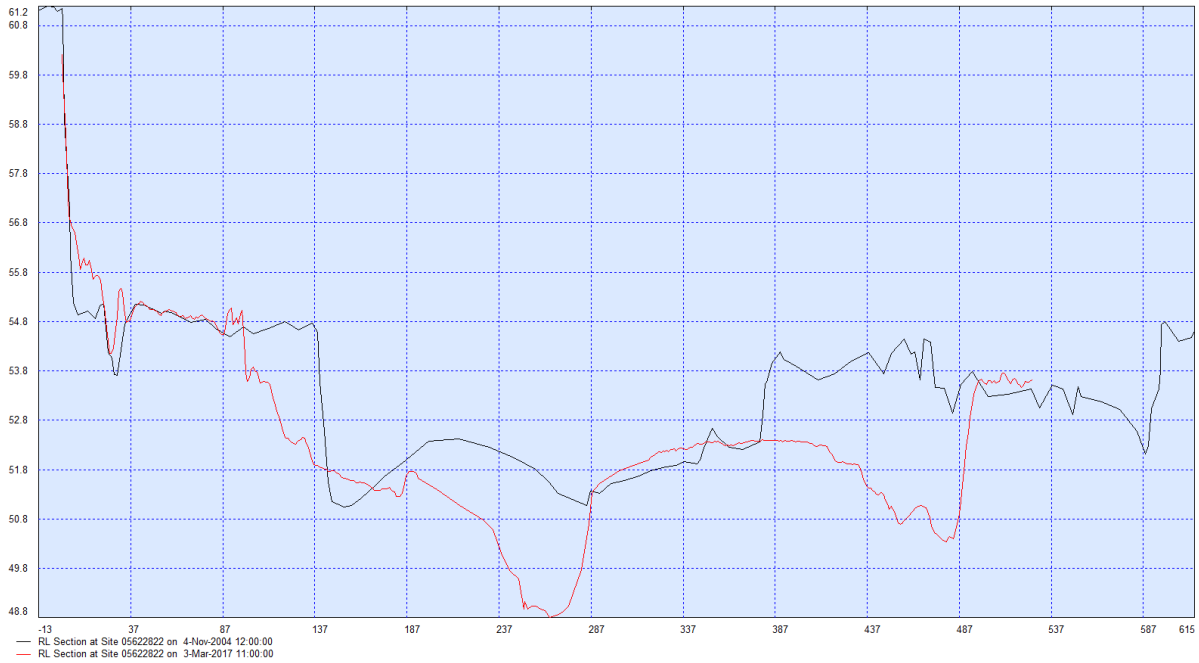
265 315 365 415 465 515 565 615 665 715 765 815 865 898
RL Section at Site 05622783 on 4-Nov-2004 10:30:00
RL Section at Site 05622783 on 3-Mar-2017 10:55:00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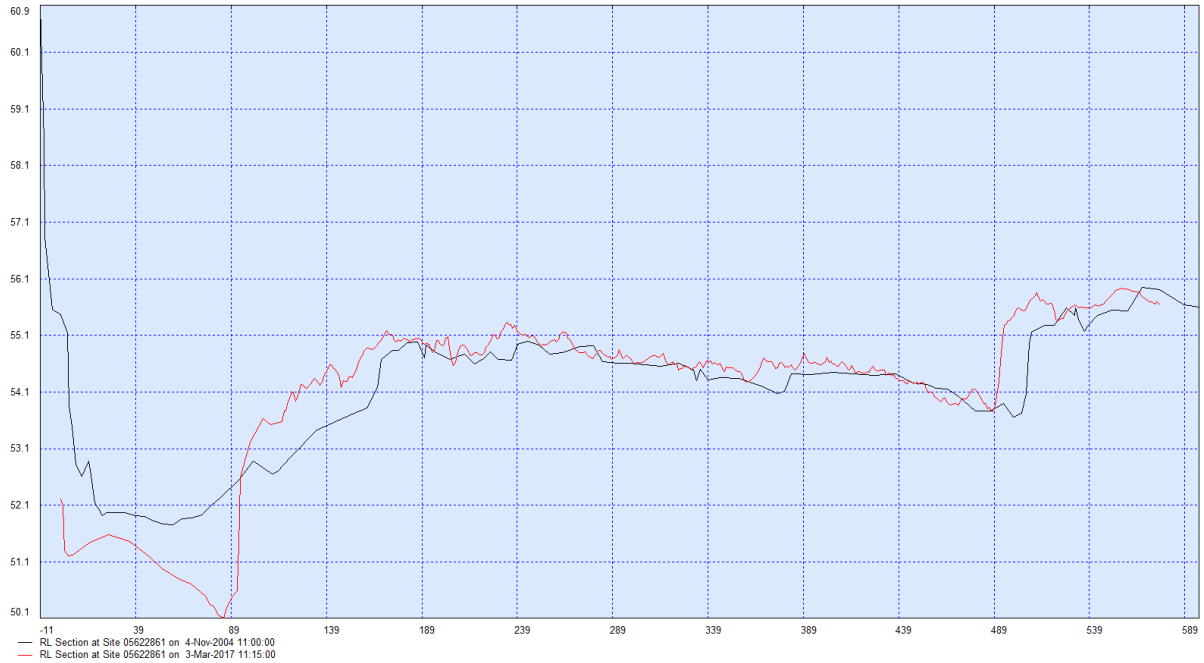
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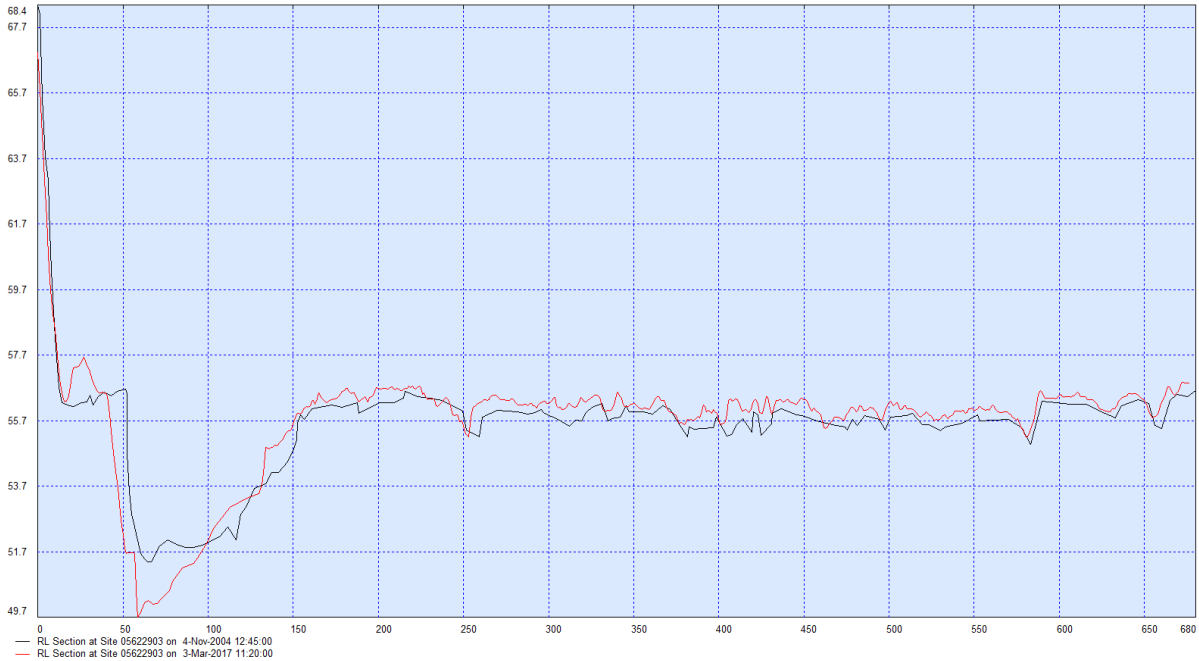
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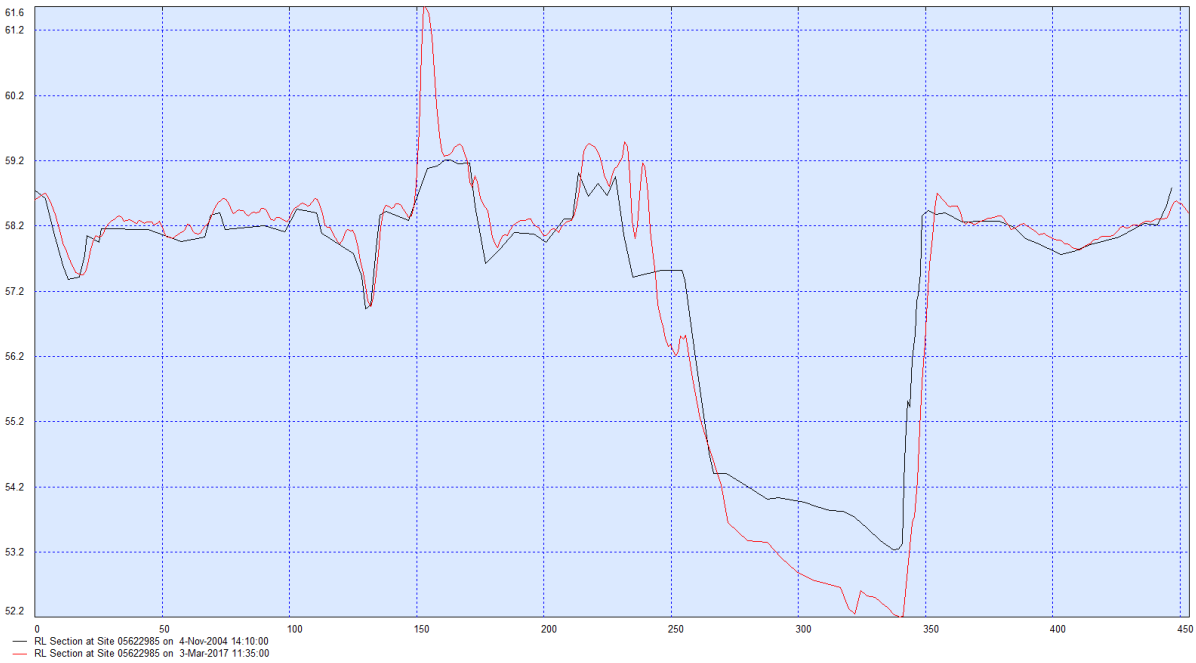
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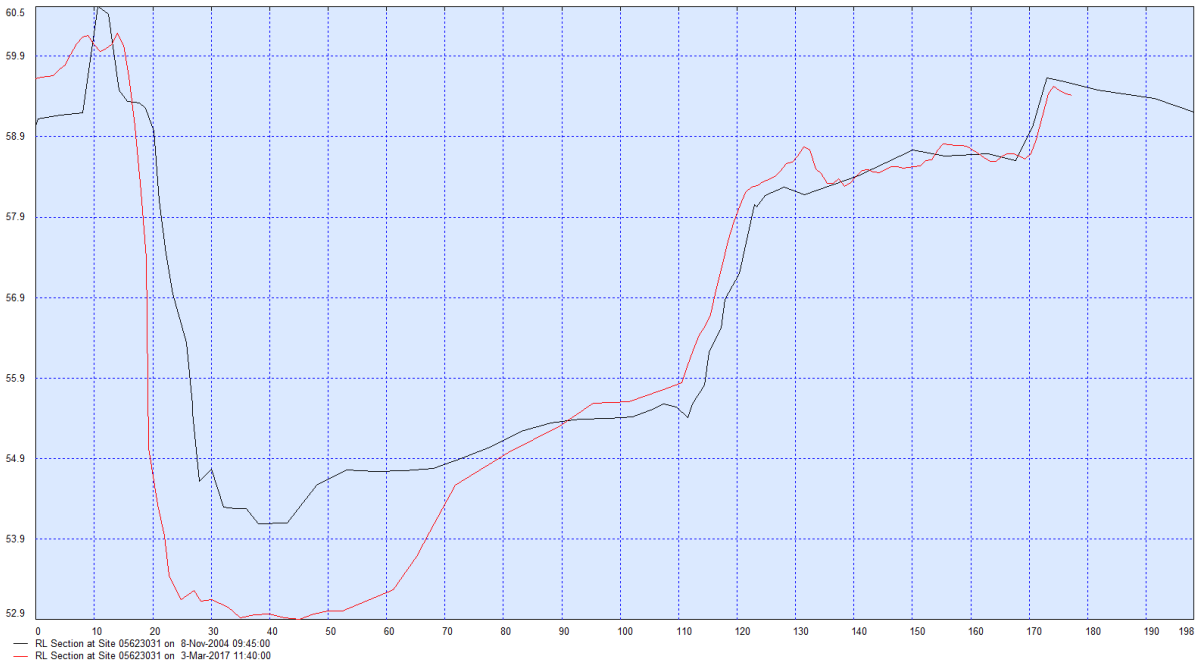
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198
RL Section at Site 05623031 on 8-Nov-2004 09:45:00
RL Section at Site 05623031 on 3-Mar-2017 11:40:00


