Ōroua River
Gravel Resource Study

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EXECUTIVE SUMMARY

This study examines the gravel resource and silt phase of the Ōroua River, based on an analysis of river cross section survey data.

The Ōroua River has been divided into a gravel reach and a silt phase of the river. The gravel reach is defined from a point around 1.2 km upstream of the Kiwitea Stream confluence to just below the Kopane Bridge, while the silt phase begins just below the Kopane Bridge and continues to the confluence with the Manawatū River at Rangiotu.

The analysis in this report indicates that the gravel volume displayed an overall trend of aggradation across the majority of the reach, as instances of degradation are noticeably limited. It has been found that the trend of degradation noticed within the gravel reach, by the 2012 gravel study, has reversed and aggradation of the gravel resource is occurring from just below Kopane Bridge to a point upstream of the Kiwitea Stream confluence.

In terms of the silt phase of the river, it has been found that significant aggradation of sediment has occurred. From just below the Kopane Bridge to the Manawatū River confluence it was found that sedimentation between the toes of the stopbanks has occurred at a rate of approximately 47,150 cubic metres per annum. Throughout the silt phase of the river the general trend is that the berm land is aggrading and the river channel is narrowing.

When gravel extraction is considered for the Ōroua River, it was observed that similar rates of extraction have occurred in both reaches one and two of the One Plan. Reach one is located upstream of Menzies Ford and reach two is located downstream of Menzies Ford. Currently as at 2019, reach one is over allocated. However, there is no survey information available for reach one so it is not known how the gravel resource has been affected, and whether the current allocation is sustainable. Since there is no survey information for this reach it was concluded to be out of the scope of this study.

From the analysis, it was concluded that the annual allocable volume for reach two of the One Plan is not appropriate and should be revised. Overall, the gravel reach of reach two is aggrading, however it was observed that it is not aggrading at the rate needed to sustain the allowable extraction rate within the One Plan.

Overall, it is recommended that the annual allocable volume in the One Plan for reach two should be revised to sustain future gravel extraction. It is also suggested that mitigation measures need to be considered and implemented in the Ōroua River catchment as it is continuing to aggrade at a substantial rate. It is also recommended that the Ōroua River survey extent should be increased to understand how the gravel resource is being affected in reach one and the rest of reach two of the One Plan. The Ōroua River should be resurveyed in the 2020 to 2021 season to see if these trends continue to occur.

CONTENTS

Ōroua River Gravel Resource Study

1. Introduction

This study examines the gravel resource, and silt phase of the Ōroua River. In this study, the Ōroua River gravel reach is from the 43.5 km benchmark, just above the confluence with the Kiwitea Stream, to the 24.32 km benchmark, which is located just below Kopane Bridge. The silt phase of the river is considered to be from the 24.32 km benchmark located just below Kopane Bridge, to the 0 km benchmark located at the confluence with the Manawatū River. This study is based on the analysis of river cross section survey information. The locations of the cross sectional surveys are shown on the aerial photograph in Figure 1 below and in Appendix A. This study focuses on the period from 2011-12 to 2016, since the completion of the previous gravel resource study in 2012.

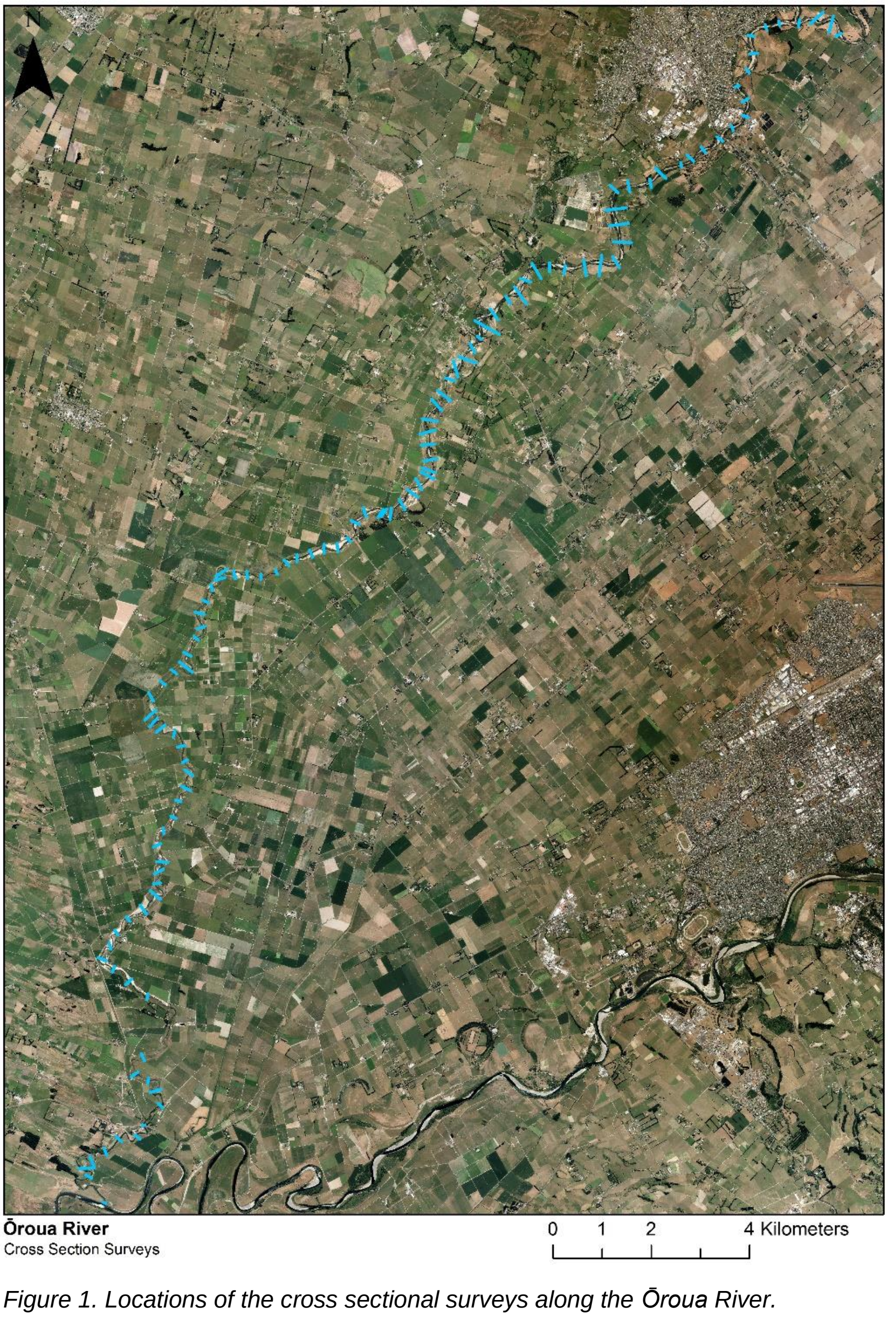


Figure 1. Locations of the cross sectional surveys along the Ōroua River.

2. The Ōroua River

The Ōroua River is situated in the south west of the North Island, and is a tributary to the Manawatū River, the river has a length of around 141 kilometres, and a catchment area of an estimated 910 square kilometres, seen below in Figure 2. The headwaters of the river are located in the western Ruahine Ranges, from here the river flows south west through Feilding and eventually joins the Manawatū River at Rangiotu between Palmerston North and Shannon.

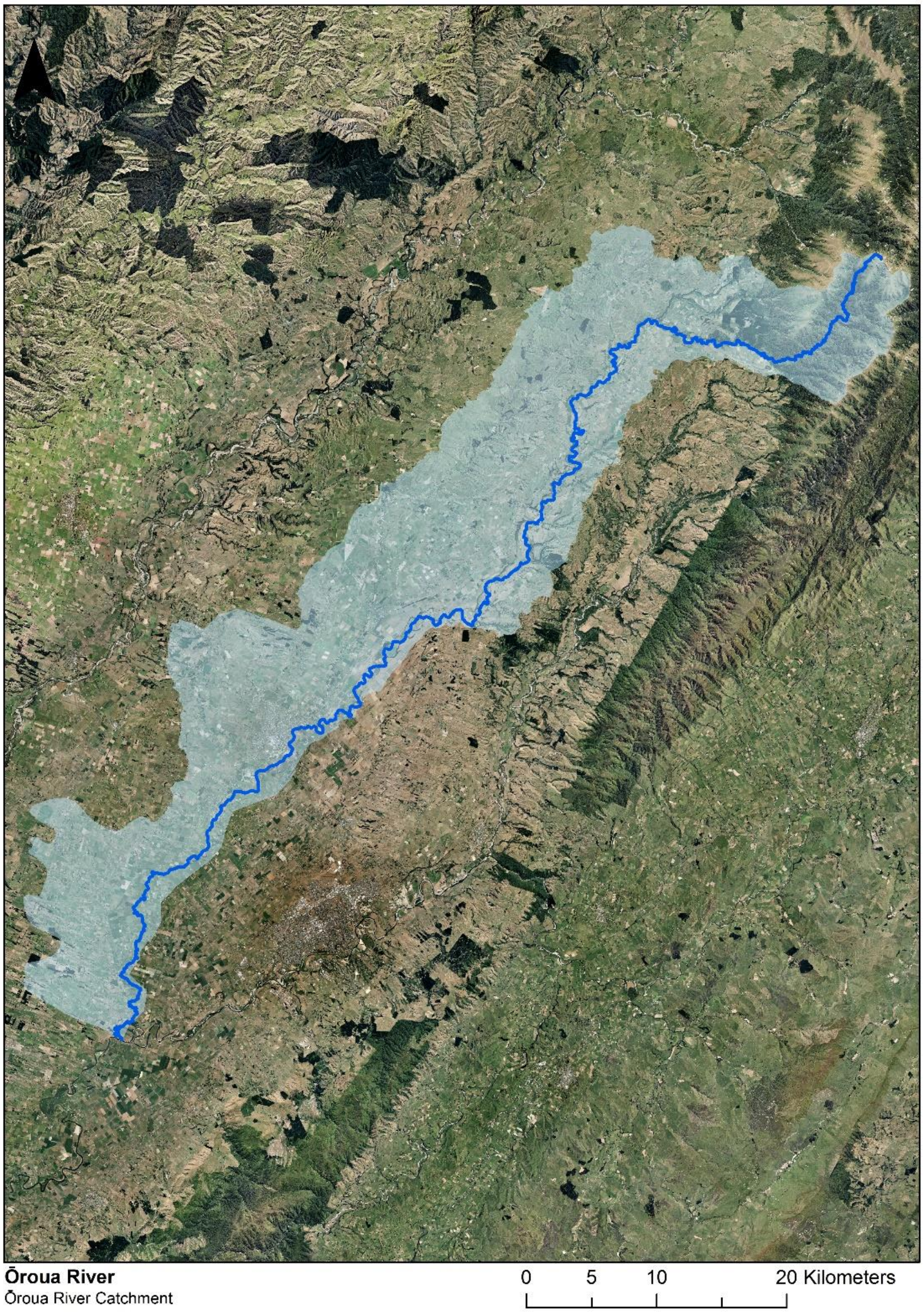


Figure 2. The Ōroua River catchment displaying the Ōroua River.

For the purpose of this study two sections of the Ōroua River are to be assessed, the gravel reach and silt phase. The gravel reach begins at the 43.5 km benchmark upstream of the Kiwitea Stream confluence with the Ōroua River, and continues to the 24.32 km benchmark located just below the Kopane Bridge. While the silt phase begins at the 24.32 km benchmark and continues to the 0 km benchmark located at the Ōroua River – Manawatū River confluence.

The gravel reach of the Ōroua River technically begins a lot further upstream in the Ruahine Ranges, but for the purpose of this study, the gravel reach begins at the 43.5 km benchmark which is about 1.2 km upstream of the Kiwitea Stream confluence with the Ōroua River, as this is the extent of the available cross section survey information. It is not known why the Ōroua cross section surveys largely stop at this location and don't continue further upstream along the rest of the gravel reach.

The silt phase of the Ōroua River begins around the 24.32 km benchmark located just below the Kopane Bridge. This benchmark represents the end of the gravel reach of the Ōroua River, as around Kopane Bridge there is a transition in the bed material. This transition is attributed to the fact that there is a change in the gradient around this location, where gradient decreases and flattens out, which would also lead to a change in the hydraulic characteristics of the river. At this location, there is also a change in the bed material, where the bed material changes from being dominantly gravel to increasing in fines, which represents the transition into the silt phase of the Ōroua River, which extends all the way to the confluence with the Manawatū River.

2.1 2012 Ōroua River Gravel Resource Study

The 2012 Gravel Resource Study concluded the following:

- The volume under the active channel shows aggradation had occurred in the lower half of the reach, below Kaimatarau Road to the Manawatū confluence.
- The main finding of the 2012 study is that there had been a general trend of degradation of the volume of gravel in the upper half of the reach from Kaimatarau Road to a point just upstream of the confluence with the Kiwitea Stream.
- The 2012 study found, that there was approximately 900,000 cubic metres more material beneath the active channel than there was in 1998, the material is thought to have consisted of a higher proportion of fine sediment.
- This study found that it was particularly important to monitor the levels of aggradation in the lower half of the reach, below Kaimatarau Road, as a continuation in this trend could lead to a loss of flood carrying capacity in the river channel.

3. Cross Section Survey Data

Cross sections of the Ōroua River have been surveyed at various times by Horizons Regional Council and its predecessors. These surveys have been undertaken for a variety of reasons including the design of flood protection and other infrastructure, as well as to inform the management of the river and its gravel resource.

Historically, the Ōroua River from the 43.5 km benchmark to the 0 km benchmark has been frequently surveyed. This section of the Ōroua River includes the gravel reach and silt phase of the river. Gravel extraction has necessitated the need to understand how these works have affected the physical characteristics of the river. Over the recent years, the surveying of the river has formed part of the fluvial programme and has been funded through the levies associated with gravel extraction consents.

In 2018, Horizons' Infrastructure Strategy 2018 to 2048 identified "sedimentation effects on levels of service" as a significant issue in regards to the management of Council's flood protection assets. With this in mind, the surveyed section of the Ōroua River has been broken into the gravel reach and silt phase, as it is recognised the effects of sedimentation need to be investigated.

This study is based on the analysis of cross section survey data collected in 2012 and again in 2016, the locations of which can be seen in Figure 1, and Appendix A.

4. Analysis of Cross Section Survey Data

To assess the change in the gravel resource of the Ōroua River, the change in the volume of gravel within the active channel has been calculated, as well as the change in the mean bed level. Analysing these two factors also provides a further understanding of the geomorphology of the river and how this may have changed over time.

This study defines the active channel as the area that includes the wetted channel and the gravel beaches, which are generally located above the water level. This can be seen below in Figure 4.1, as well as how the mean bed level is defined. The analysis of the gravel resource and mean bed level will produce a clearer picture of what state the gravel resource of the Ōroua River is in, and whether there are any obvious trends of aggradation and degradation.

When considering the silt phase of the Ōroua River, the change in the volume of sediment has been calculated, as well as the change in mean bed level. This study assesses the sediment volume between the right bank toe and left bank toe of the stopbanks however, when the toes were not available the furthest extents of the left and right offsets were used, which can be seen in Figure 4.2, below. This extent helps to give an idea of how the overall sediment volume is being affected in the river. The analysis of the change in sediment volumes can help to quantify any aggradation or degradation of the river channel and berms that may be occurring. In terms of the Ōroua River, changes in sediment volume may indicate that the flood carrying capacity of the river may be changing.

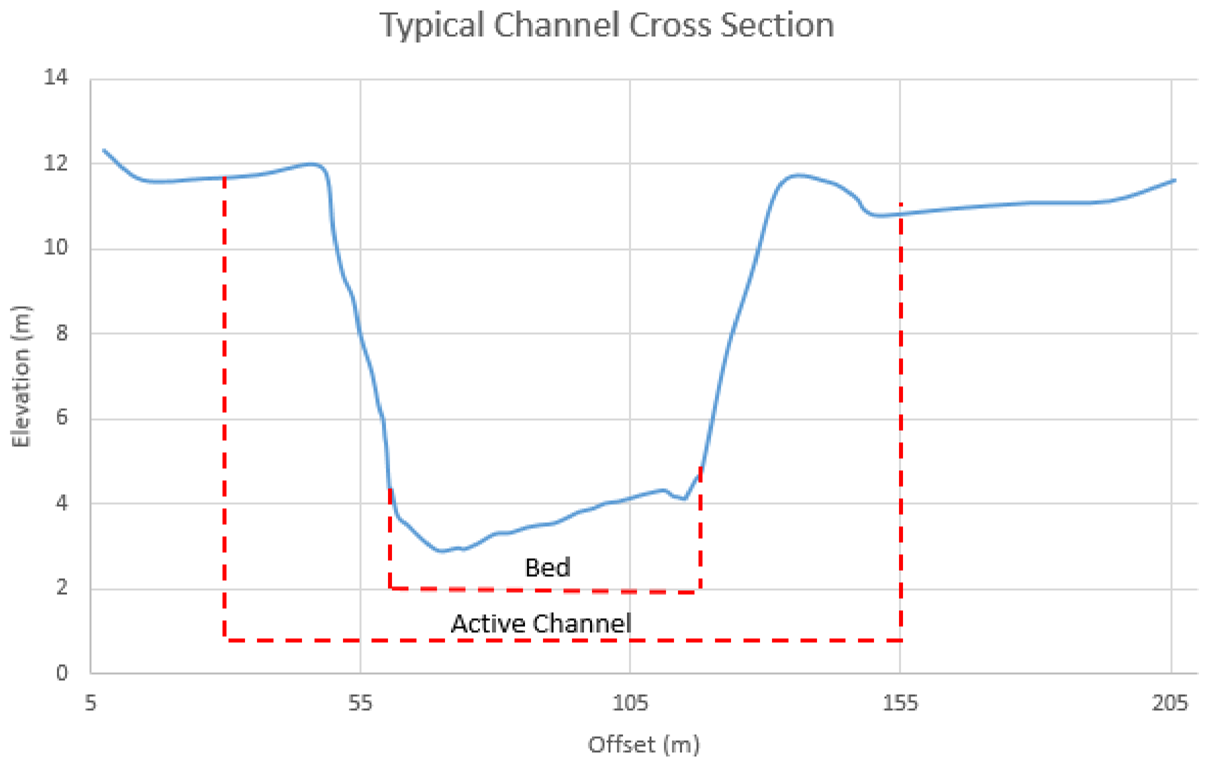


Figure 4.1. Typical channel cross section.

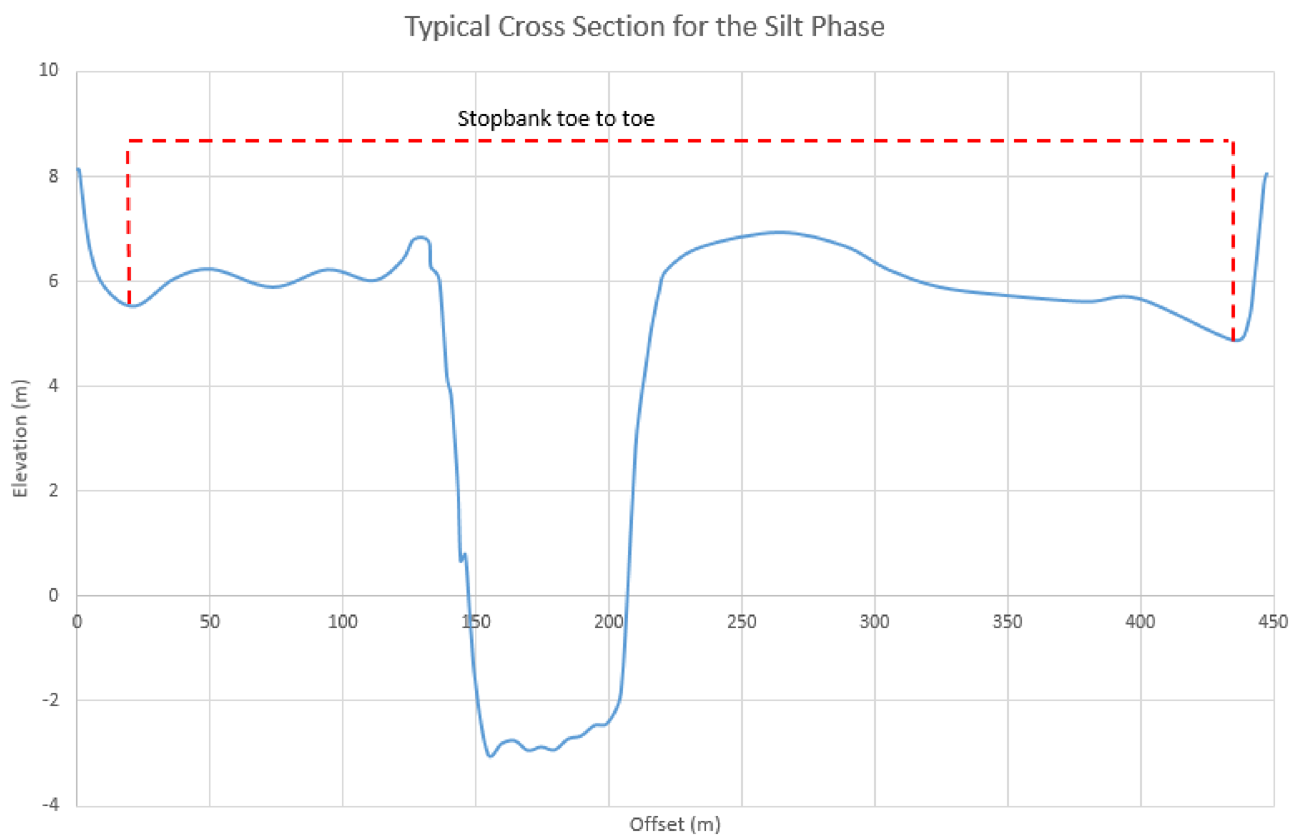


Figure 4.2. Typical cross section for the silt phase.

4.1 Gravel Resource

For this study, an individual analysis of each cross section was undertaken to calculate the volume of gravel within the active channel of the Ōroua River. HILLTOP Hydro software was used to calculate the area beneath each cross section survey. Using the areas and distances between the cross sections a calculation has been made to obtain a series of volumes along the river. These volumes were then compared to different surveys to obtain a change in volume.

To calculate the volume of gravel between two cross sections, the areas beneath the active channel, (Figure 4.1), of both cross sections were calculated using HILLTOP Hydro software. The average of these areas was then integrated across the distance between the two cross sections to give an assumed volume.

While this volume would include all bed material within the active channel and down to the assumed datum, it is reasonable to assume that any differences between the surveys will be due to changes in the gravel resource of the river. Attached in Appendix B are the river cross sections that have been analysed as part of this study.

4.2 Silt Phase

For the study of the silt phase, an individual analysis of each cross section was carried out to calculate the volume of sediment between the toes of the stopbanks on the left and right banks of the river. HILLTOP Hydro software was used to calculate the area beneath each cross section survey. Using the areas and distances between the cross sections a calculation has been made to obtain a series of volumes along the river. These volumes were then compared to different surveys to obtain a change in volume.

To calculate the volume of sediment between two cross sections, the areas beneath the channel of both cross sections were calculated using HILLTOP Hydro software, and the extents viewed in Figure 4.2. The average of these areas was then integrated across the distance between the two cross sections to give an assumed volume.

While this volume would include all the material between the stopbank toes and assumed datum, it is reasonable to assume that any differences between the surveys will be due to changes in the sediment volume of the river. Attached in Appendix B are the river cross sections that have been analysed as part of this study.

4.3 Mean Bed Level

To determine the mean bed level an individual analysis of each cross section was carried out. The cross section profiles were plotted using the over plot function in Manager. HILLTOP Hydro software was used to calculate the mean bed level for each cross section. The bed is defined in Figure 4.1, above.

5. Gravel Reach Results

5.1 Gravel Volume Analysis

5.1.1 Summary of Results

Figure 5.1, displays the change in the gravel volume from 2011-2012 to 2016. From the graph, it can be seen how the gravel volume has fluctuated across the gravel reach.

From the figure it is observed that the trend is generally one of an increasing gravel volume, which clearly indicates that aggradation of the gravel resource has occurred across the reach. It is noted, that although there is a general trend of aggradation there are a number of locations that saw a decrease in gravel volume over the study period.

The limited areas that show a loss of gravel volume are mainly between the 25.44 km to 25.67 km benchmarks near Kopane Bridge; the 29.4 km to 31.05 km benchmarks around the Awahuri Bridge; and the 40.87 km to 41.69 km benchmarks below the Kiwitea Stream confluence. The losses of volume shown between these benchmarks are not hugely significant in comparison to the rest of the aggrading reach.

The results show that between the 25.44 km to 25.67 km benchmarks there was a loss of approximately 8,500 m^3 of gravel between 2012 and 2016. This loss of gravel is most likely attributable to the loss observed on the gravel beaches within this section of the reach. The aerial photographs in Figure 5.2, clearly show there has been a loss of gravel within this section of the reach and also upstream of the 25.67 km benchmark. The cross sections in Figures 5.3 and 5.4 further support that overall gravel loss has occurred. This is because in these two figures it is readily observed that there has been a loss of gravel on the beaches. This overall loss of gravel is likely attributed to the natural movement of a gravel bedded river as the loss equates to around 2,125 m^3 per annum, which would be within the order of magnitude that could occur naturally within a gravel bedded river.