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RL Section at Site 05623086 on 8-Nov-2004 10:15:00
RL Section at Site 05623086 on 3-Mar-2017 11:45:00


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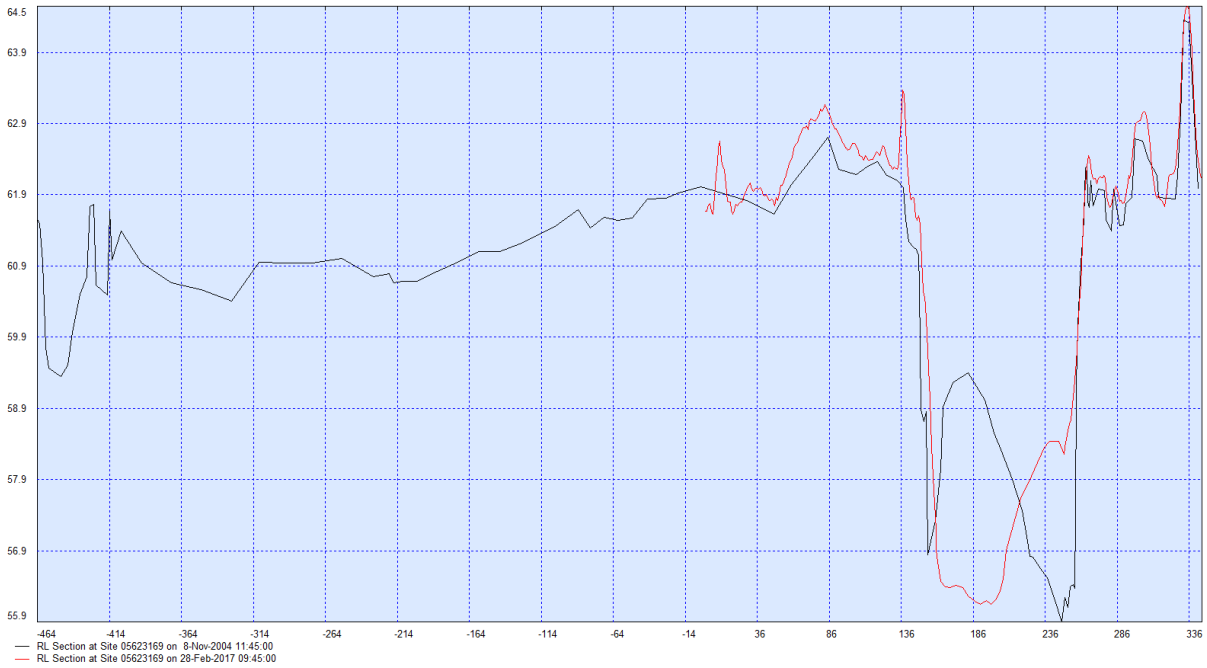
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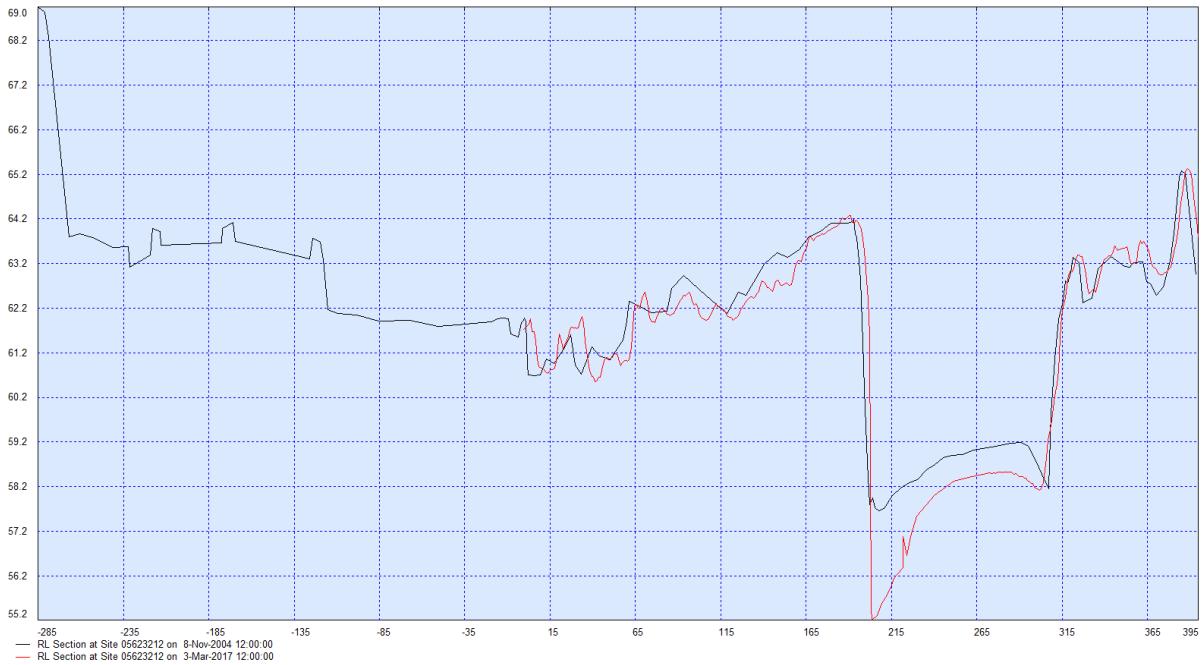
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395
RL Section at Site 05623212 on 8-Nov-2004 12:00:00
RL Section at Site 05623212 on 3-Mar-2017 12:00:00


69.7
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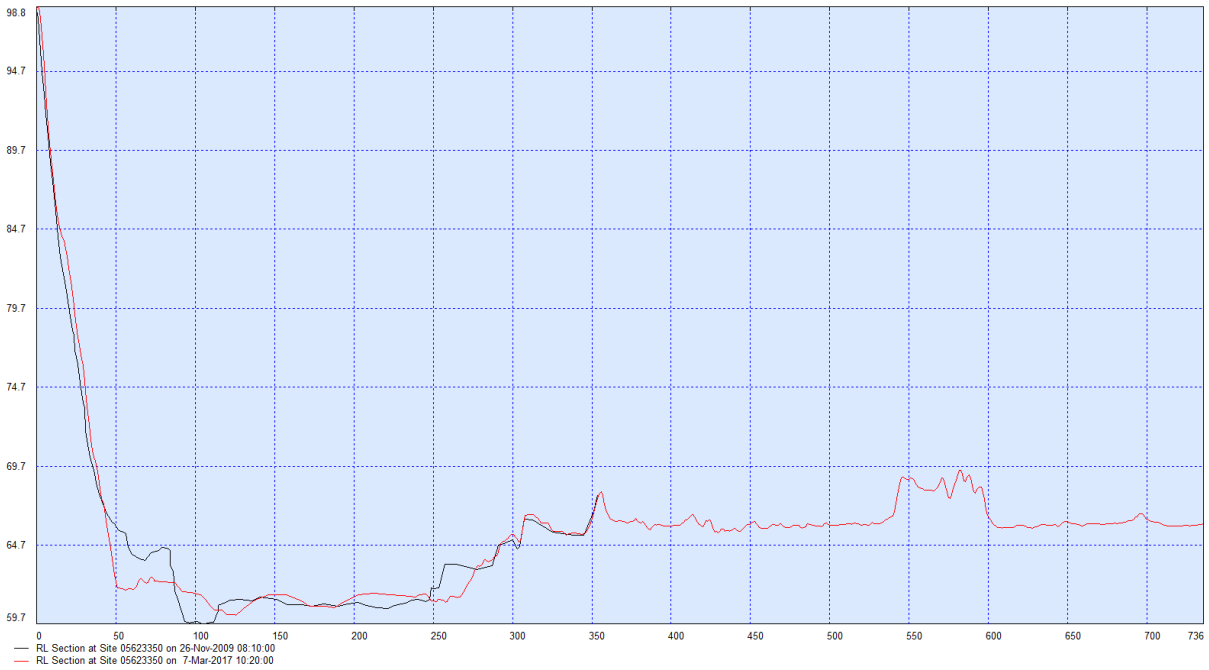
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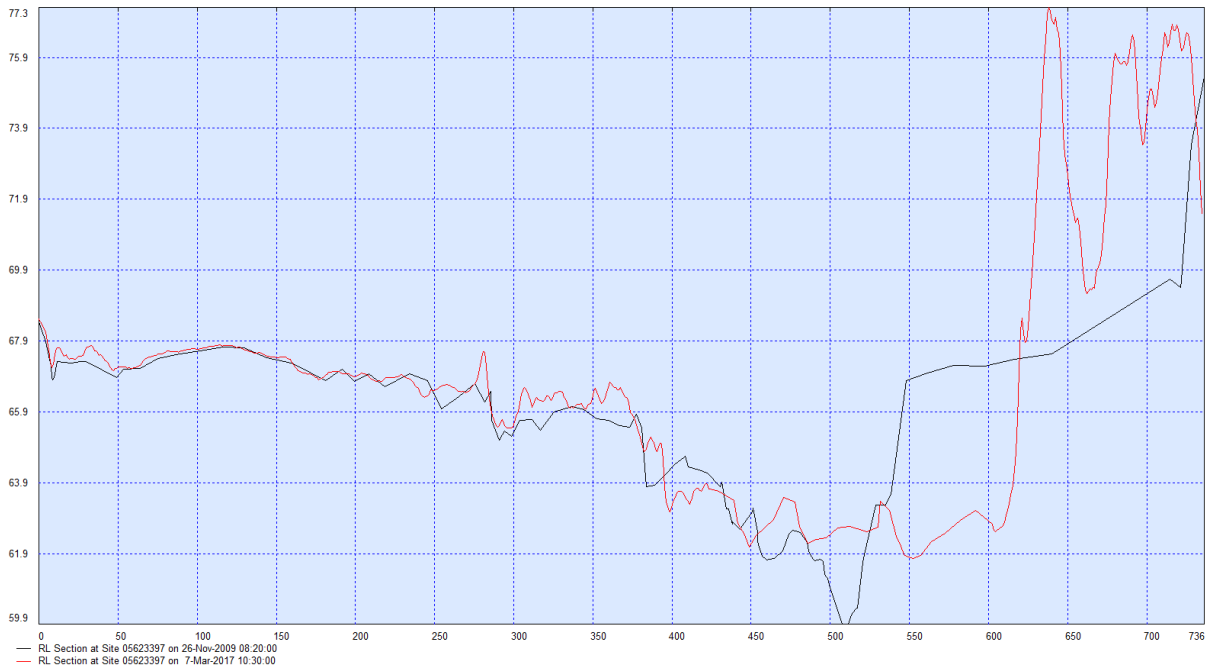
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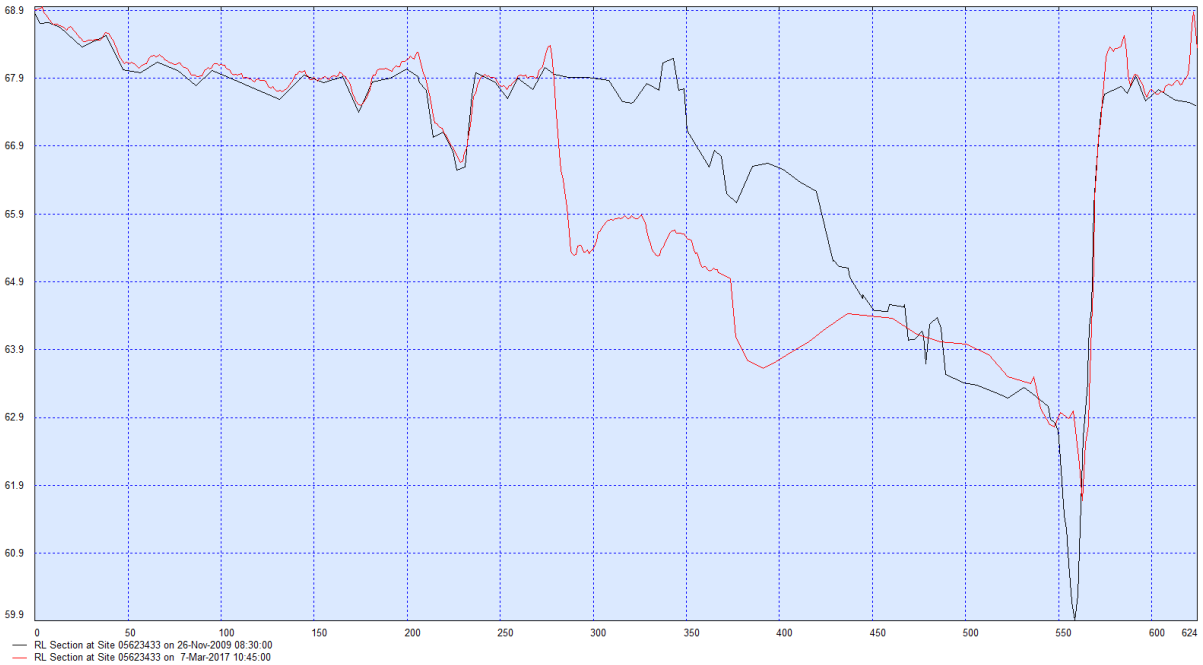
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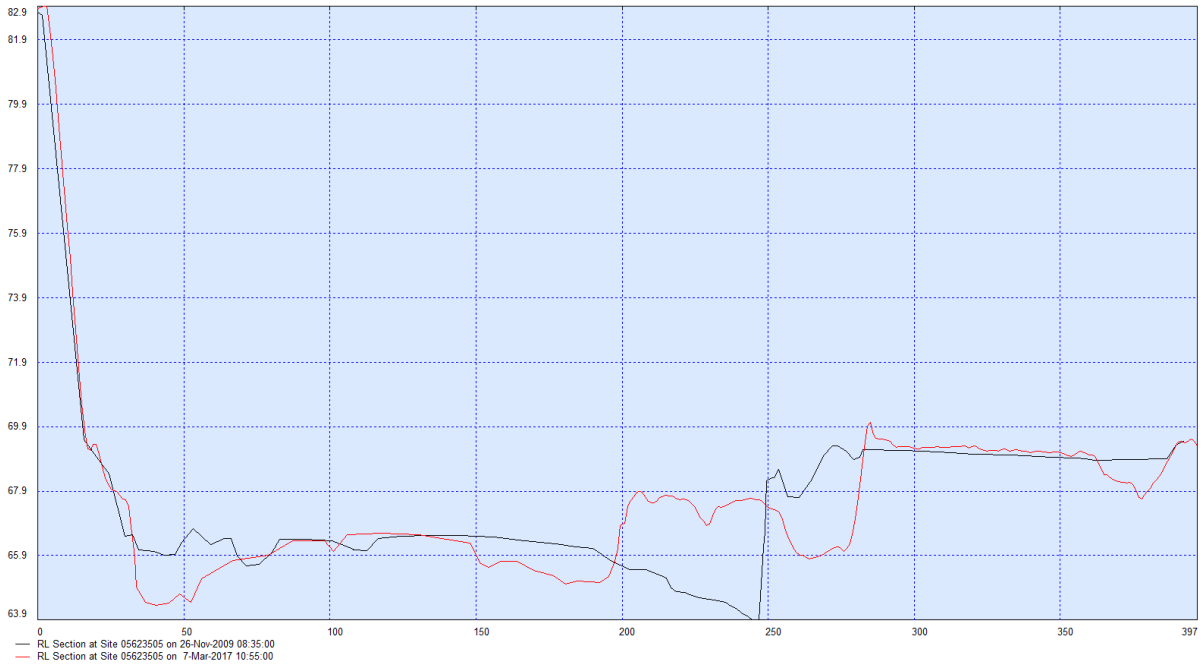
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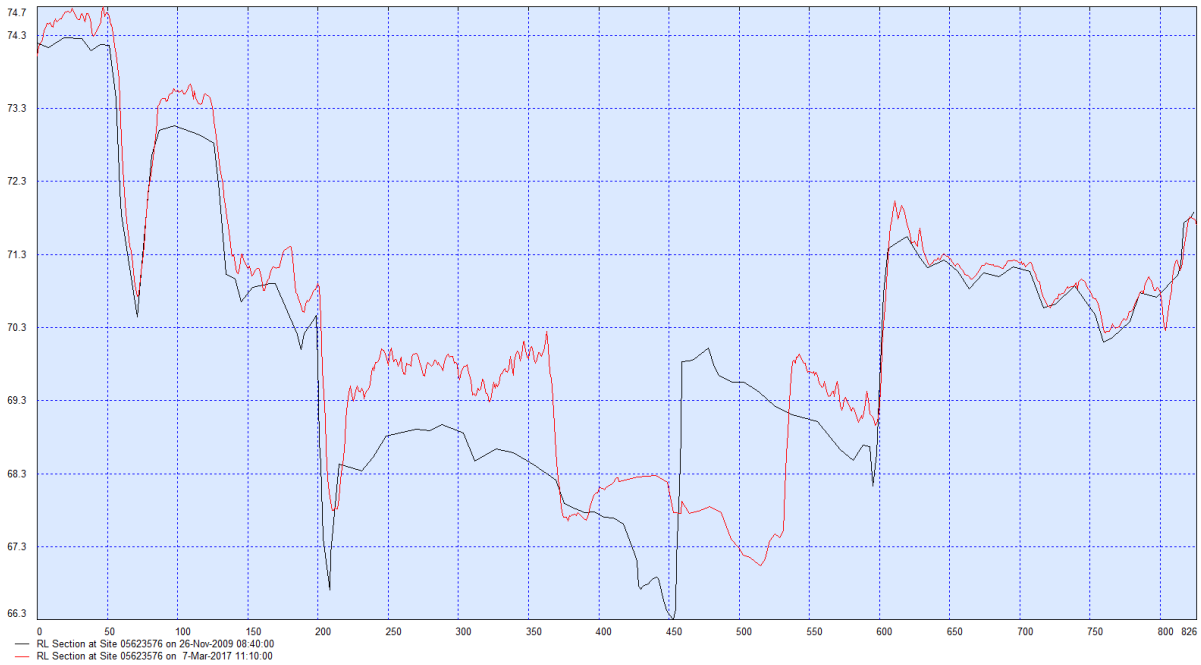
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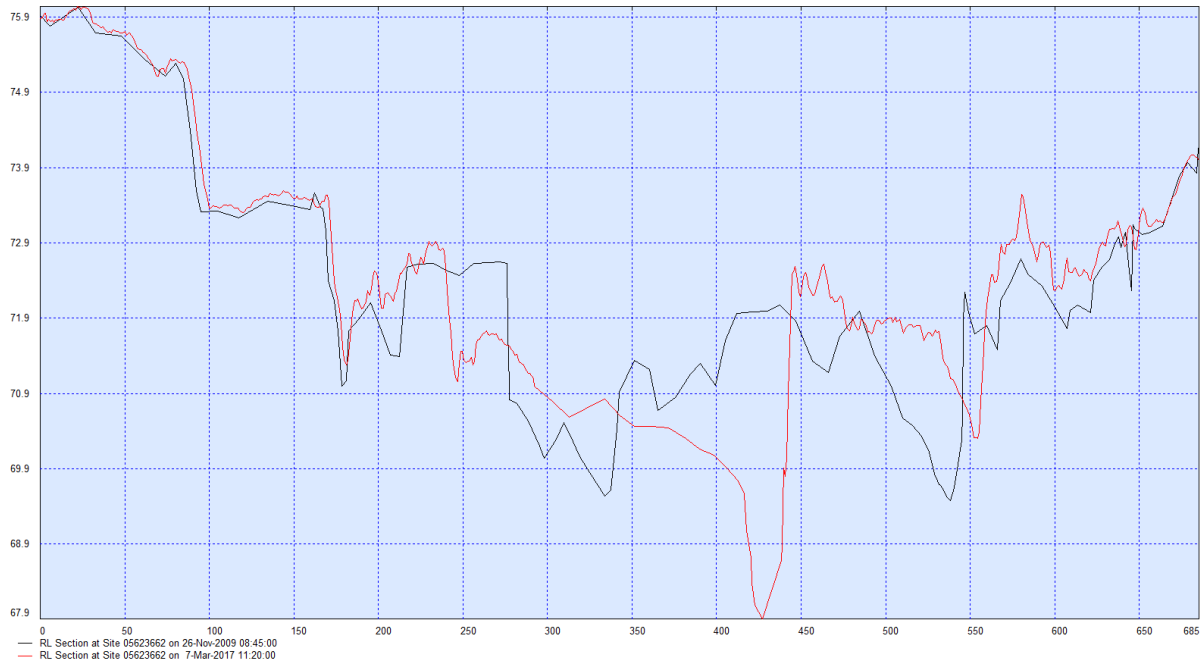
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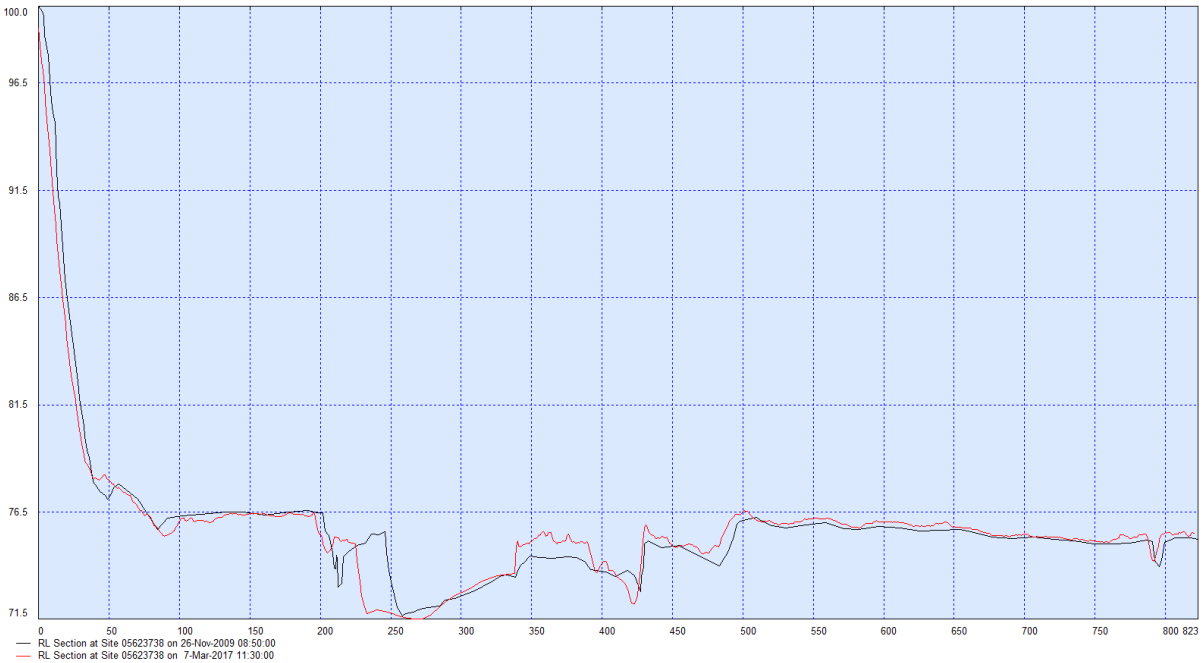
RL Section at Site 05623662 on 7-Mar-2017 11:20:00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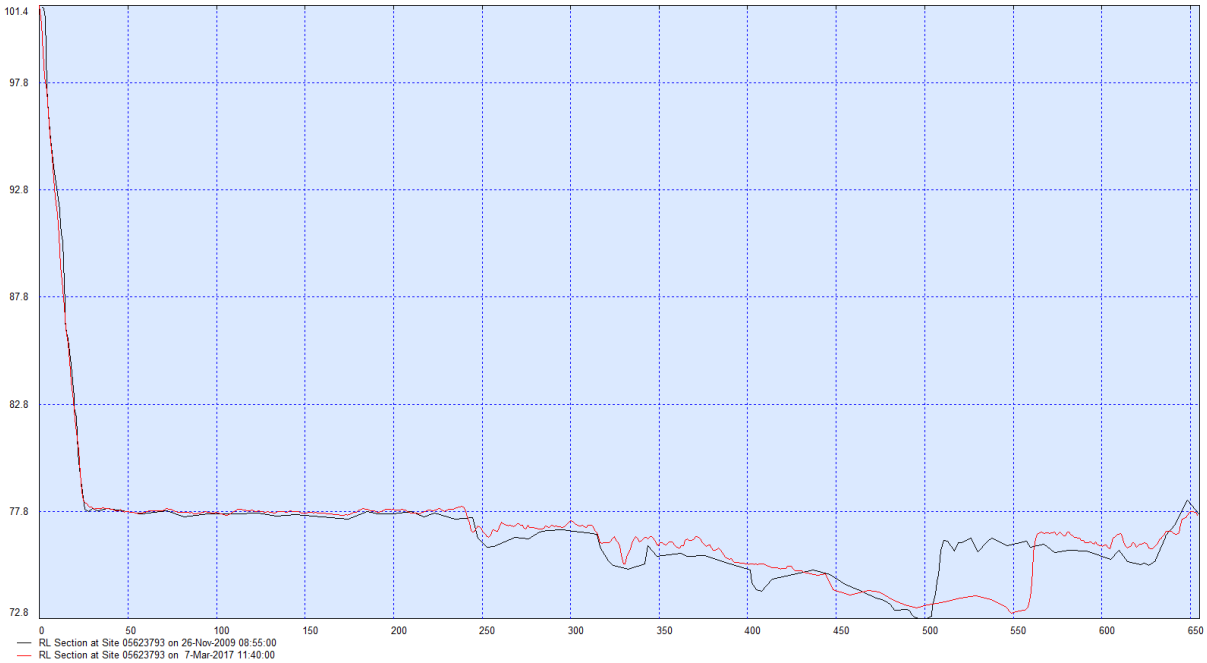
RL Section at Site 05623738 on 7-Mar-2017 11:30:00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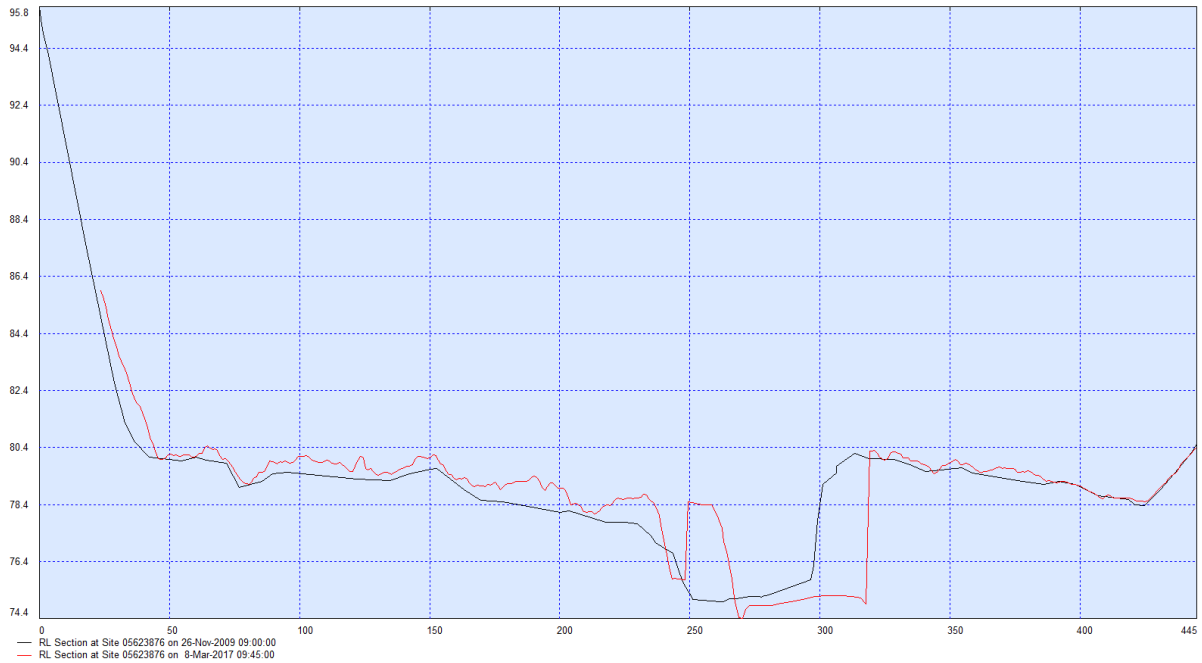