There are two distinct sections where aggradation has been dominant along the reach, which occur from the 32.56 km to 38.57 km benchmarks, between the Awahuri and Aorangi Bridges, and from the 26.08 km to 29.12 km benchmarks, which are located between the Kopane and Awahuri Bridges, the locations of which can be seen in Appendix A. From Figure 5.1, it is observed between these benchmarks noteworthy aggradation is occurring, where between these benchmarks the gravel volume is largely aggrading between the 0 to 5000 cubic metre boundaries.

The gravel volume between 2012 and 2016 has fluctuated over time, with an overall increase in volume. The net gain in gravel volume is estimated to be 112,600 m^3 during this period, which is about 28,150 m^3 per annum of gravel aggradation.

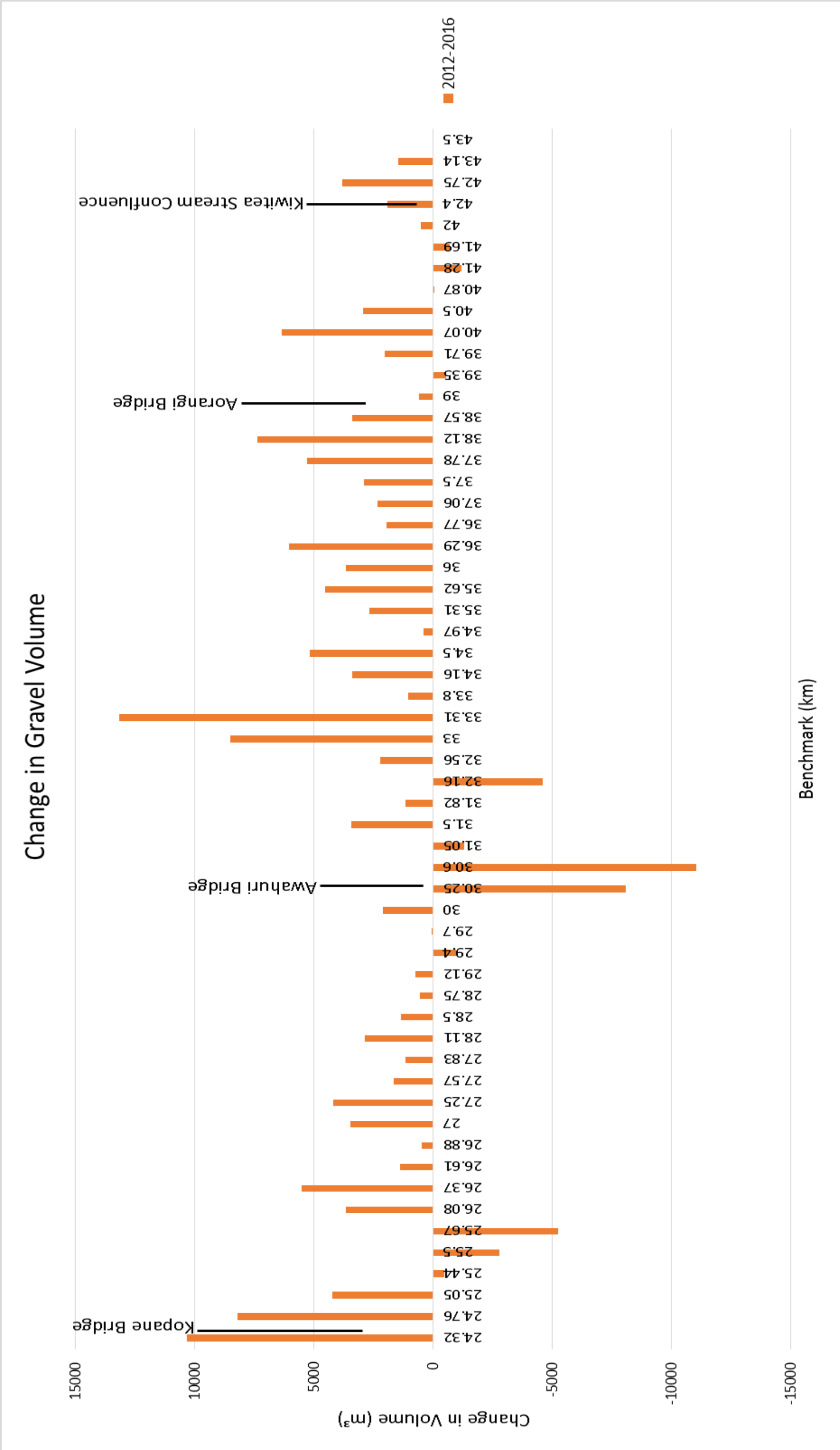


Figure 5.1. Change in gravel volume from just above the Kiwitea Stream confluence to Kopane Bridge.

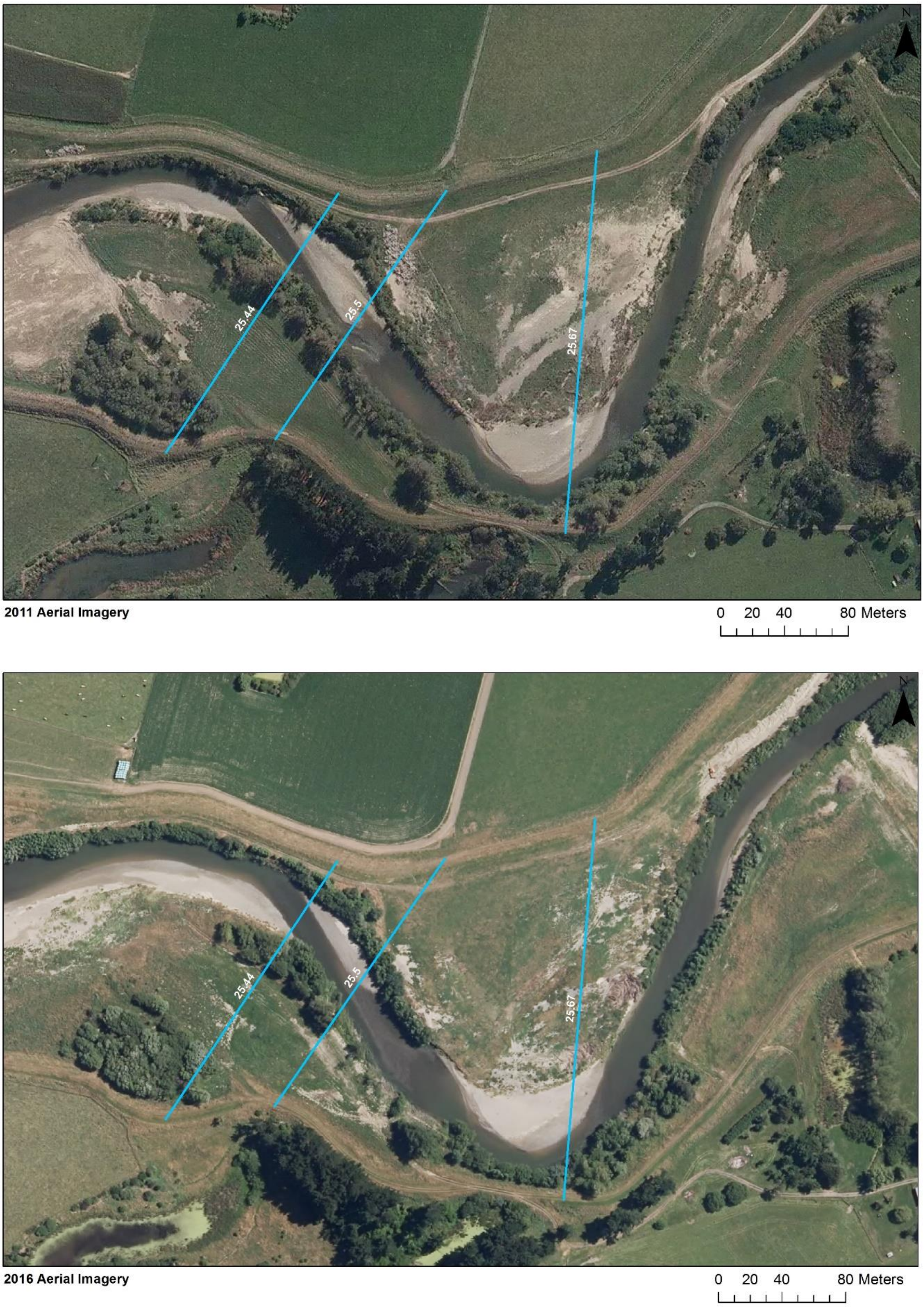


Figure 5.2. 2011 and 2016 aerial imagery, displaying the section between the 25.44 km to 25.67 km benchmarks.

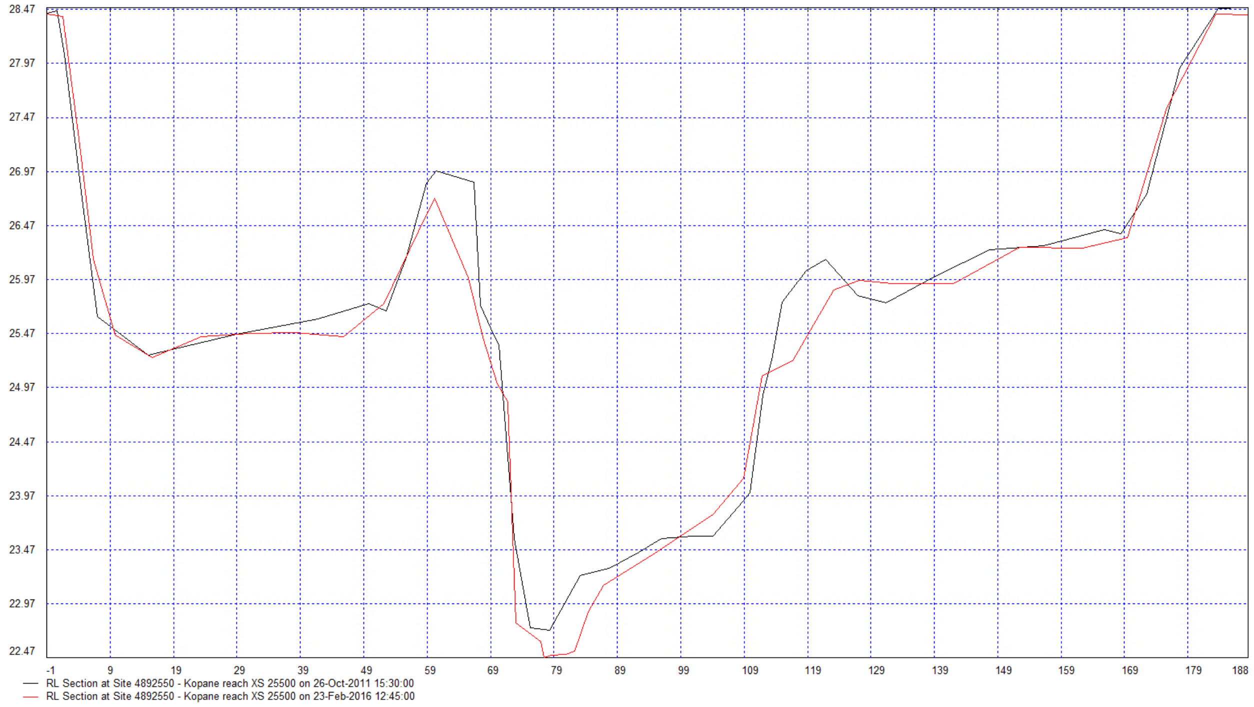


Figure 5.3. 2011 and 2016 cross section overlay at benchmark 25.5.

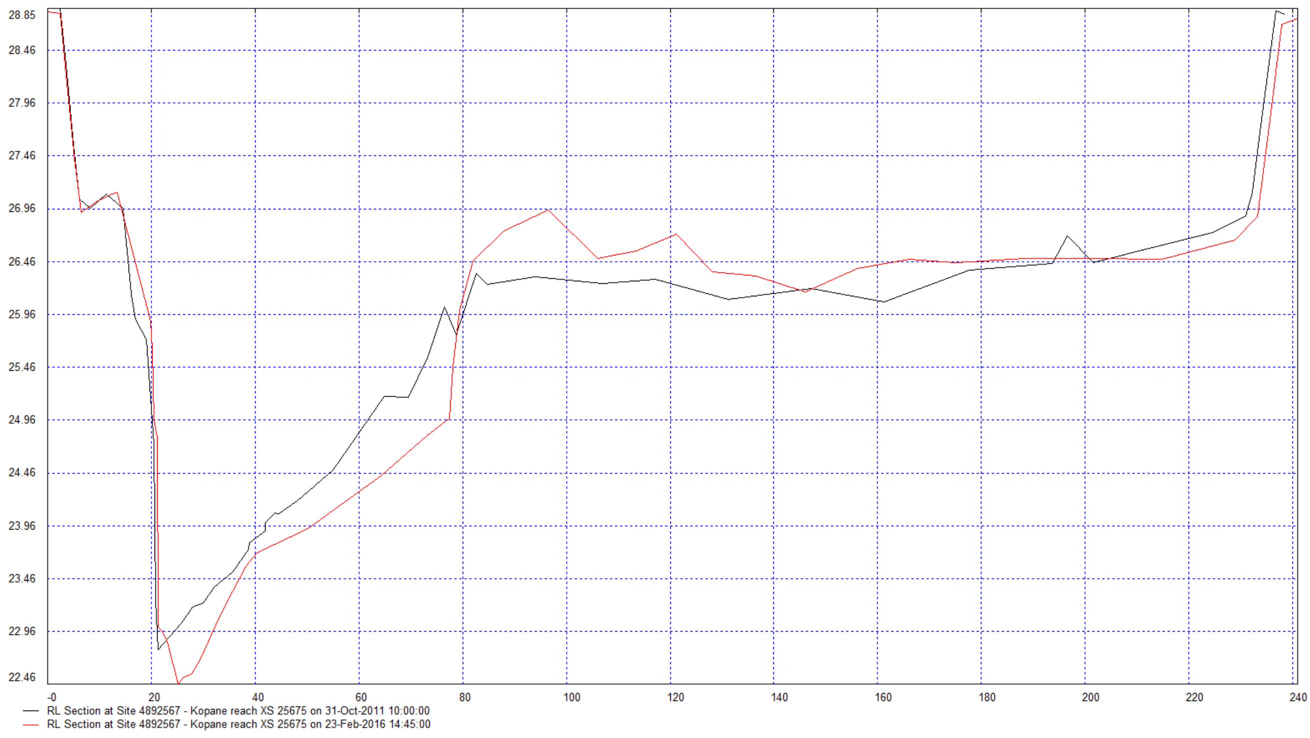


Figure 5.4. 2011 and 2016 cross section overlay at benchmark 25.67.

5.1.2 Reliability of the data

From Figure 5.1, it is observed that most of the changes in gravel volume between cross sections fluctuates between 0 and 5000 m^3. However, there are a number of locations where the analysis suggests that there has been a significant change in gravel volume. Further consideration needs to be given to these data points to determine if they provide an accurate representation of the change in the gravel resource. As such, the changes observed around the 24.32 km, 30.6 km, and 33.1 km benchmarks have been further analysed to determine if there are outstanding variables that could explain the quantum change that has been calculated.

The results shown graphically in Figure 5.1 indicates that an aggradation of nearly 18,500 m^3 has occurred between the 24.32 km and 25.05 km benchmarks. From the aerial imagery in Figure 5.5 it can be seen that from 2011 to 2016 this section of the reach has undergone some changes such as the completion of the new Kopane Bridge, as well as observed changes in the large area of berm land located downstream of the 25.05 km benchmark. To quantify the changes that have occurred at this location an understanding of the works that have been undertaken is required.

This stretch of the river has seen significant change take place with the replacement of the Kopane Bridge, as well as the alteration of the berm land on the true left bank above Kopane Bridge. This berm land was used as a borrow area as it is comprised of good quality material which primarily consists of silt and sand. This material would have been used for stopbank construction and raising as well as the road approaches for the new bridge.

It is readily observed in Figure 5.5 that overall there has been a visual reduction in size of the berm land however, the cross section analysis is contradicting this assumption and indicates an overall increase in material from 2011 to 2016. To help understand these changes the cross section observed in Figure 5.6 can be discussed in further detail.

This cross section shows that from January 2011 to October 2011 a significant amount of berm land was cleared, but from October 2011 to February 2016 this resource has recovered and backfilled the cut to a certain level. However, even though the resource recovered at this location, similar recovery has not occurred further upstream as the analysis has assumed. As such, the calculated aggradation of approximately 18,500 m^3 is likely to be an over estimate and not an accurate representation of the aggradation that has actually occurred. This has also been concluded because it is berm land that has been altered and not the gravel beaches that are located within the channel.

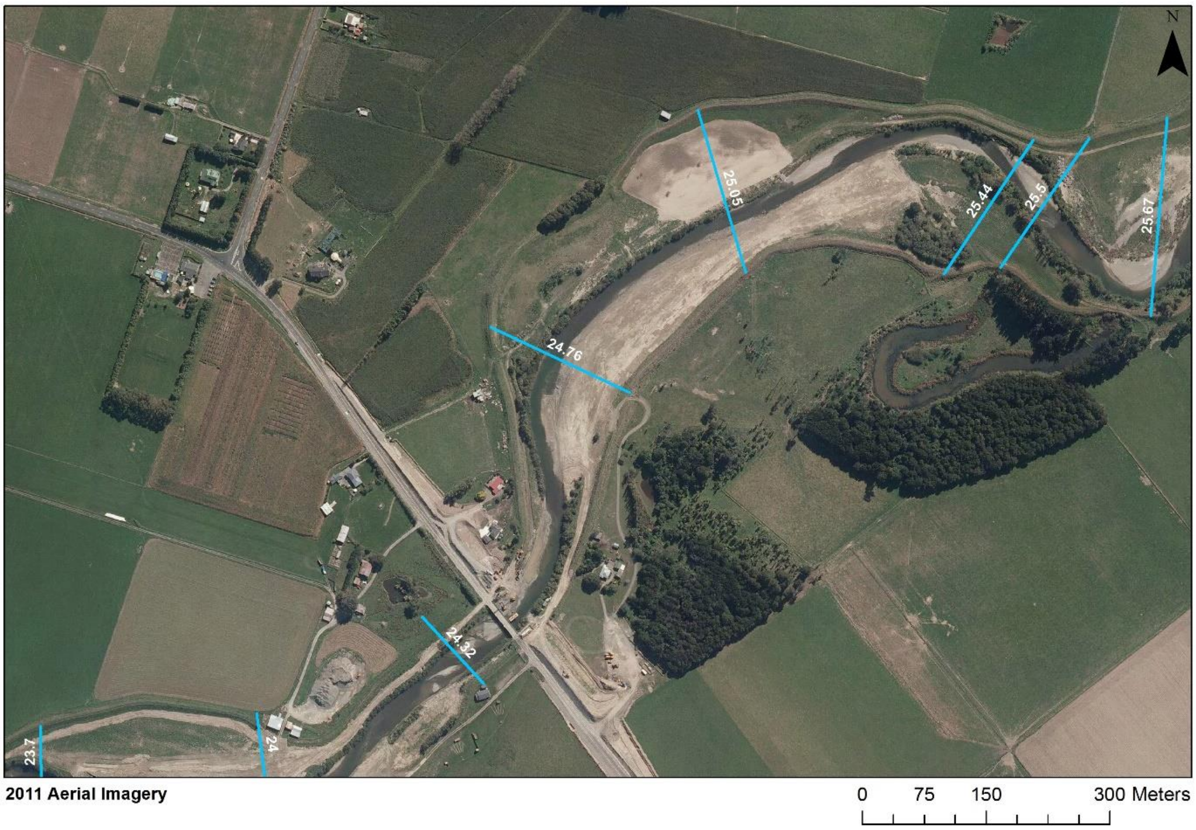


Figure 5.5. 2011 and 2016 aerial imagery, displaying the section between the 24.32 km and 25.05 km benchmarks.

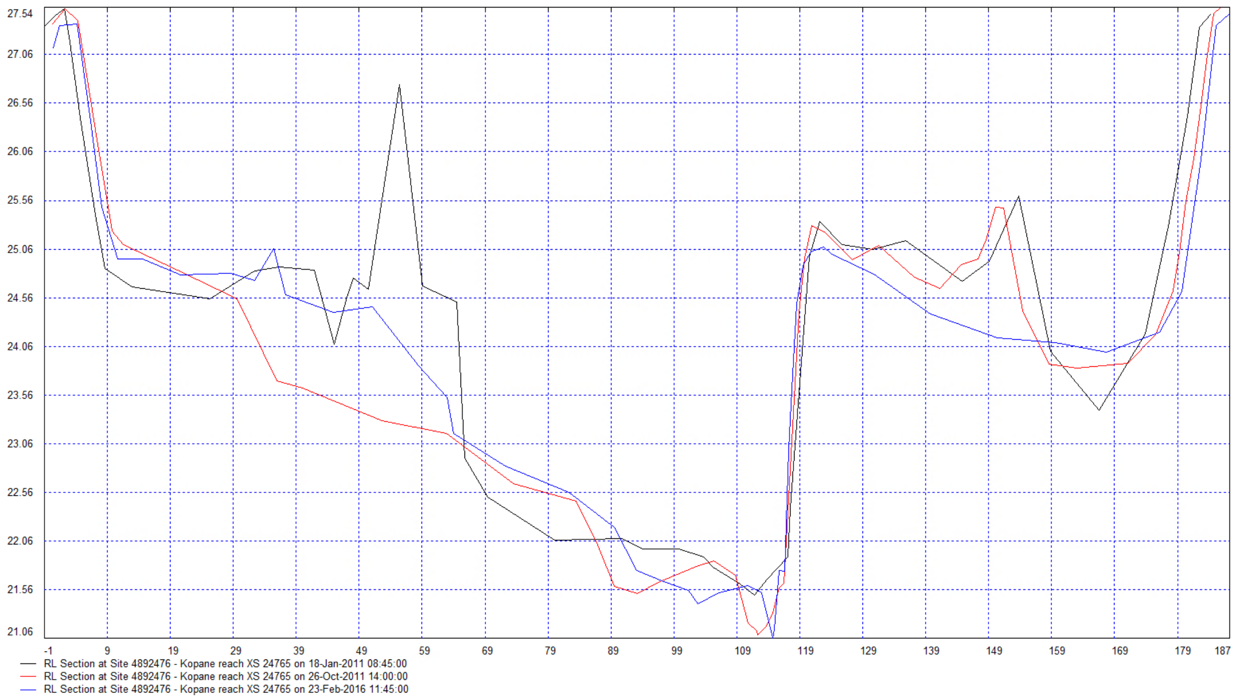


Figure 5.6. October 2011, January 2011, and February 2016 cross section overlay at benchmark 24.76.

The outliers that are observed graphically in Figure 5.1 at the 30.25 km and 30.6 km benchmarks indicate that an estimated loss of around 19,000 m³ has occurred between the 30.25 km to 30.6 km benchmarks, and between the 30.6 km to 31.05 km benchmarks respectively. From the aerial imagery in Figure 5.7, below, it can be seen that from 2011 to 2016 this section of the reach has seen a loss of gravel on the gravel beaches, which could account for the loss shown in Figure 5.1. This loss is also observed in cross section 30.6 and 31.05 in Appendix B, where noticeable degradation has occurred. This overall loss of gravel can be attributed to the gravel extraction that occurs along this part of the reach. Gravel extraction takes place to alleviate the pressure on the outside of the right angled bend, as well as further downstream, as the beaches aggrade at a significant rate and threaten to change the characteristics of the flow heading into the bridge. This leads to the idea that the gravel volume result obtained between these benchmarks is likely to be a realistic representation of how the gravel volume has changed in this part of the reach.

Figure 5.7. 2011 and 2016 aerial imagery, displaying the sections from the 30 km to 30.6 km benchmarks, and the 30.6 km to 31.05 km benchmarks.

The last data point that is considered to be an outlier is observed at the 33.31 km benchmark, which suggests that an aggradation of almost 15,000 m³ has occurred between the 33.31 km to 33.8 km benchmarks. From the aerial imagery in Figure 5.8, below, it is observed that since 2011 there has visually been aggradation of the gravel beaches between these benchmarks. This can also be seen in cross sections 33.31 and 33.8 in Appendix B, where noticeable aggradation of the beaches has occurred. This leads to the idea that the gravel volume result obtained for this part of the reach is likely to convey a more realistic representation of how the gravel volume has changed.