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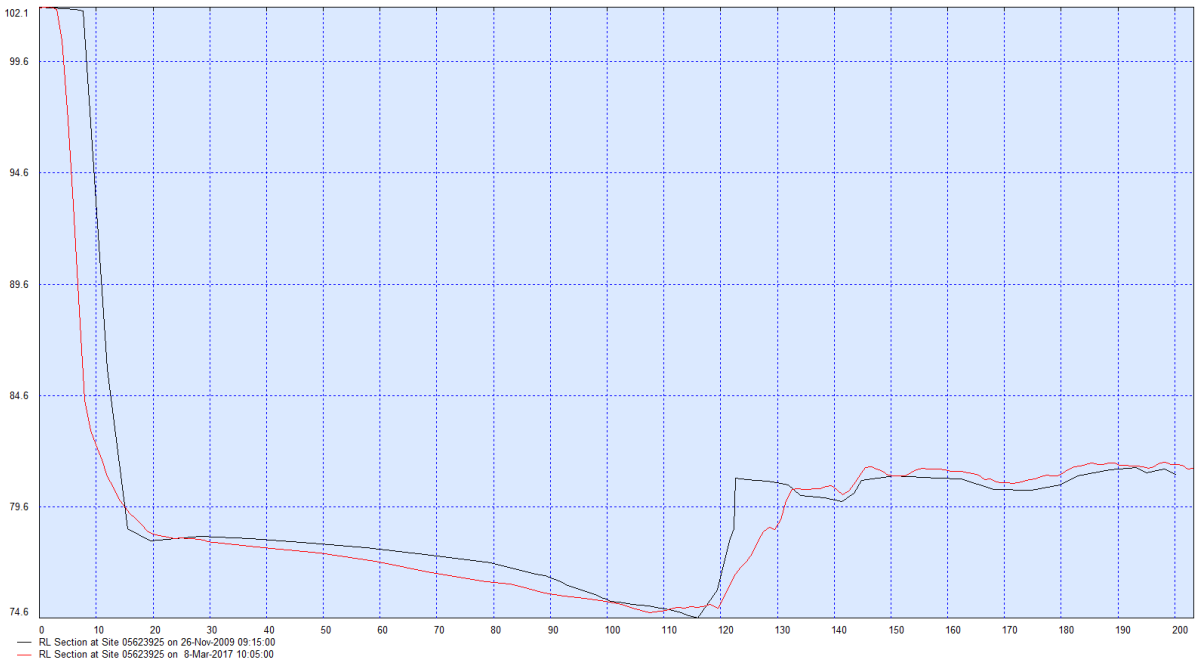
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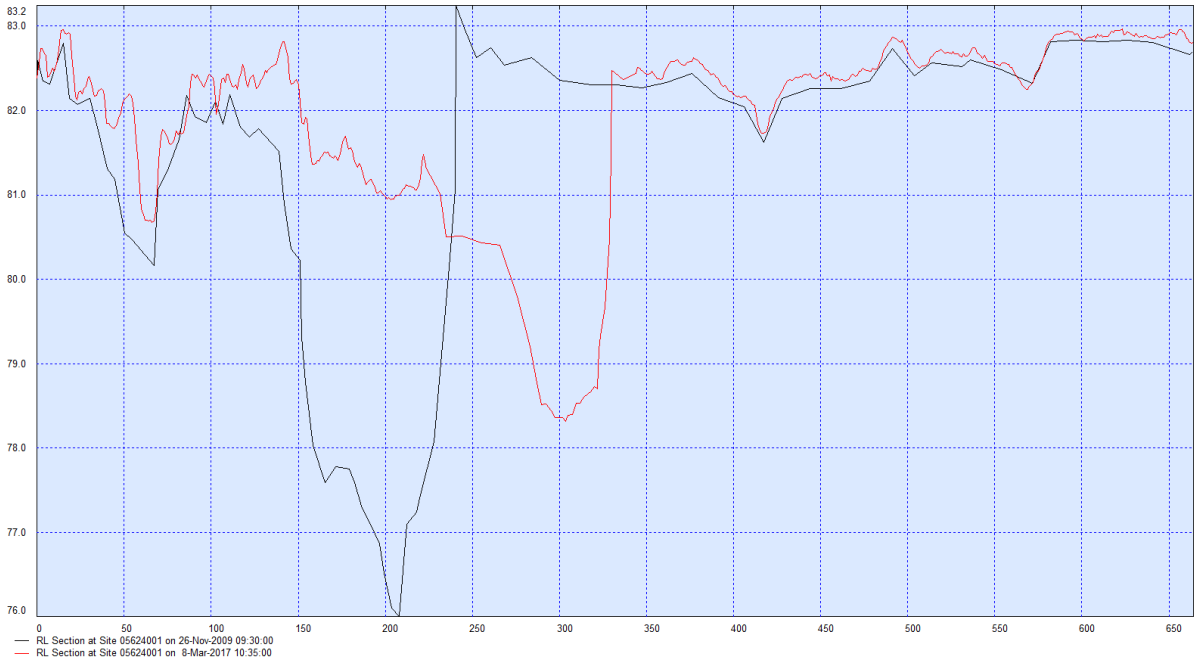
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RL Section at Site 05624001 on 8-Mar-2017 10:35:00


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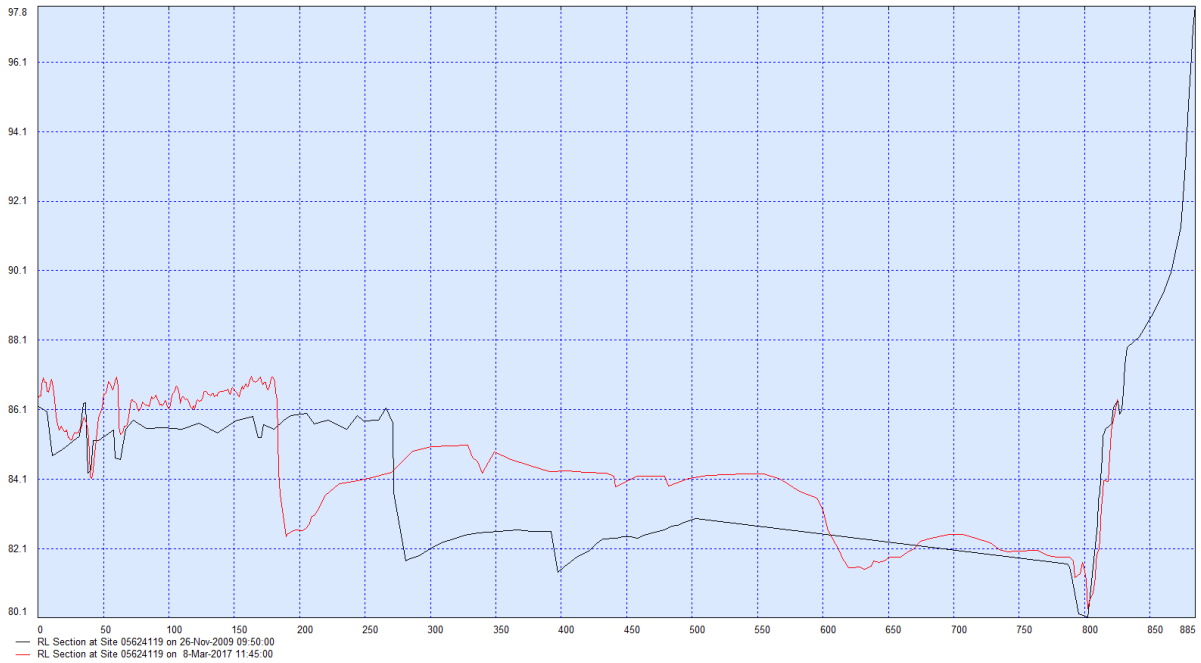
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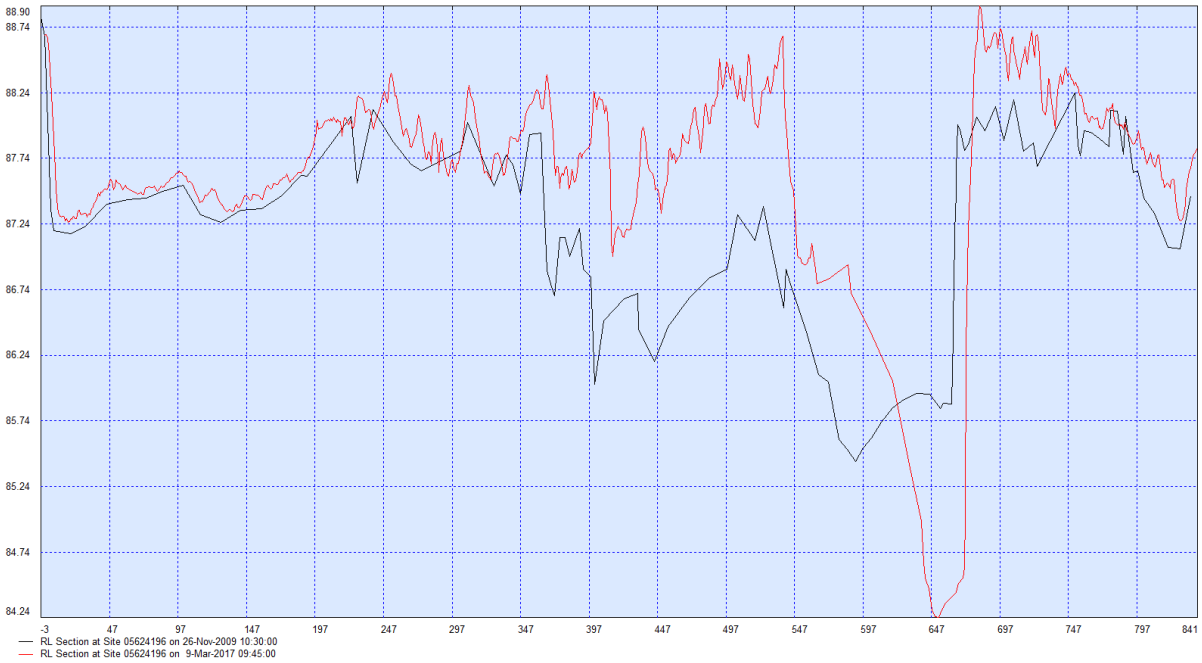
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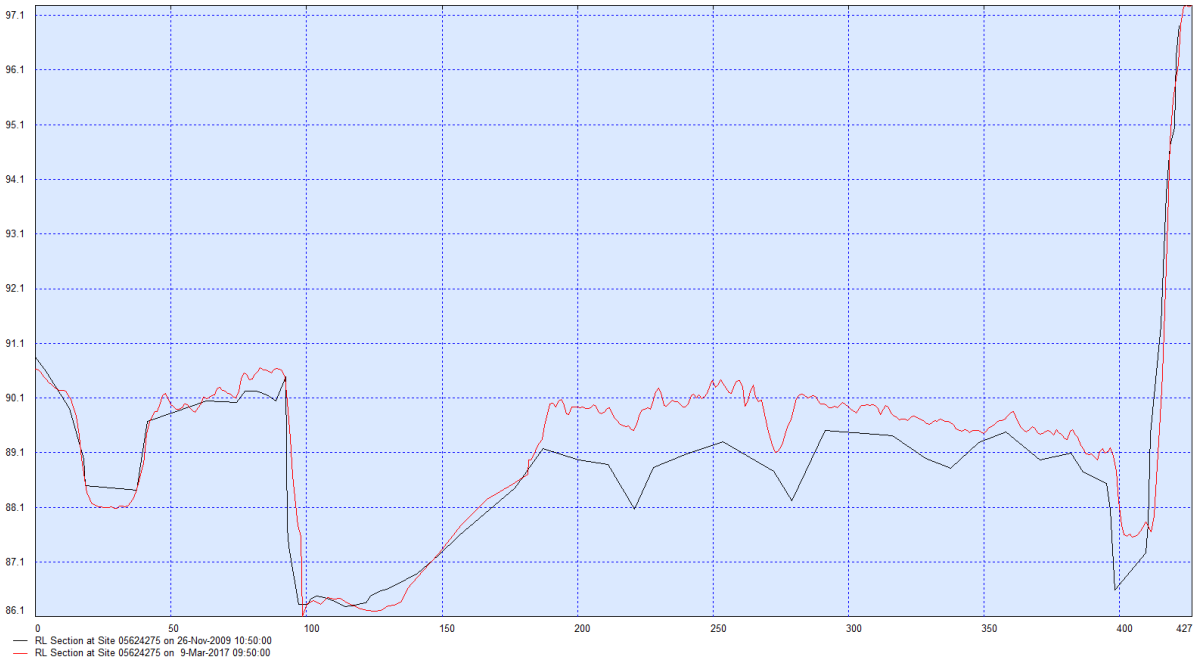
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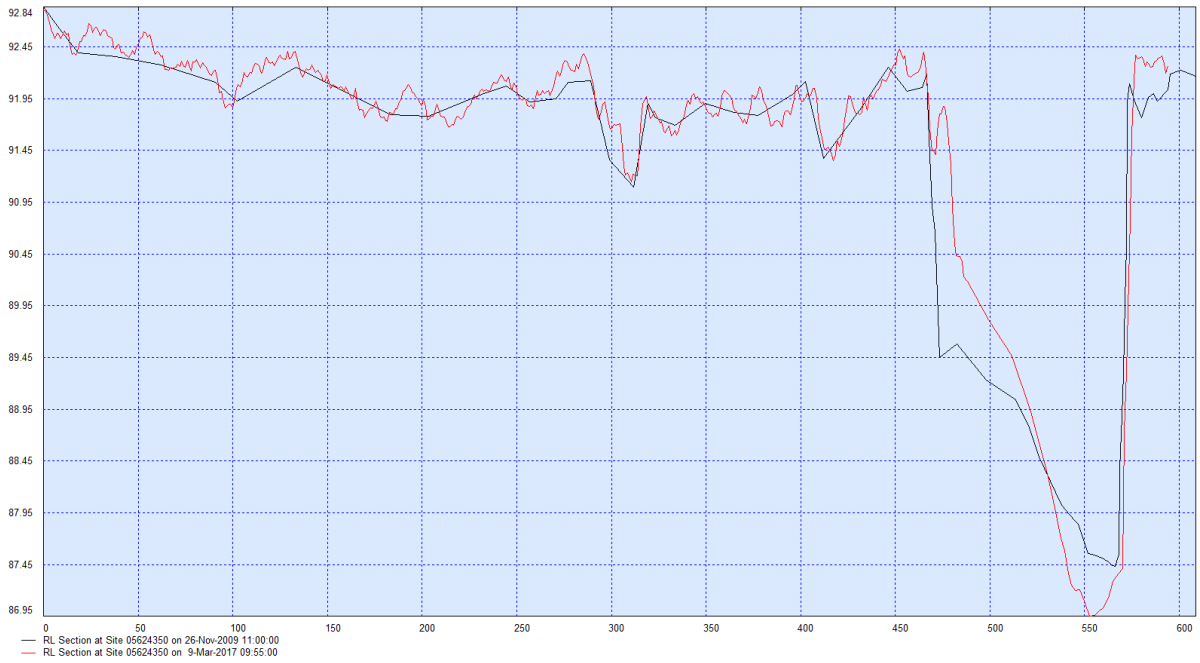
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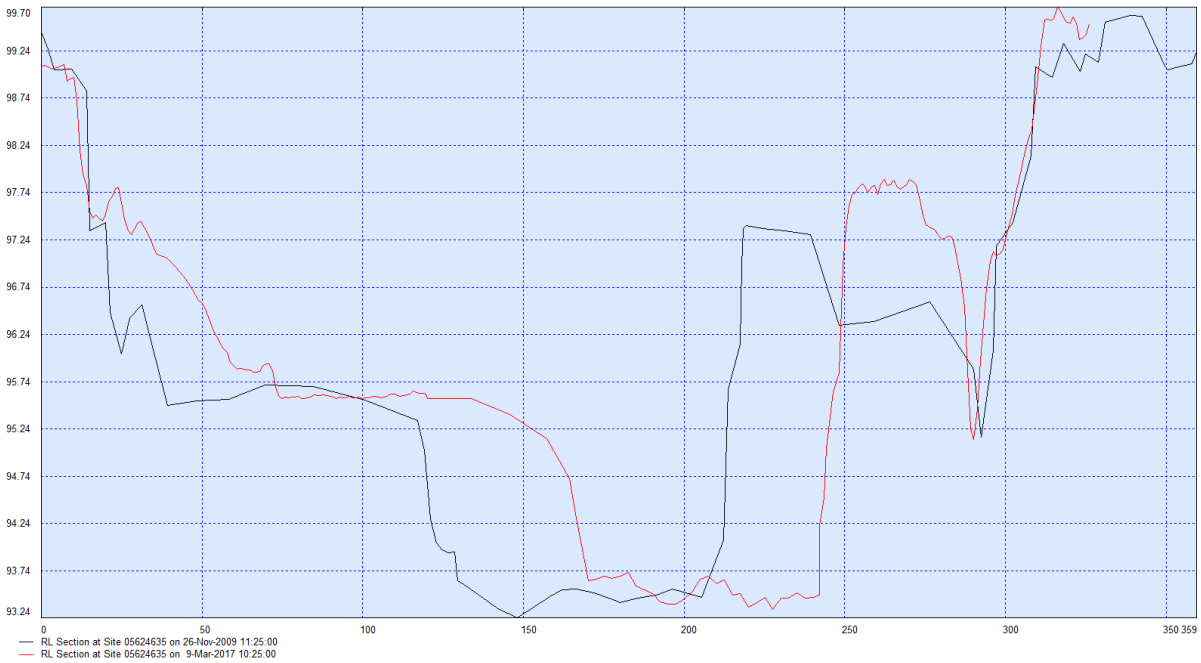