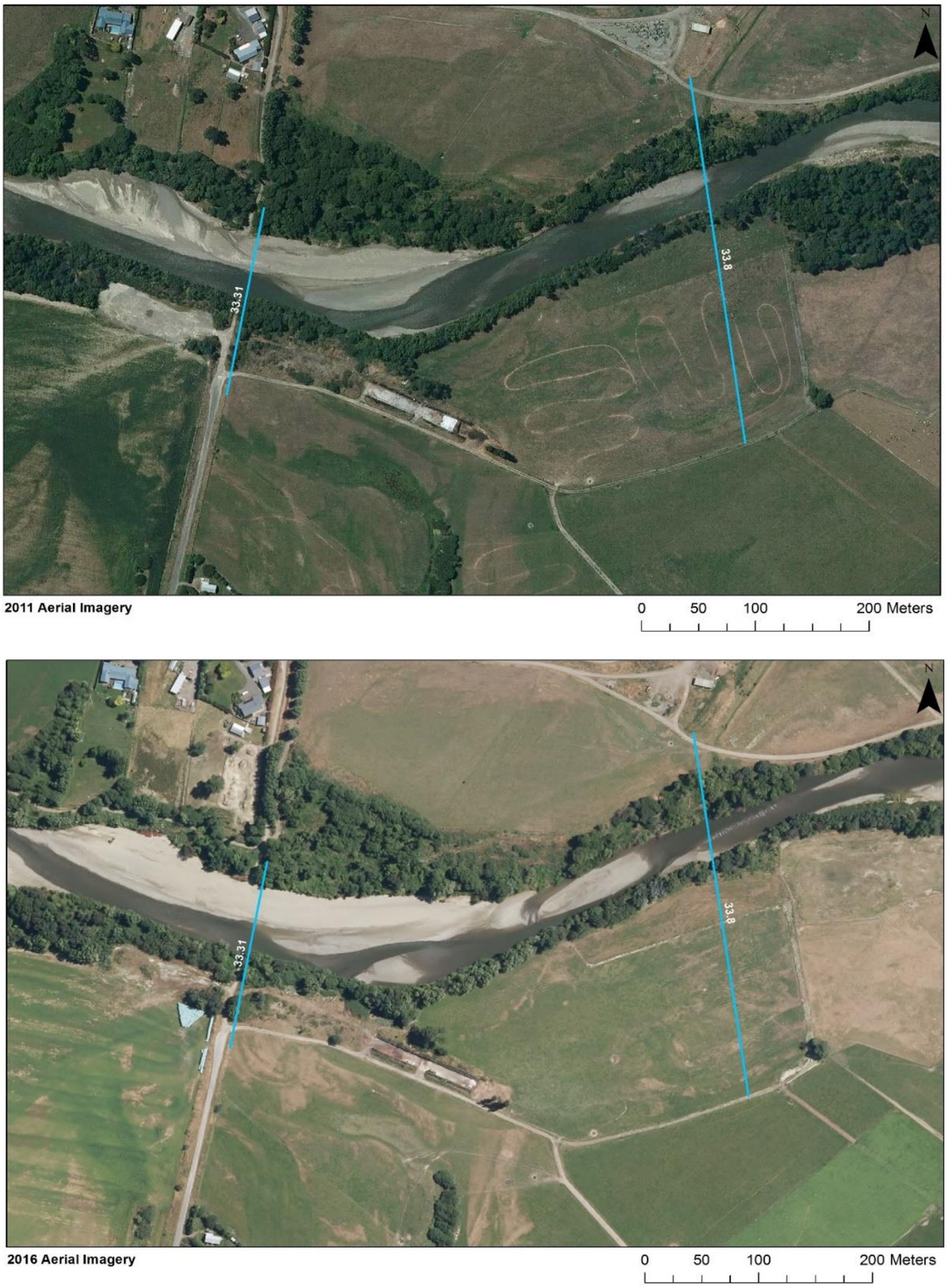


Figure 5.8. 2011 and 2016 aerial imagery, displaying the section between the 33.31 km and 33.8 km benchmarks.

From this analysis of the reliability of data, it can be concluded that the overall change in the gravel volume is not of the magnitude that was initially estimated in the summary of results, which was an estimated net gain of 112,600 m³. This has been concluded because as discussed in the reliability of data section above, there is a volume that is assumed to be inaccurate. This has led to the conclusion that the inaccurate volume should be removed from this total to provide a more accurate estimation of the net gravel volume change. The removal of the unreliable volume provides a new estimation of an overall volume change of 94,100 m³ during this period, which equates to an estimated 23,525 m³ per annum of gravel aggradation.

5.2 Mean Bed Level Analysis

Figure 5.9, below, shows how the mean bed level has changed across the gravel reach from 2012 to 2016.

The figure clearly shows that the mean bed level along the Ōroua River has fluctuated where both instances of rising and falling have occurred. However, the overall trend observed is one of a rising mean bed level.

Figure 5.9 overall, displays a trend of an increasing elevation across the reach, however there are some locations along the gravel reach that have been subjected to a mean bed level fall. The section from the 28.75 km benchmark to the 32.16 km benchmark, shows the biggest loss of elevation, with a significant trough at the 30.6 benchmark. At this cross section the survey shows that the mean bed level of the river has dropped by almost 0.7 m.

The section from the 39 km to 43.5 km benchmarks and the 25.5 km to 26.61 km benchmarks also displays an overall loss of mean bed elevation, where these two sections of the reach display an overall loss largely in the order of magnitude of less than 0.2 m, which one would expect to see within a gravel bed river.

When analysing changes in the mean bed level of a gravel bed river, such as the Ōroua River one would expect to see fluctuations, due to the natural movement of gravel through the river system. However, as Figure 5.9 shows there has clearly been an overall trend of rising bed levels throughout the study reach.

The section from the 32.56 km benchmark to the 38.57 km benchmark, shows the greatest increase in elevation, as this part of the reach is where a majority of the mean bed level increases have occurred. Other sections of the graph also display periods of a mean bed level increase. These occur between the 24.32 km benchmark and 25.44 km benchmark, and also between the 26.88 km benchmark and 28.5 km benchmark. Overall, the changes in mean bed level that are observed at these sections are generally of an order of magnitude of less than 0.2 m which could be expected to be seen naturally within a gravel bed river.

When considering the mean bed level, and gravel volume analysis a correlation between the two variables is observed, where generally as the gravel volume increases and decreases, the mean bed level increases and decreases as well, Figure 5.10. This general correlation is observed over a majority of the gravel reach. However, there are some locations where this correlation is absent, notably from the 39 km benchmark to the 43.5 km benchmark. This section of the reach shows that the gravel volume is increasing overall, whereas the mean bed level has mainly decreased. However, in Figure 5.10 it is observed that the overall changes from the 39 km benchmark to the 43.5 km benchmark are not of a huge order of magnitude. From the cross sectional evidence which is attached in Appendix B it can be seen that the overall bed elevation loss is due to the cutting down of the channel on the outside of the bend or the loss of elevation on the gravel beaches.

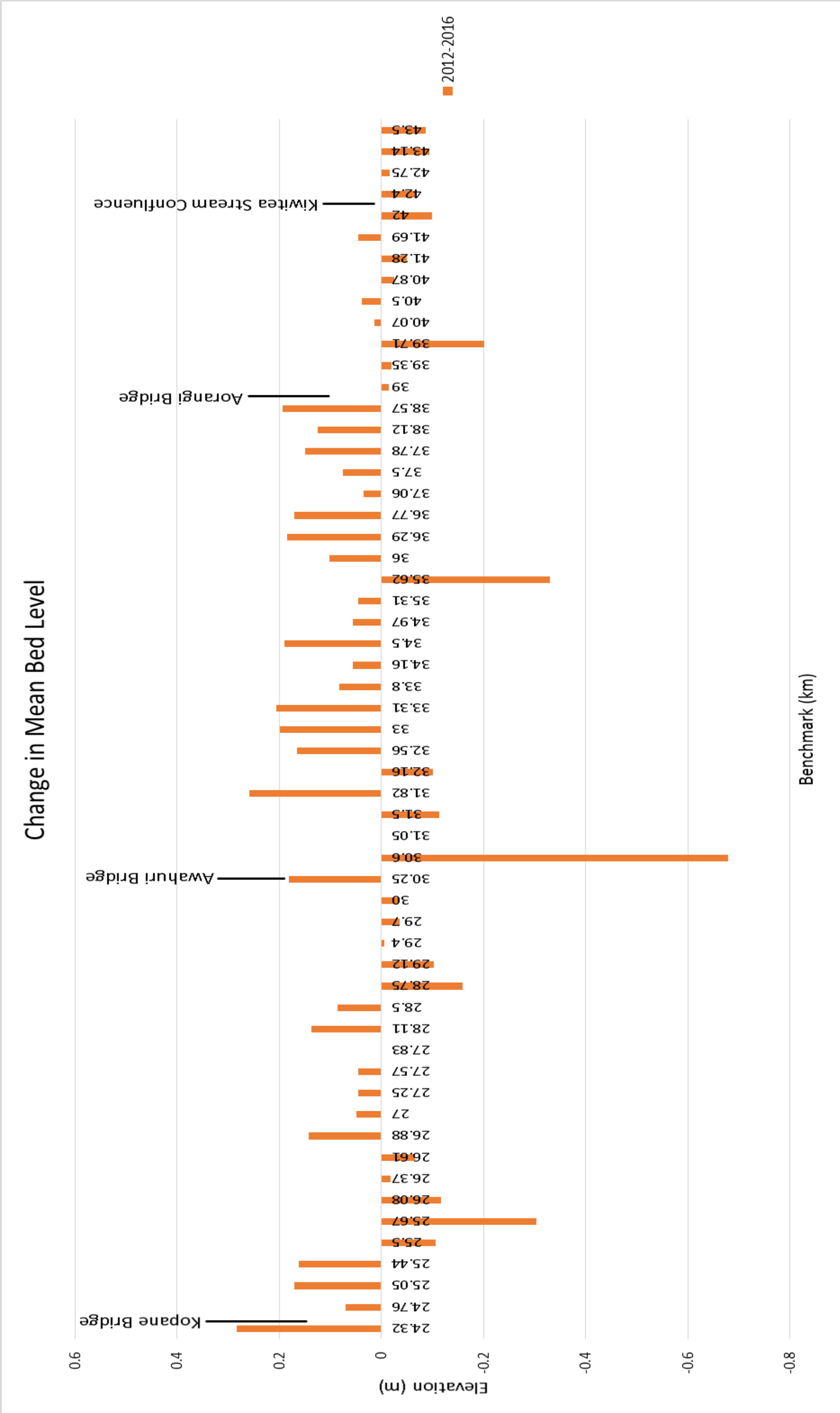


Figure 5.9. Change in mean bed level from just above the Kiwitea Stream confluence to Kopane Bridge.

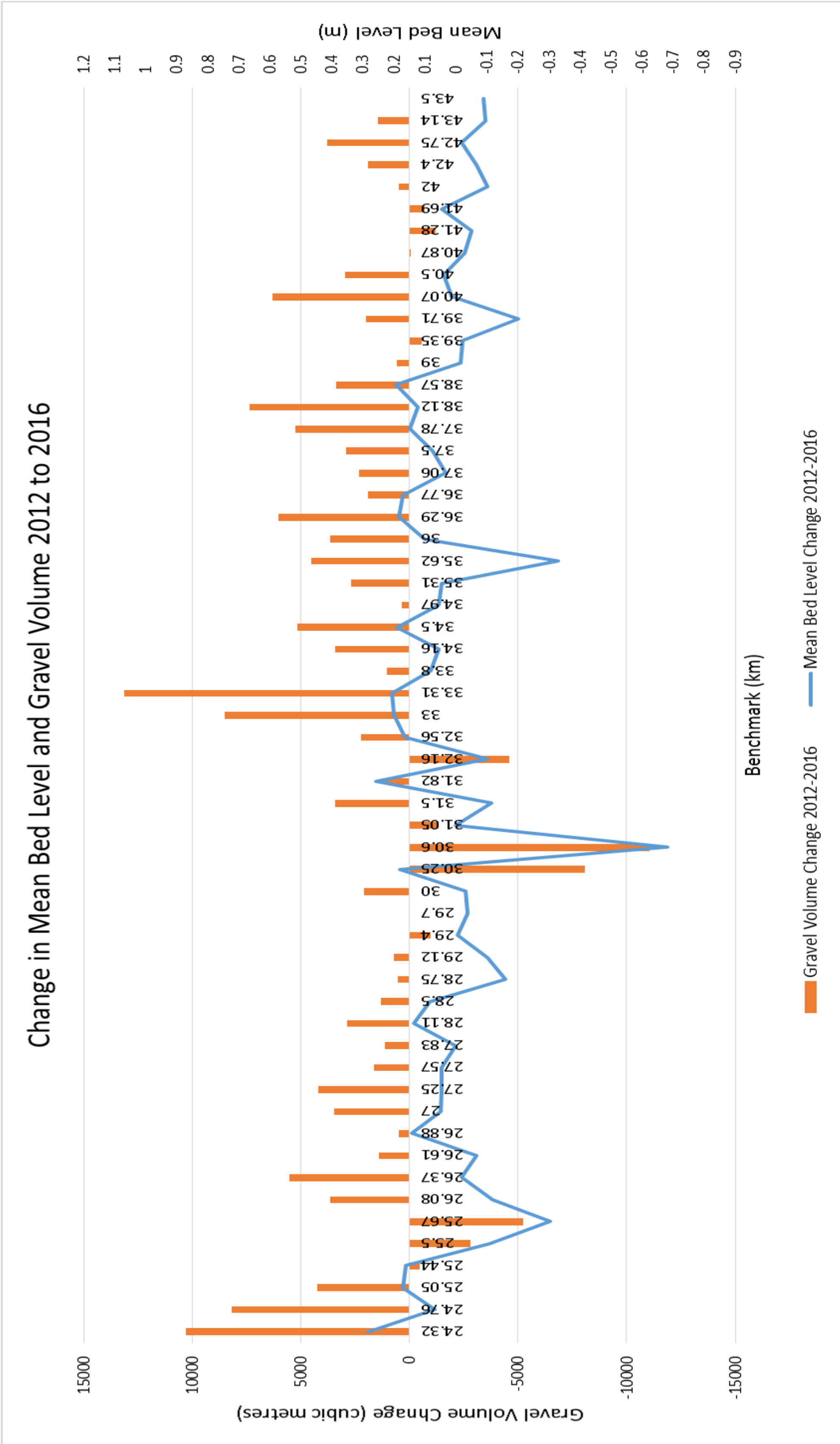


Figure 5.10. Gravel volume change and mean bed level change.

6. Silt Phase Results

The silt phase of the Ōroua River is being taken into consideration for this study because there is a need to understand what is happening in terms of sedimentation rates, geomorphological changes, and what impact this could potentially have on the flood carrying capacity of the river.

Previously, the silt phase of the river was included as part of the gravel reach for the Ōroua River. The reason for this is unknown, it is just how the surveys have been instructed to be done in the past.

The location of the silt phase of the Ōroua River is from the 24.32 km benchmark, which is located just below the Kopane Bridge, to the 0 km benchmark, located at the Manawatū River/Ōroua River confluence, located below in Figure 6.1. This stretch of the river consists of some distinct meander curves and is largely confined by stopbanking that runs along the right and left banks of the river. It is also observed along this stretch of the river, that there is a reduced amount of significant beach build-ups, whereas above Kopane Bridge beach build ups are significant. The transition from the gravel phase of the river to the silt phase of the river is marked by these distinct changes in geomorphic characteristics.

Figure 6.1. Silt phase of the Ōroua River from Kopane Bridge to the Manawatū confluence.

6.1 Silt Phase Analysis

6.1.1 Summary of volume change results

Figure 6.2, below shows the change in sediment volume from 2012 to 2016. From the graph, it can be observed how the sediment volume has fluctuated along the silt phase of the Ōroua River.

Overall, Figure 6.2 displays a trend of an increase in sediment volume, where along the majority of the silt phase there is an observed aggradation of sediment. However, even though a general trend of aggradation has occurred there are still some locations where a loss of sediment has been dominant.

The section from the 8.48 km benchmark to the 13.5 km benchmark shows that there has been a significant loss of sediment overall. This part of the silt phase has degraded where an overall loss of sediment in the order of magnitude of 184,000 m^3 has occurred. There is also another location where a loss of sediment has occurred, which is located from the 1.15 km benchmark to the 1.5 km benchmark. The loss observed at this location is significantly smaller than the previous section, where overall a loss of almost 10,000 m^3 has occurred.

There are two sections along the silt phase which display a significant aggradation, which occur from the 2.12 km benchmark to the 6.57 km benchmark, as well as from the
13.85 km benchmark to the 24.32 km benchmark. From Figure 6.2 it is observed that the aggrading sections are mainly increasing in the order of up to 10,000 m^3.

The sediment volume has fluctuated between the 2012 to 2016 period, with an overall increase in volume occurring along the silt phase of the river. The overall gain in sediment volume is estimated to be 218,000 m^3 during this period, which is about 54,500 m^3 per annum of sediment aggradation. However, it has been determined that the outlier observed at the 6.57 km benchmark should be removed from the overall gain in sediment volume. This outlier is discussed further in section 6.1.2. The removal of the unreliable volume provides a new overall volume change of 188,600 m^3 during this period, which equates to an estimated 47,150 per annum of sediment aggradation.

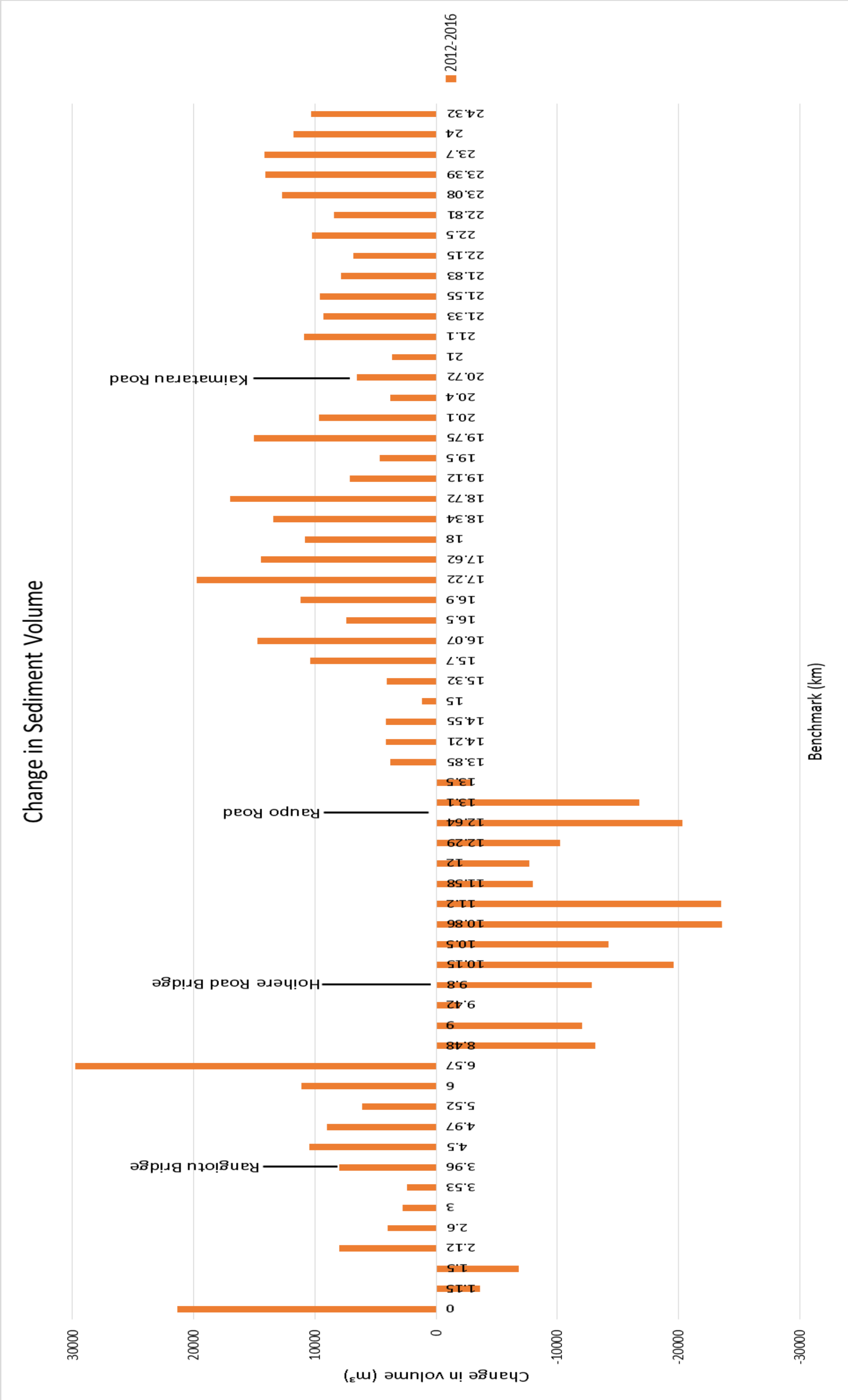


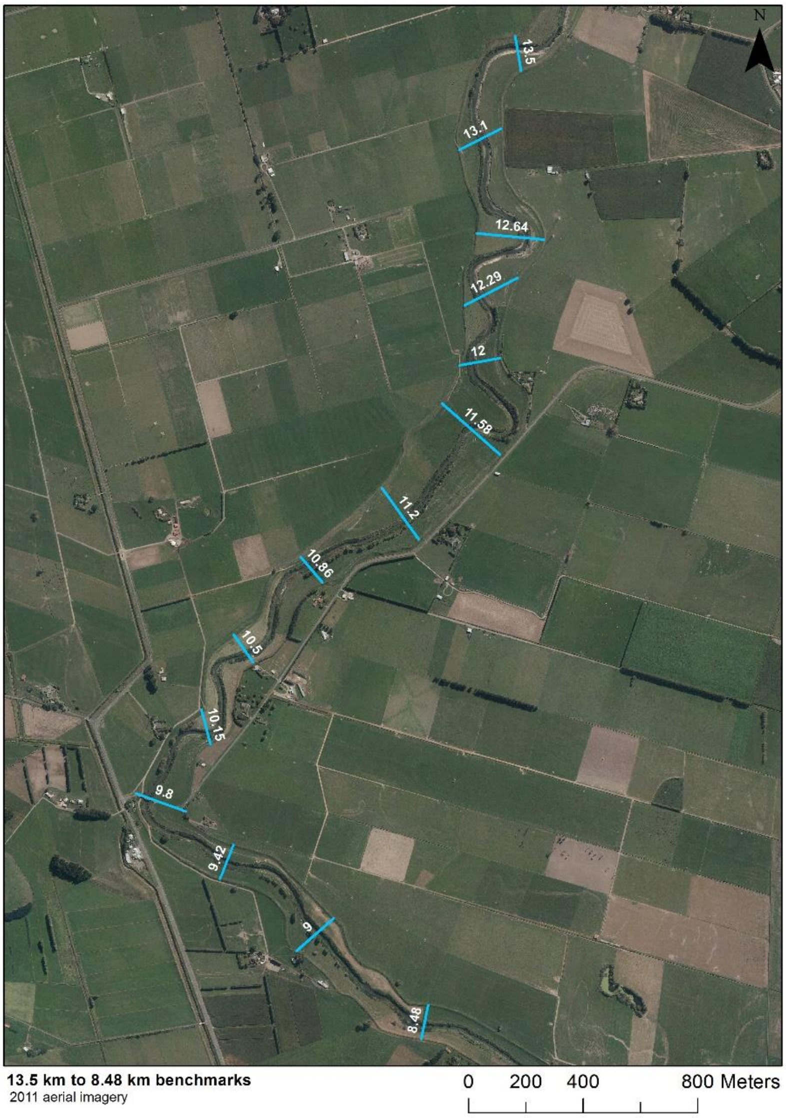
Figure 6.2. Change in sediment volume from Kopane Bridge to the Manawatū confluence.

6.1.2 Analysis of the volume change results

The results that are displayed in Figure 6.2, above, are further analysed and discussed through cross sectional evidence and aerial imagery from 2011 and 2016.

The section from the 8.48 km benchmark to the 13.5 km benchmark displayed an overall loss of sediment. From the 2011 and 2016 aerial imagery in Figure 6.3, below, it is observed that considerable changes have occurred along the river. In the imagery it can be seen that construction works have been undertaken within this stretch of the river since 2011, as it is noticed, there has been a disturbance to the sediment layer on the berms, as the berms were used as borrow sites to source quality material for upgrades to the stopbank network.

In Figures 6.4 and 6.5 the cross sections located at the 10.5 km and 13.1 km benchmarks confirm that this section of the river has been subjected to significant construction works. In these two figures the loss of sediment on the berms is observed as well as the upgrades that have been made to the stopbanks. The construction that has occurred within this section of the river can largely account for the overall loss of sediment that has occurred.



13.5 km to 8.48 km benchmarks
2011 aerial imagery

Figure 6.3. 2011 and 2016 aerial imagery, which displays the section of the silt phase from the 13.1 km to 8.48 km benchmarks.

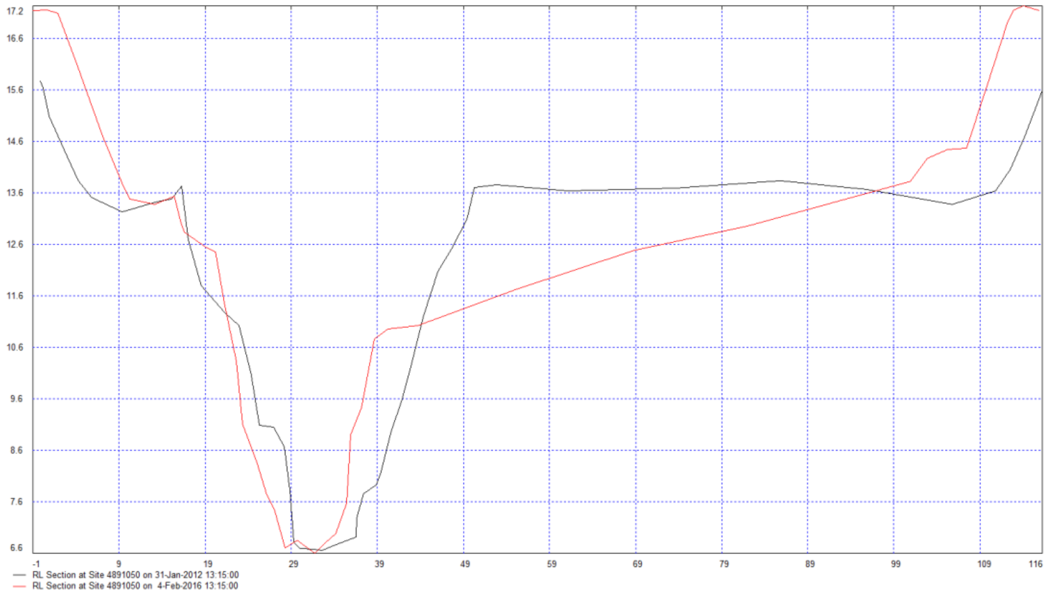


Figure 6.4. 2012 and 2016 cross section overlay at benchmark 10.5.