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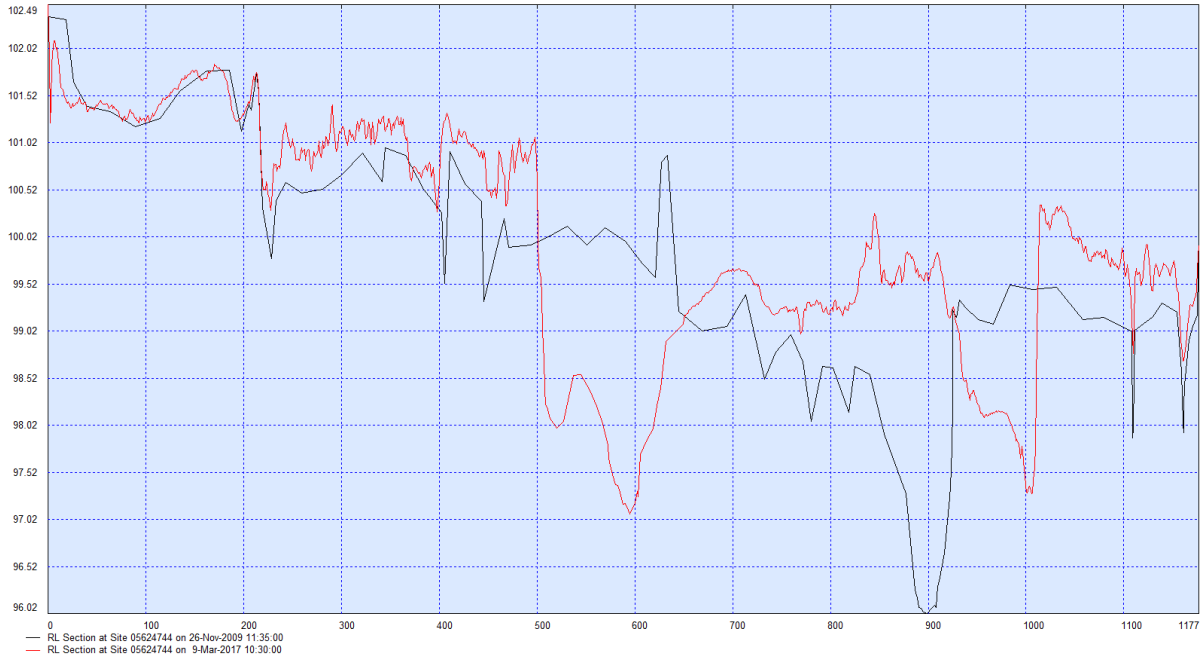
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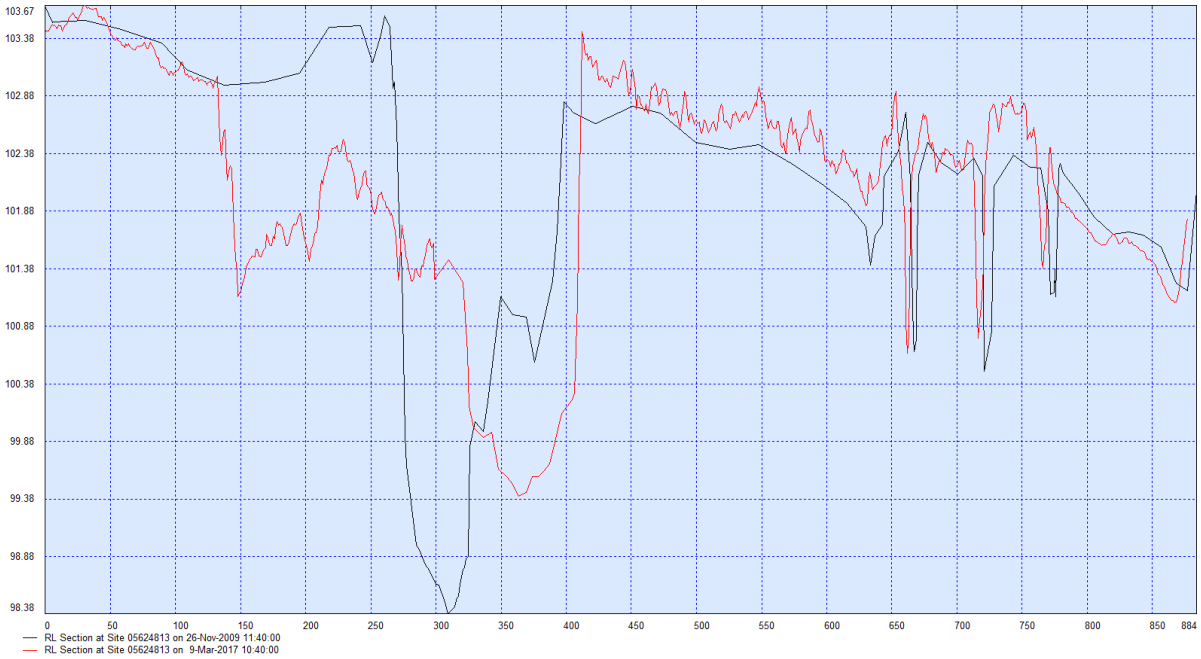
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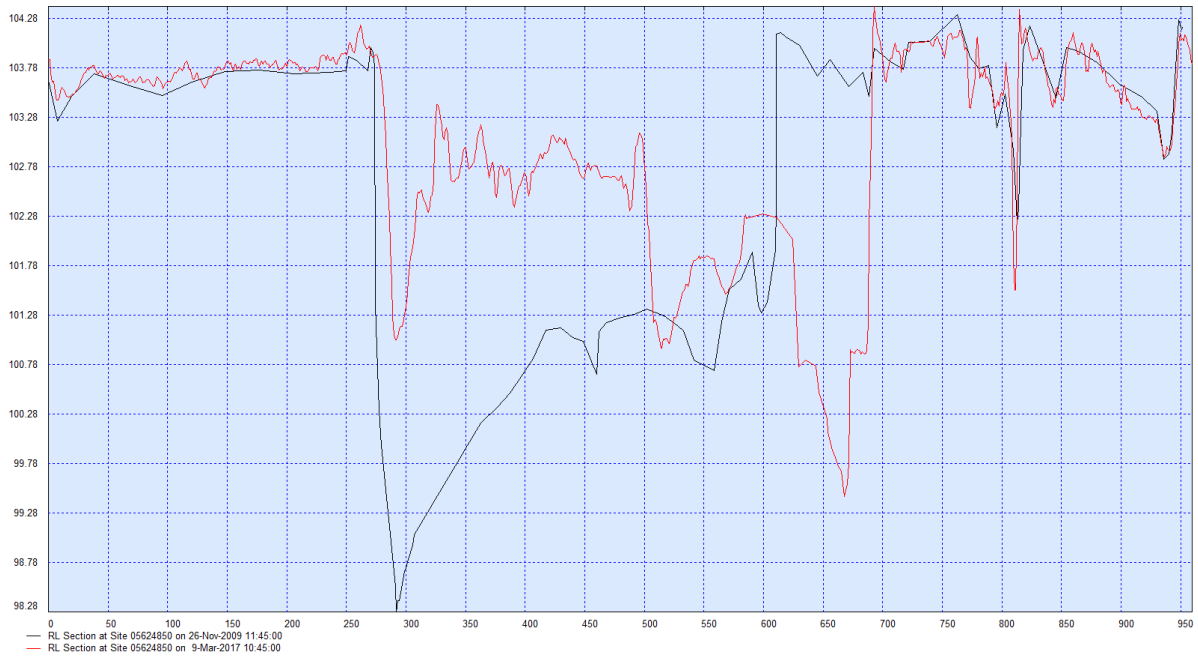
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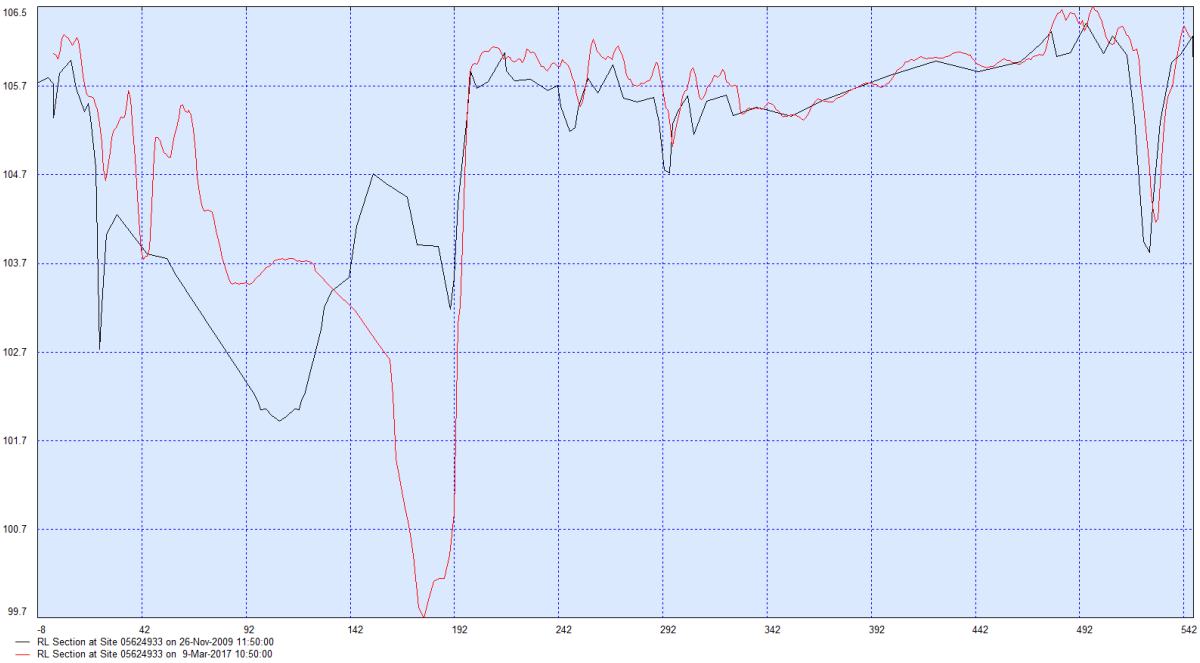
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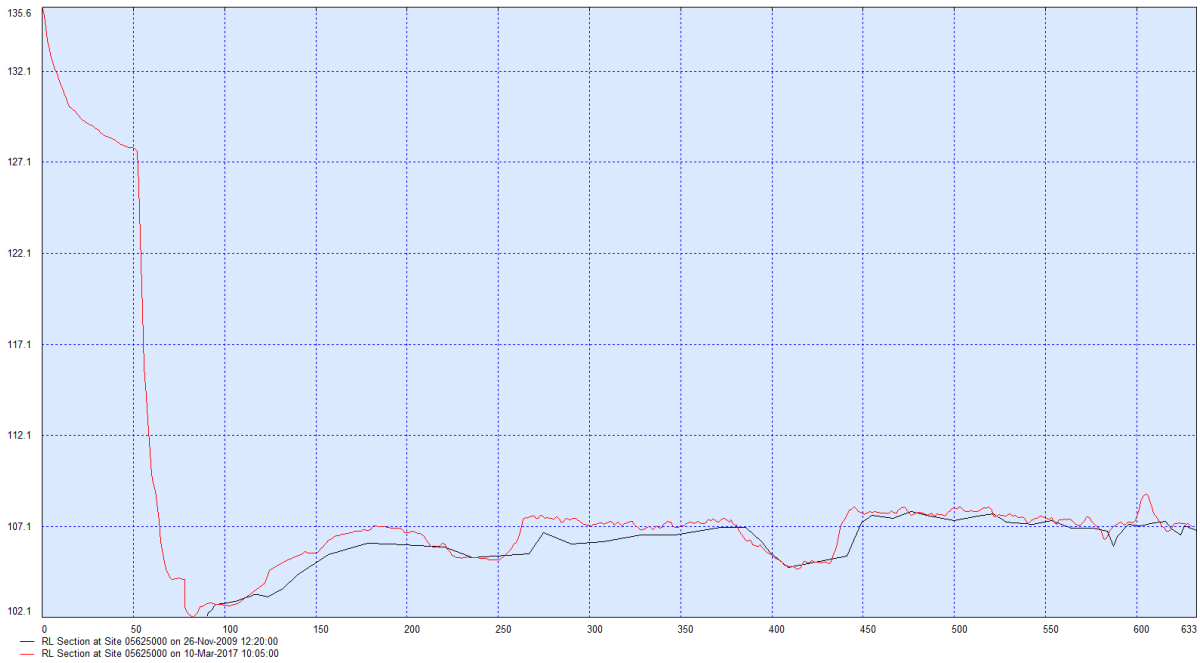
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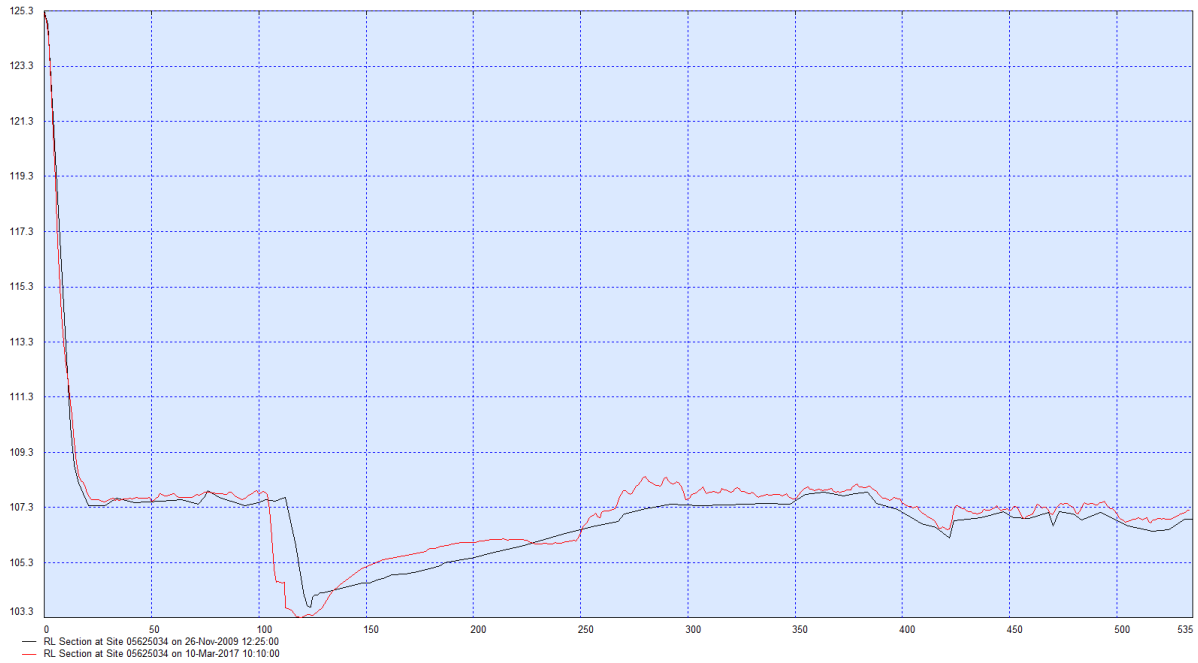
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RL Section at Site 05625034 on 26-Nov-2009 12:25:00
RL Section at Site 05625034 on 10-Mar-2017 10:10:00


111.9