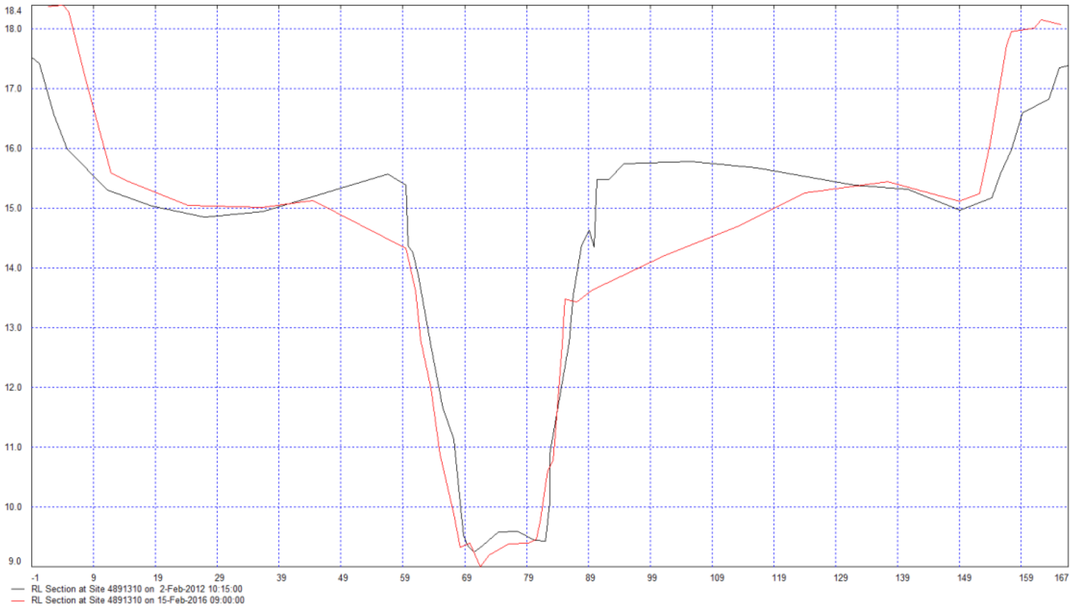


Figure 6.5. 2012 and 2016 cross section overlay at benchmark 13.1.

The section of the silt phase form the 13.85 km to the 24.32 km benchmarks shows that a significant increase in sediment has occurred. Part of this section of the silt phase can be seen in the 2011 and 2016 aerial imagery below in Figure 6.6 where readily observed changes are seen along this part of the river. From 2011 to 2016, it is noticed that obvious deposition on the berms has occurred. This conclusion has been drawn because in the 2016 imagery there are increased areas of noticeable siltation along the berms of the river between the stopbanks. Whereas in the 2011 imagery, these noticeable areas of siltation are reduced. This observation can be further confirmed in Figures 6.7 and 6.8, where the observed trend is one of berm aggradation and channel narrowing.

In Figures 6.7 and 6.8, the cross sections located at the 20.1 km and 21.83 km benchmarks are displayed. The cross sections provide a visual representation of how the sediment has changed over this period. Both Figures 6.7 and 6.8 display typical cross sections for this part of the silt phase, both of which indicate that aggradation of the berms is occurring as well as a narrowing of the channel, which has led to an overall aggradation of sediment for this section of the silt phase.

Figure 6.6. 2011 and 2016 aerial imagery, which displays the section of the silt phase from the 23.7 km to 19.75 km benchmarks.

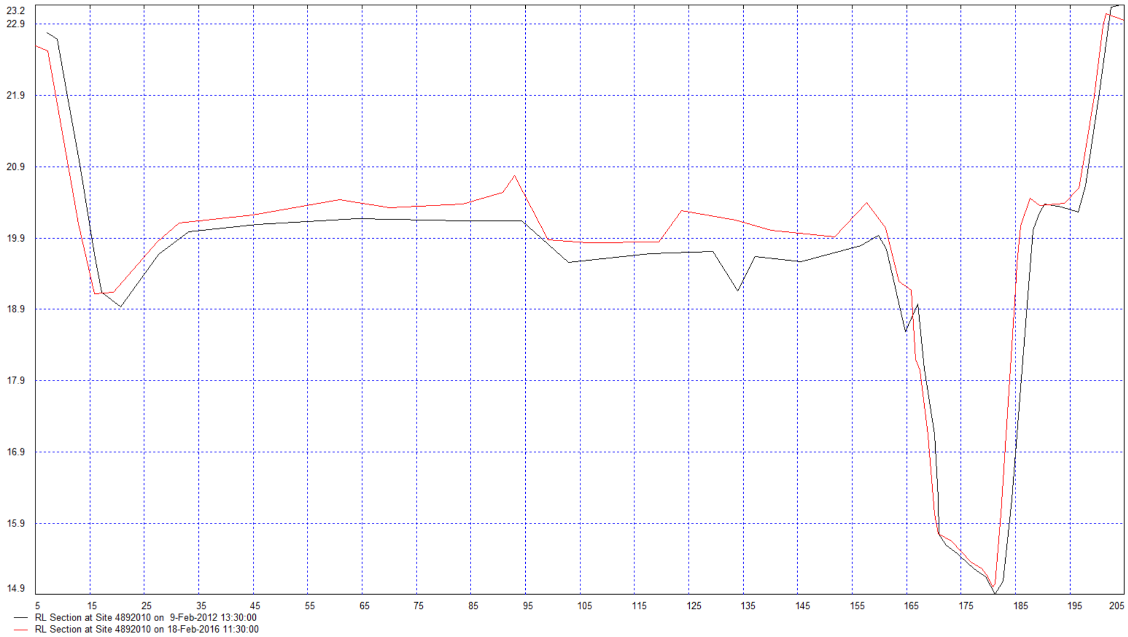


Figure 6.7. 2012 and 2016 cross section overlay at benchmark 20.1.

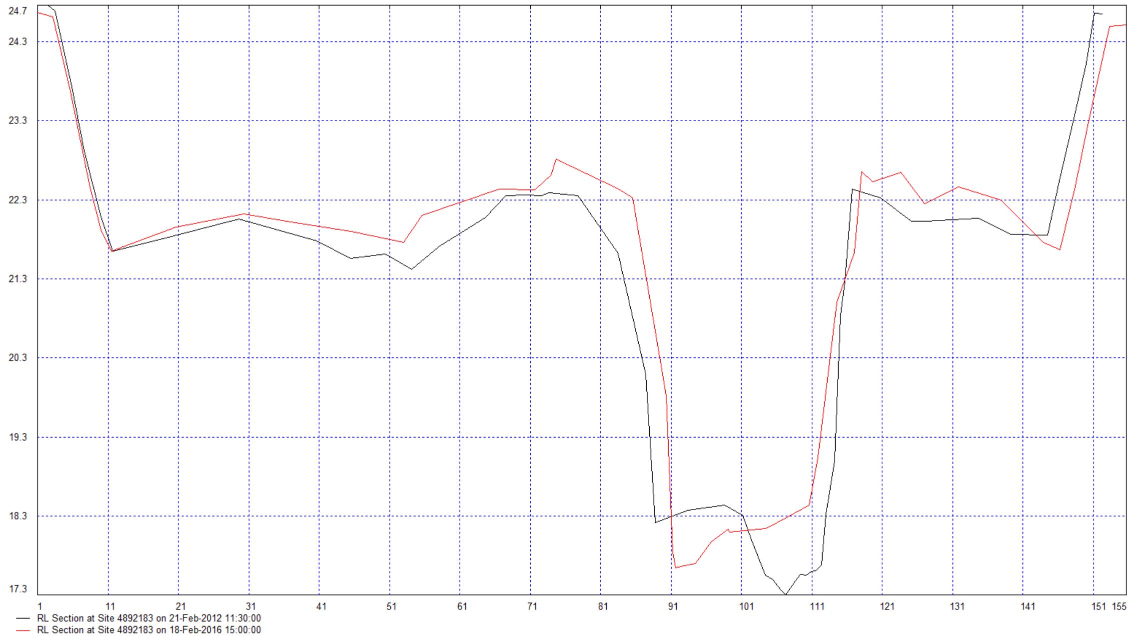


Figure 6.8. 2012 and 2016 cross section overlay at benchmark 21.83.

Another section of the silt phase to be further analysed is from the 6.57 km benchmark to the 0 km benchmark the latter of which marks the confluence with the Manawatū River. Overall aggradation of sediment has occurred along this section of the river, with one area displaying degradation from the 1.15 km to 1.5 km benchmarks. In the 2011 and 2016, aerial imagery seen in figure 6.9 below it is observed that that no obvious channel changes have occurred over this time period. To better understand how this reach is being affected by changes in sedimentation rates the cross sections in figures 6.10 and 6.11 can help to provide a visual representation as to what is happening.

In figure 6.10, the cross section located at the 1.5 km benchmark is displayed. This cross section represents the location of where sediment loss has occurred, and it is observed that sediment has been lost due to a widening of the river channel, which could account for the degradation that has occurred at this section of the silt phase. Figure 6.11 displays the cross section located at the 4.5 km benchmark, this cross section represents what is occurring in the aggrading part of this section of the silt phase. From the figure, it is observed that typically the channel is narrowing and there is some slight aggradation on the berms. Along this section of the silt phase aggradation on the berms is considerably less than was observed in the section discussed above from the 24.32 km to 13.85 km benchmarks.

6.57 km to 0 km benchmarks
2011 aerial imagery

0 200 400 800 Meters

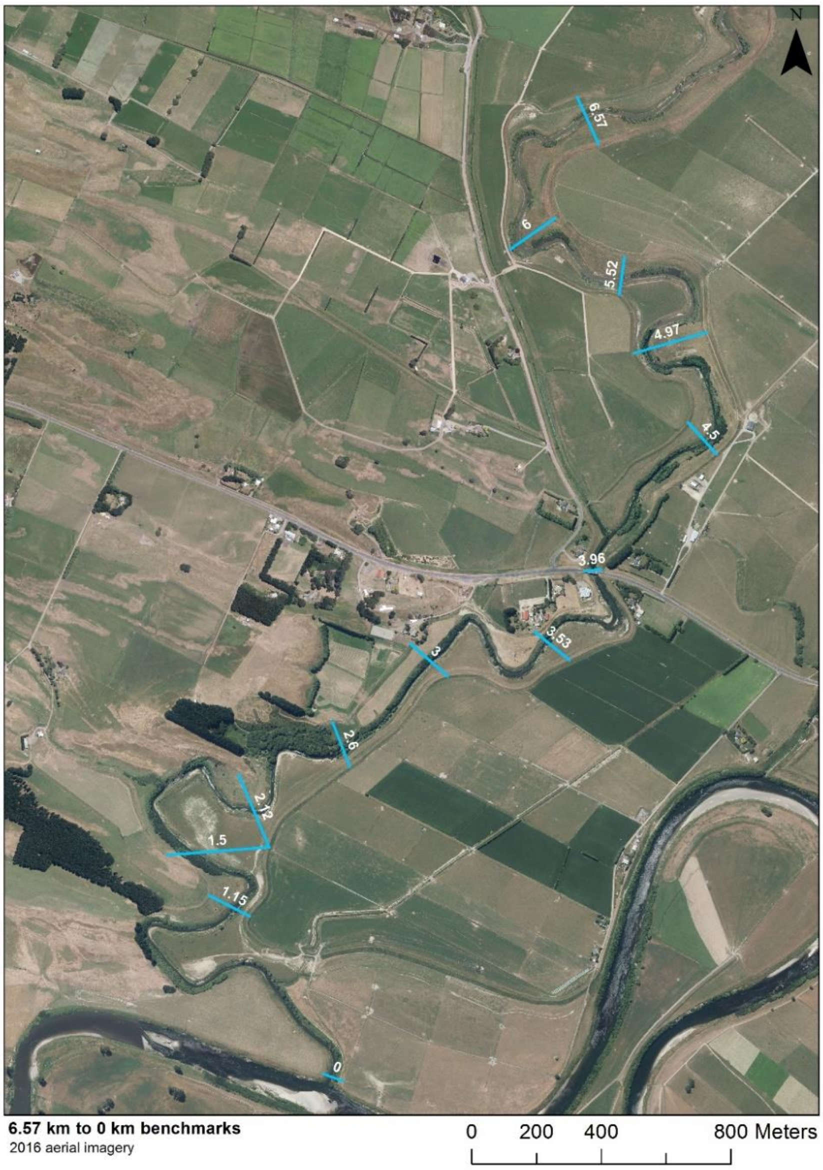


Figure 6.9. 2011 and 2016 aerial imagery, which displays the section of the silt phase from the 6.57 km to 0 km benchmarks.