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107.6
106.6
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104.6
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567
RL Section at Site 05625092 on 26-Nov-2009 12:40:00
RL Section at Site 05625092 on 10-Mar-2017 10:15:00


113.8
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108.0
107.0
106.0
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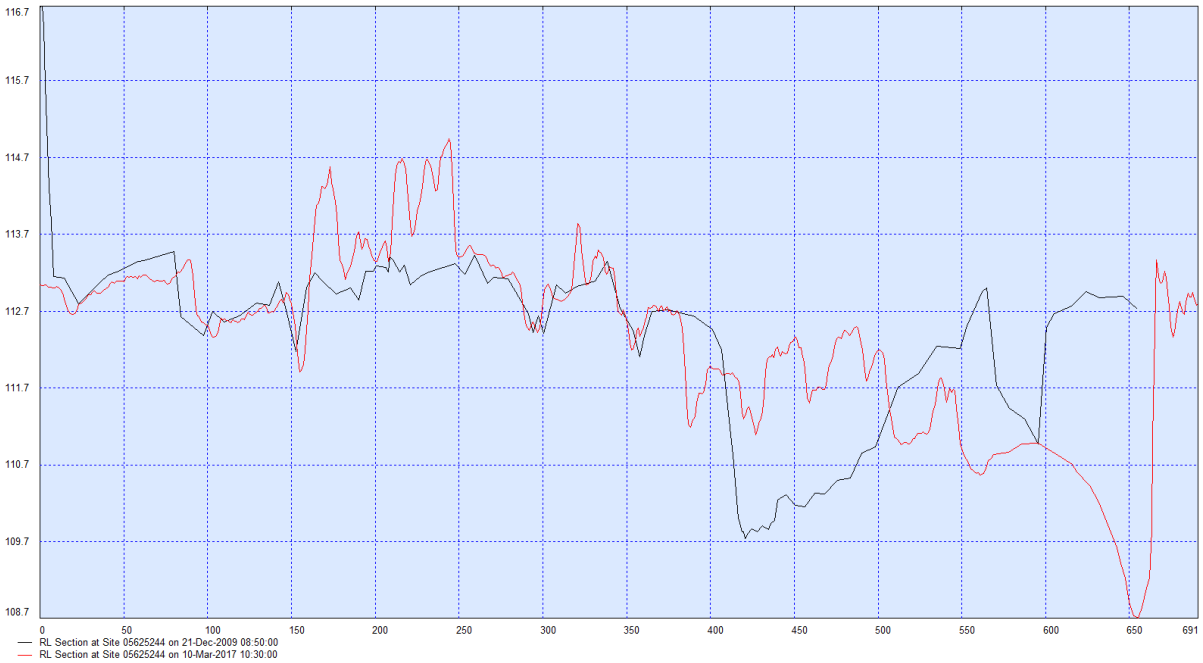
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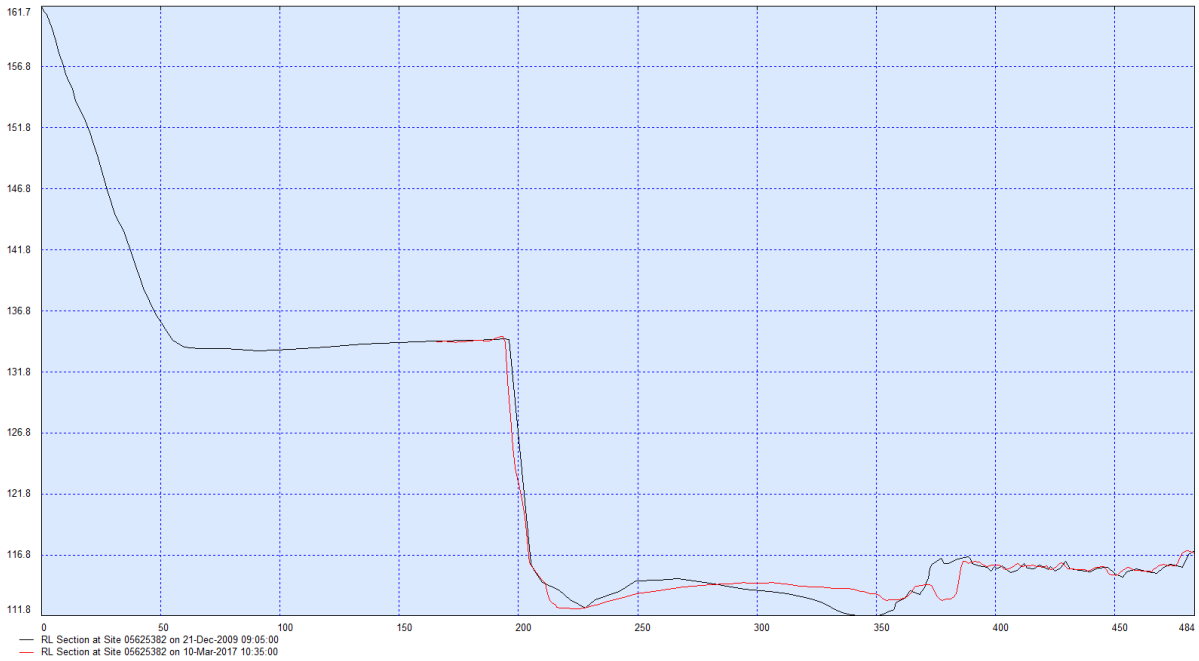
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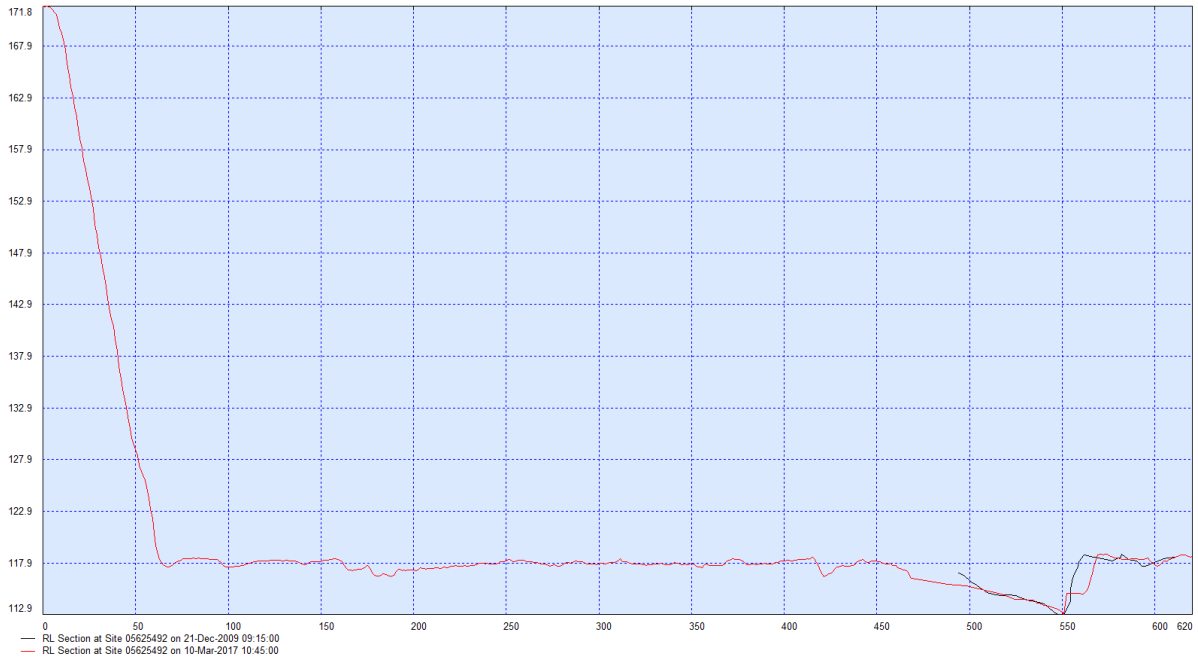
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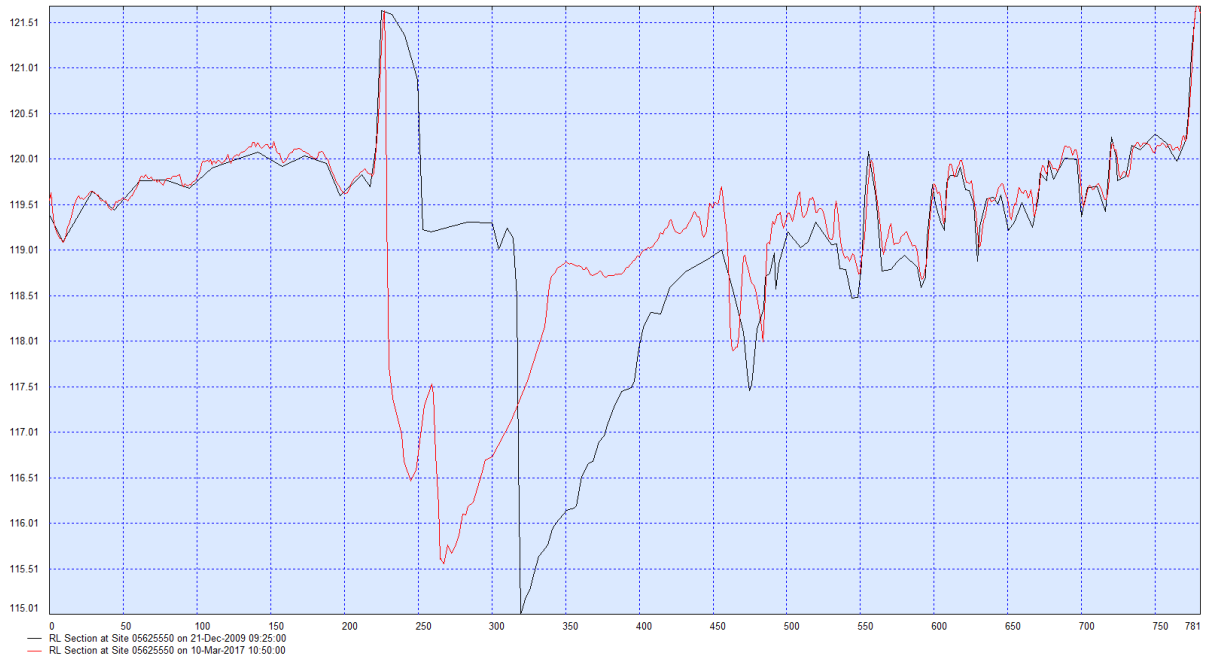
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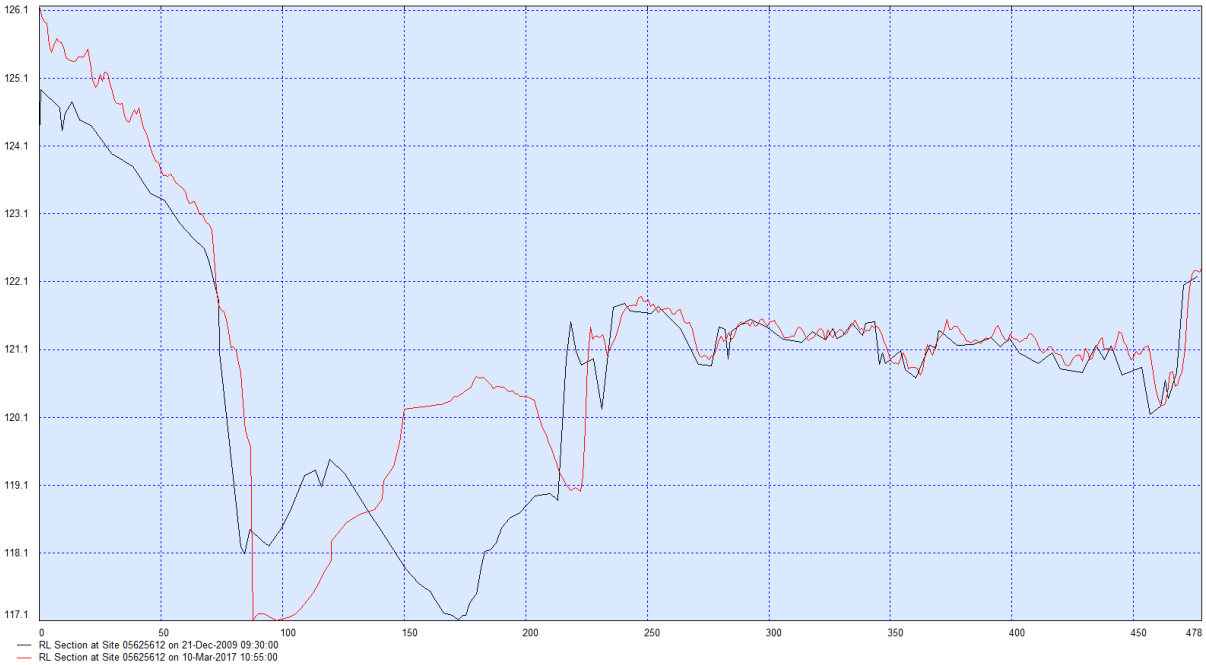
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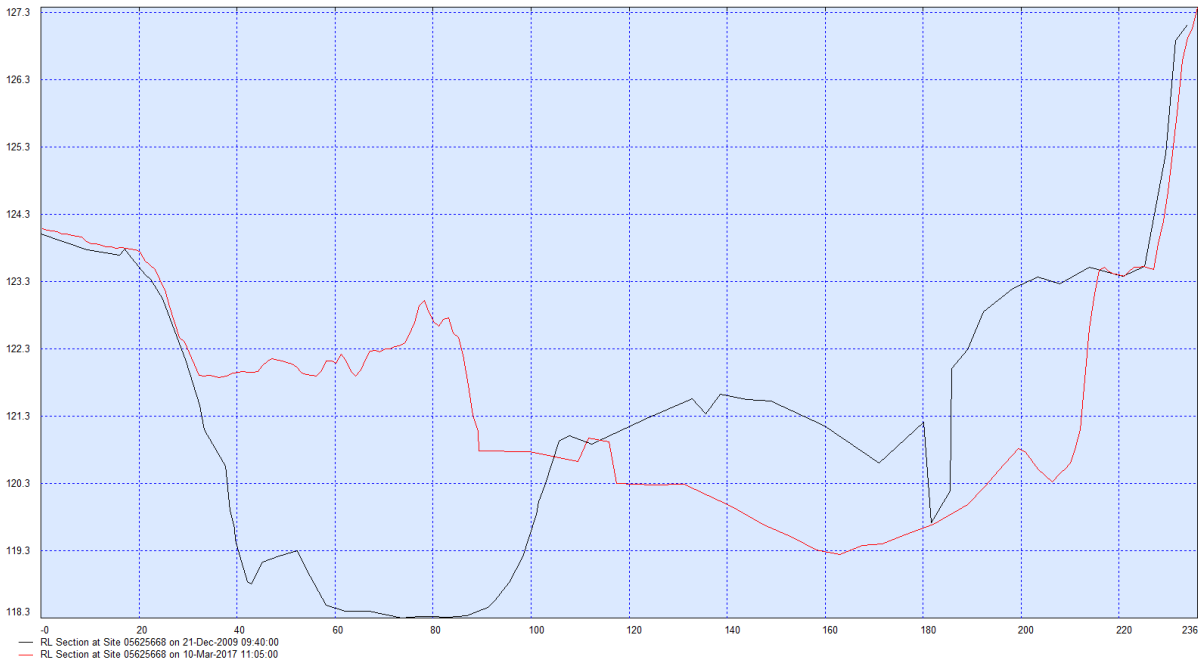
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236
RL Section at Site 05625668 on 21-Dec-2009 09:40:00
RL Section at Site 05625668 on 10-Mar-2017 11:05:00


125.96
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124.96
124.46
123.96
123.46
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122.46
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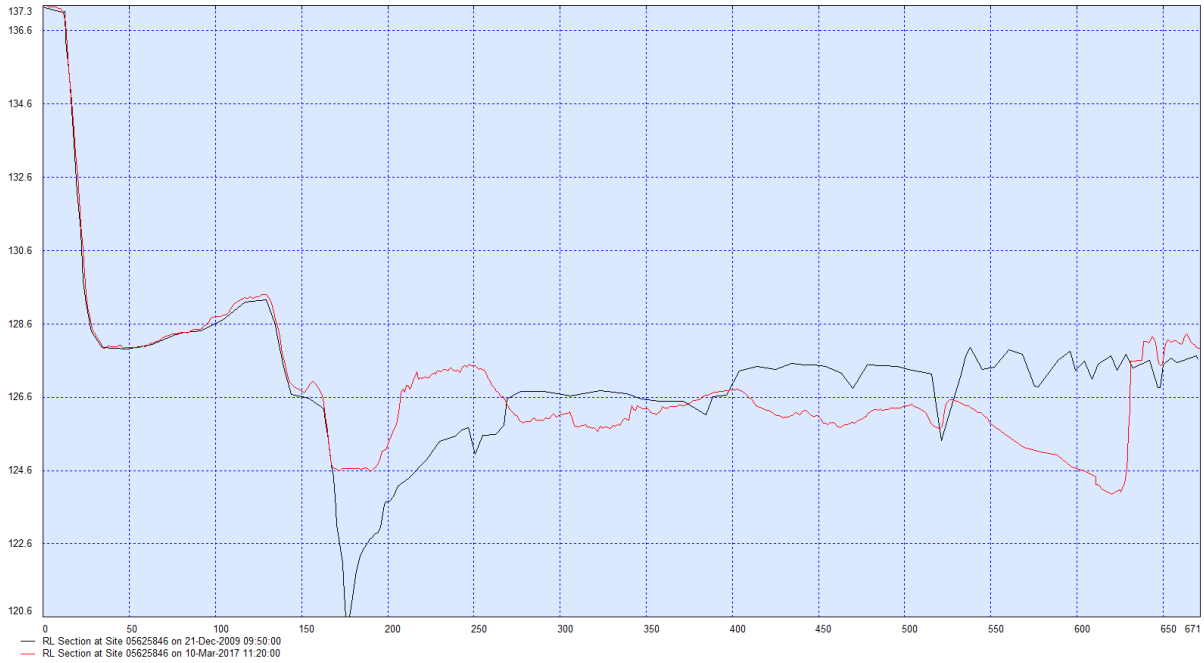
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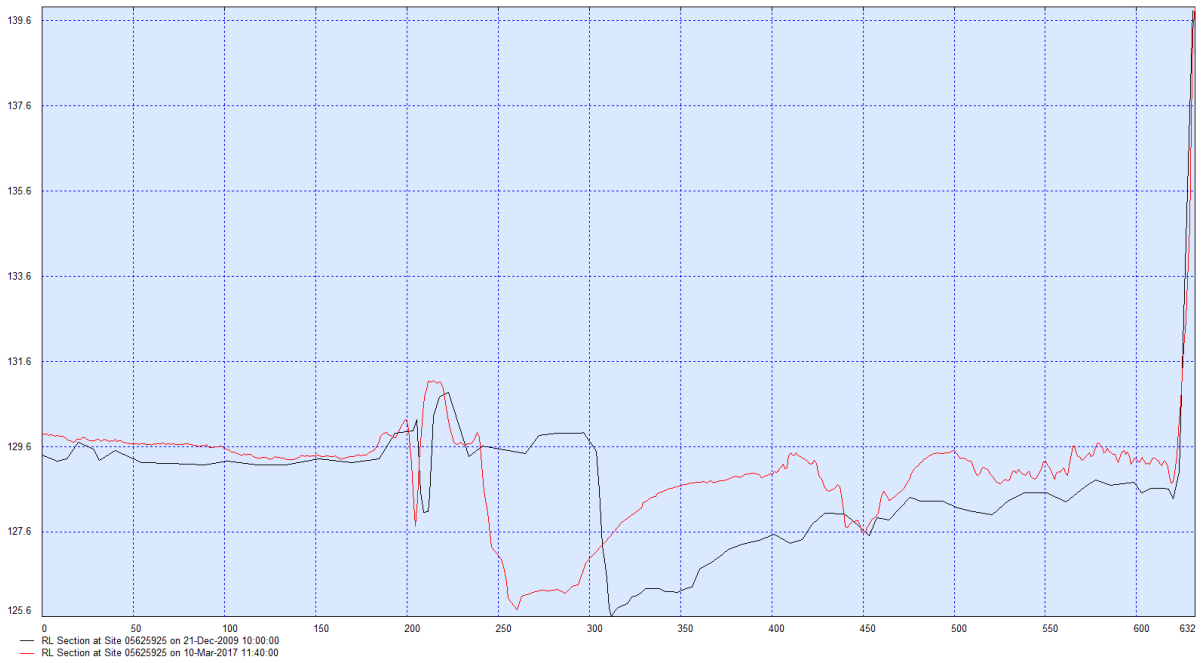
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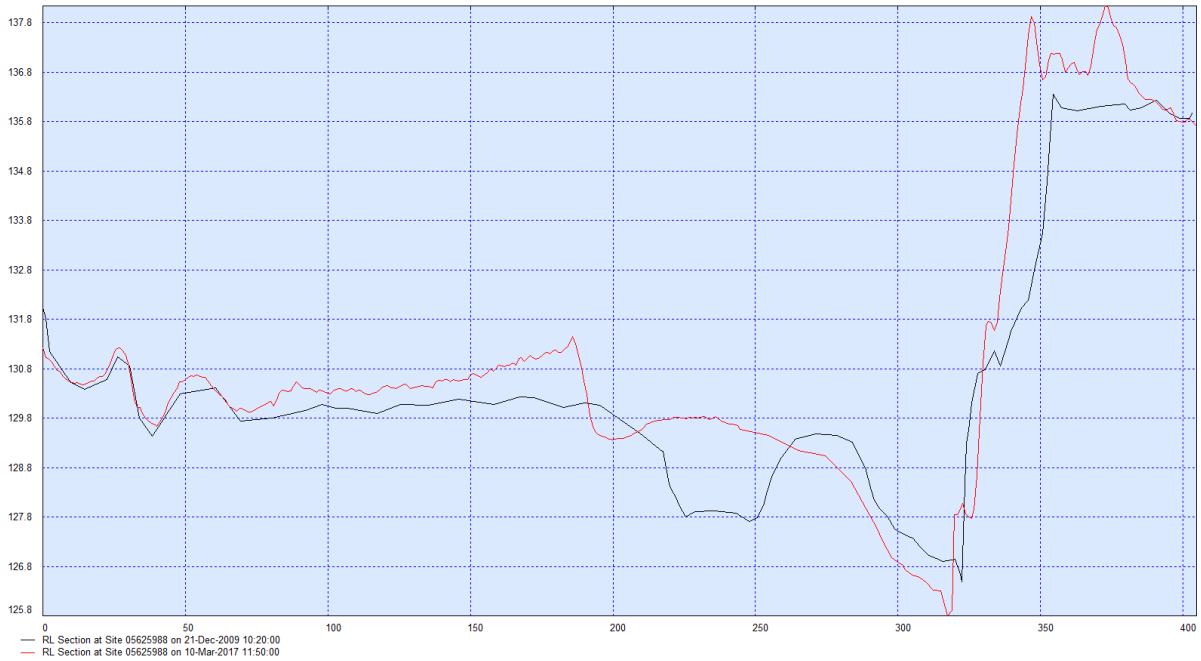
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RL Section at Site 05625988 on 21-Dec-2009 10:20:00
RL Section at Site 05625988 on 10-Mar-2017 11:50:00


139.5
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RL Section at Site 05626046 on 21-Dec-2009 10:30:00
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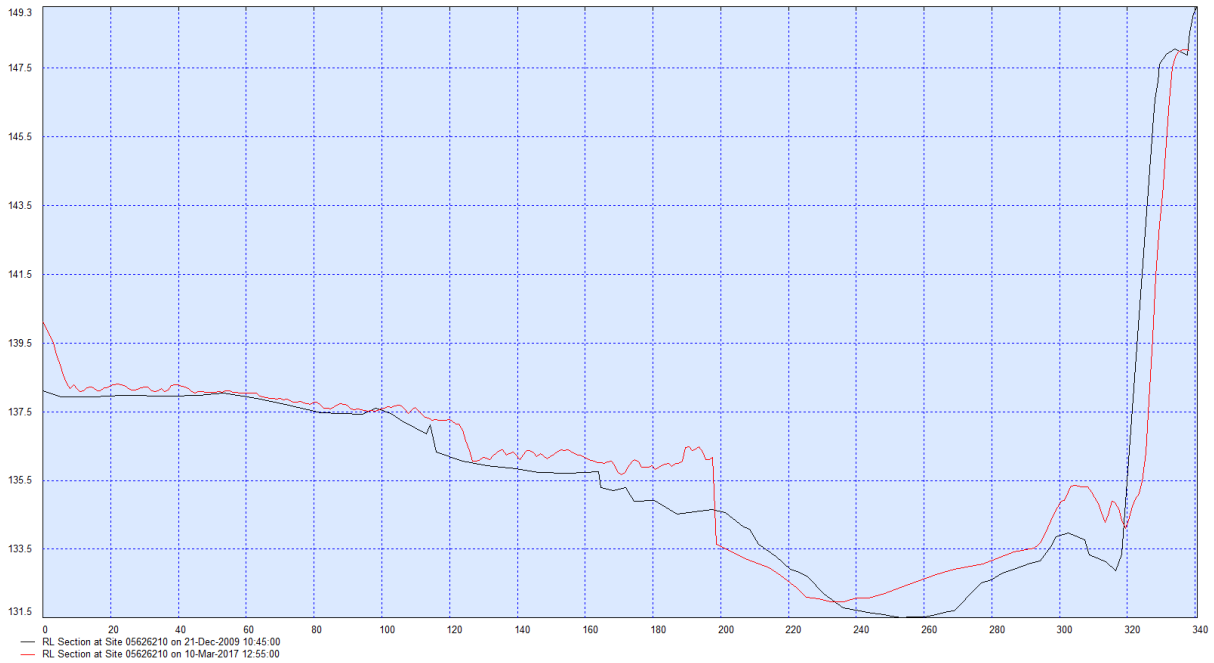
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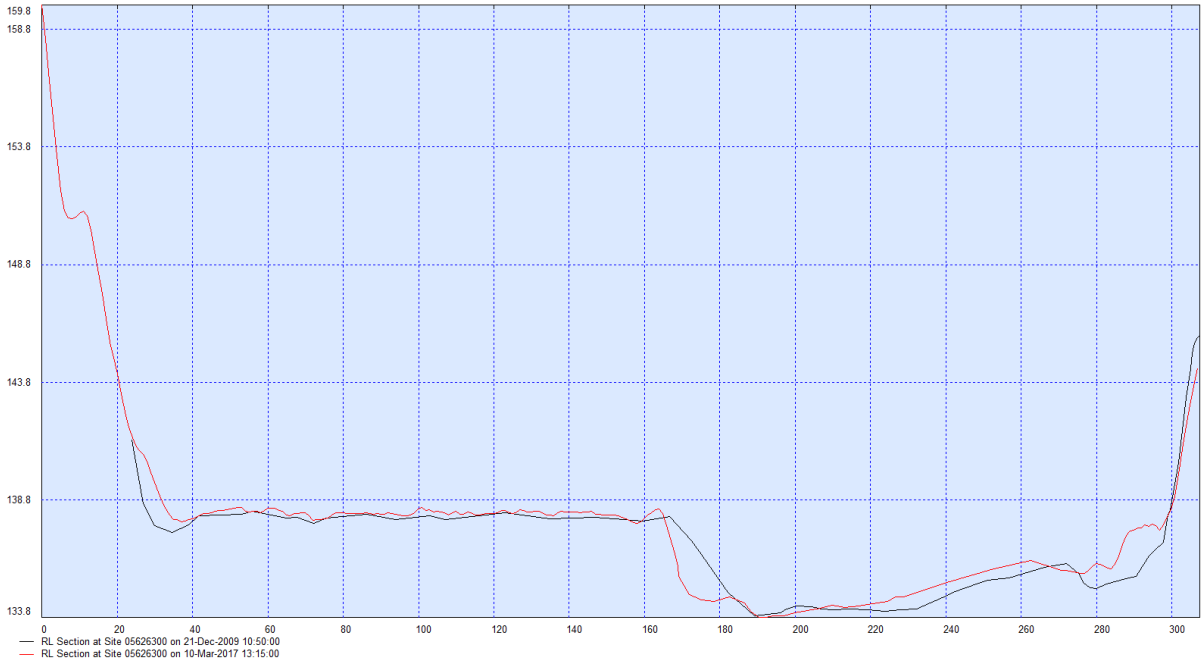
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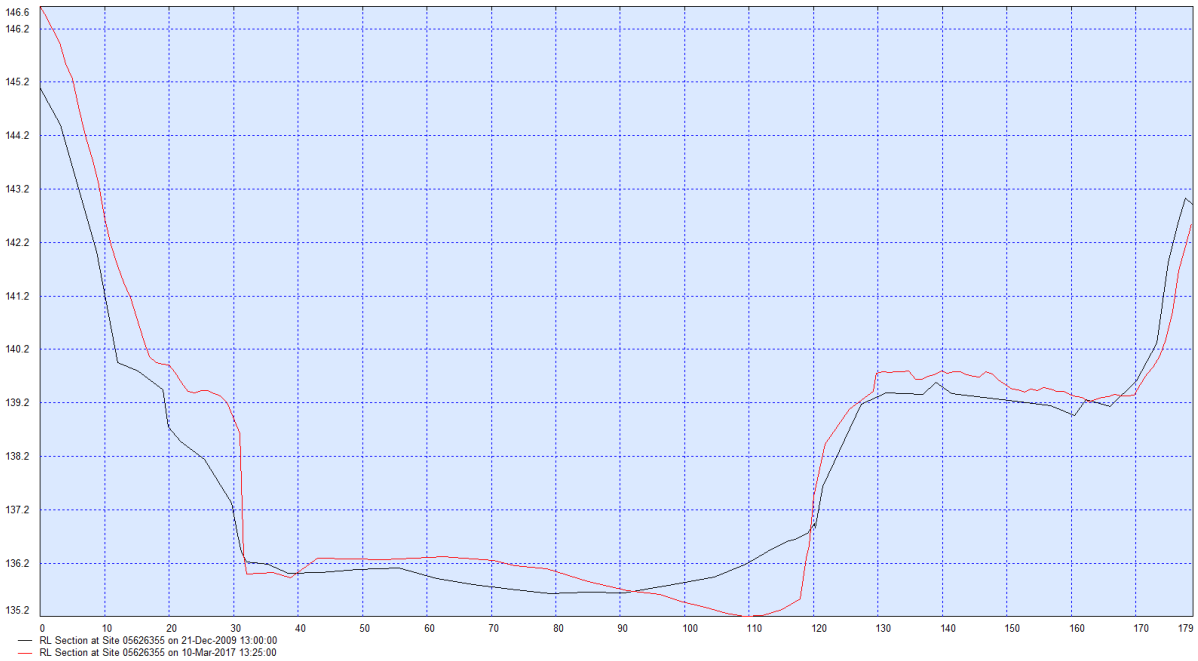
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179
RL Section at Site 05626355 on 21-Dec-2009 13:00:00
RL Section at Site 05626355 on 10-Mar-2017 13:25:00