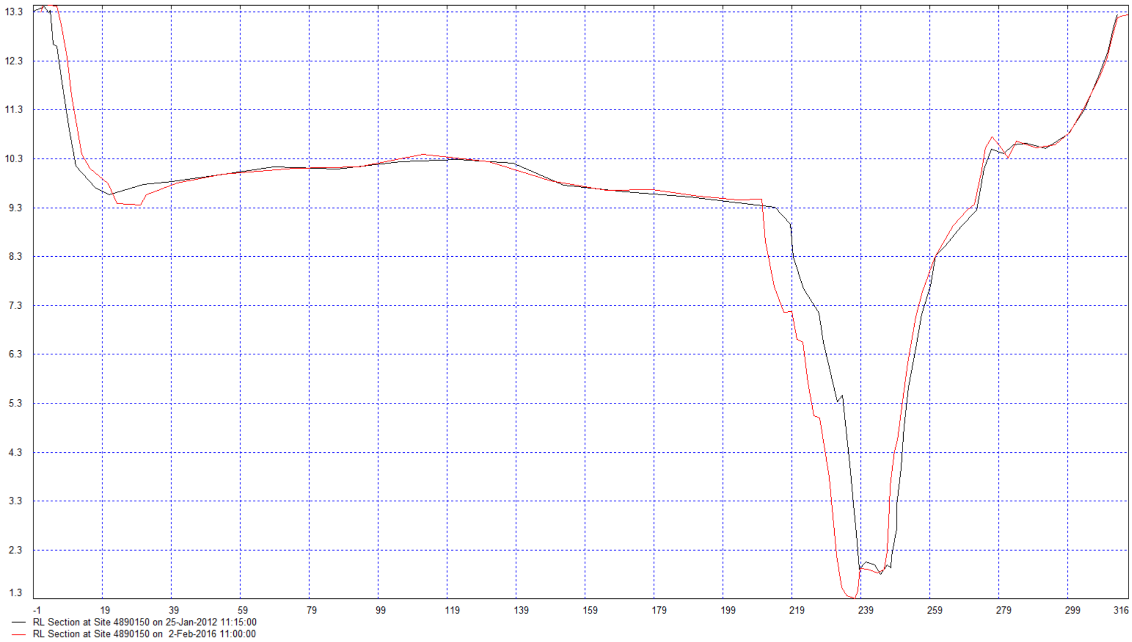


Figure 6.10. 2012 and 2016 cross section overlay at benchmark 1.5.

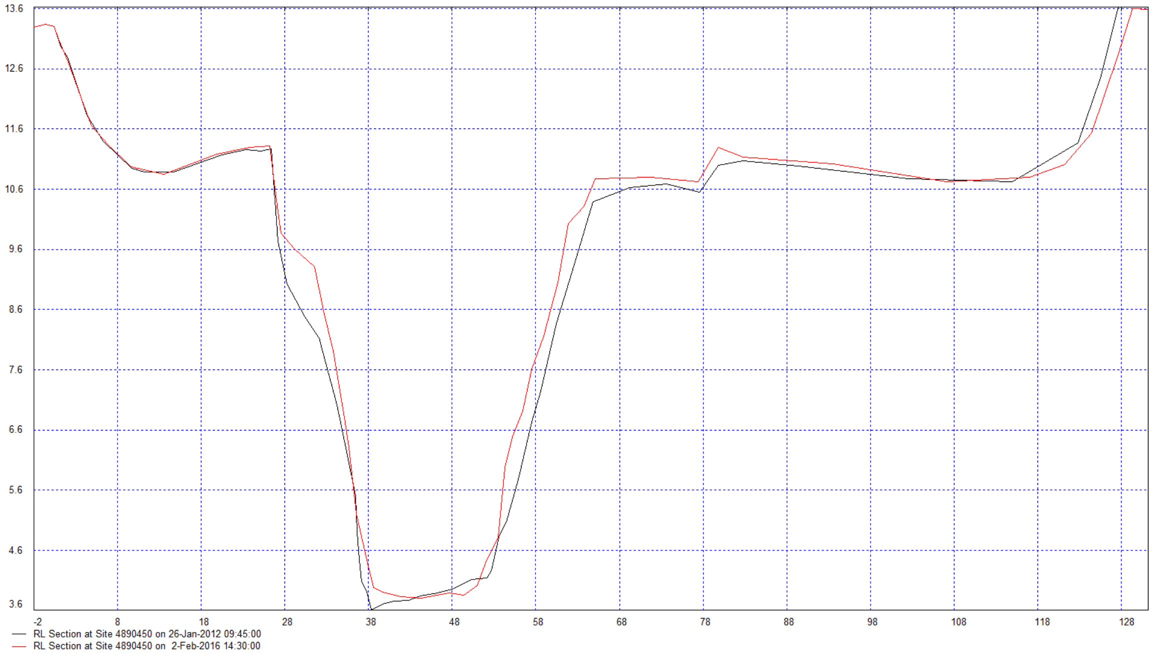


Figure 6.11. 2012 and 2016 cross section overlay at benchmark 4.5.

At the 6.57 km benchmark, it has been inferred that a substantial amount of sediment aggradation has occurred in the order of almost 30,000 m³. The volume observed at this cross section is considered to be an outlier. This conclusion has been drawn because the volume observed at the 6.57 km benchmark is the volume that has been calculated from the 6.57 km benchmark to the 8.48 km benchmark. This is significant because seen below in Figure 6.12 are the locations of both cross sections, and as can be observed there is a considerable distance between these two cross sections. The distance between the two cross sections is substantial, which diminishes the accuracy of the sediment volume produced between the two sections, which leads to the conclusion that this volume should be considered an outlier. In HILLTOP there are a number of cross sections located between these two cross sections, however they were last surveyed in 2013 not 2016, which is outside the scope of this study.

Figure 6.12. 2011 and 2016 aerial imagery, which displays the section of the silt phase from the 8.48 km to 6.57 km benchmarks.

6.1.3 Mean Bed Level Analysis

Figure 6.13, below, shows how the mean bed level across the silt phase has changed from 2012 to 2016.

The figure clearly shows that the mean bed level along the silt phase of the Ōroua River has fluctuated, where instances of rising and falling have occurred. However, the overall trend observed is one of a rising mean bed level.

Figure 6.13 largely displays a trend of an increasing elevation across the reach, where only a few certain areas are subject to a loss. The section from the 1.5 km to 2.12 km benchmarks, shows the biggest loss of elevation, with a significant trough at the 1.5 km benchmark. At this cross section the surveys show that the mean bed level of the river has dropped by 0.7 m. Across the rest of the silt phase there are other locations which display a loss of bed elevation, however a majority of the losses are in the order of magnitude of less than 0.2 m, which one could expect to see naturally within a river system.

The increases in mean bed level also largely occur within the order of magnitude of 0.2 m, with only a few cross sections displaying a bed level increase of greater than 0.2 m. The largest bed level increase has occurred at the 9.8 km benchmark which displays a peak of almost 0.9 m. This peak corresponds with the cross section located at Hoihere Road Bridge, seen in Figure 6.15, the cross section shows that overall the bed has seen significant aggradation.

Overall, the silt phase has not seen a huge variation in mean bed level increases and decreases, as most of the fluctuations remain in the order of up to 0.2 m, one would expect to see fluctuations of this magnitude within a river system due to the natural movement of sediment through the river system.

When considering the mean bed level and sediment volume analysis no distinct correlation is observed between the two variables. This has been determined because when observing Figure 6.14 it is noticed that there is a lot of variation between the mean bed level and sediment volume results. Whereas the sediment volume increases the mean bed level does not always tend to increase, as well as when mean bed level decreases the sediment volume does not always decrease. This is particularly noticed between the 8.48 km to 13.5 km benchmarks, where significant loss of sediment volume has occurred, but overall the mean bed level has increased. An example from this section is displayed in Figure 6.16, which displays the cross section located at the 11.58 km benchmark. In Figure 6.2, a decrease in the sediment volume is observed between the 11.58 km to 12 km benchmarks, but in Figure 6.13 a considerable mean bed level gain of almost 0.4 m has occurred, which can be visually seen in Figure 6.1.

It has to be taken into account that this relationship between the mean bed level and the sediment volume has been affected by the construction works that have occurred along this section of the river between 2012 and 2016. This leads to the conclusion that a meaningful analysis of the relationship between these two variables along the silt phase of the river cannot be drawn.

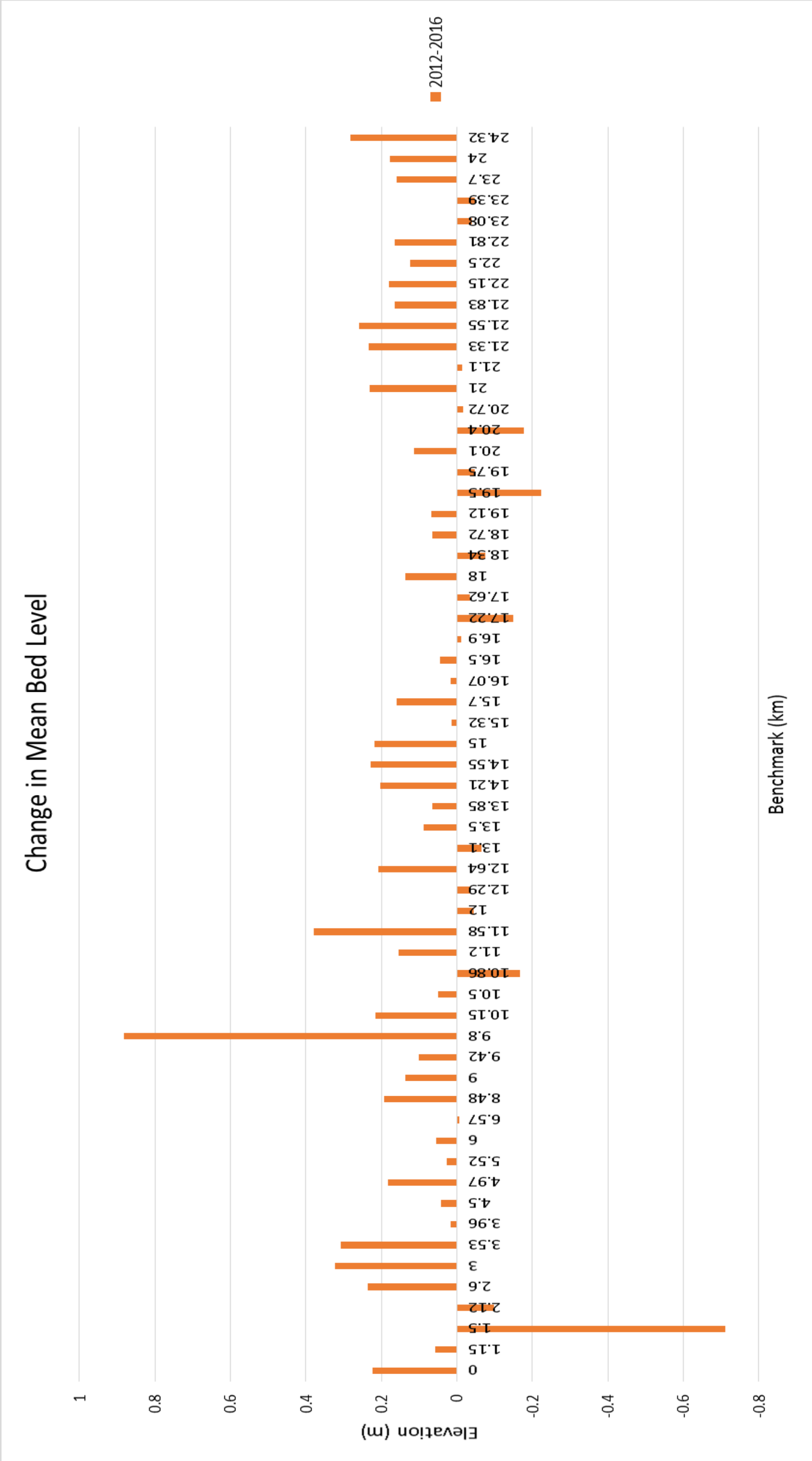


Figure 6.13. Change in mean bed level from the Manawatū confluence to Kopane Bridge.

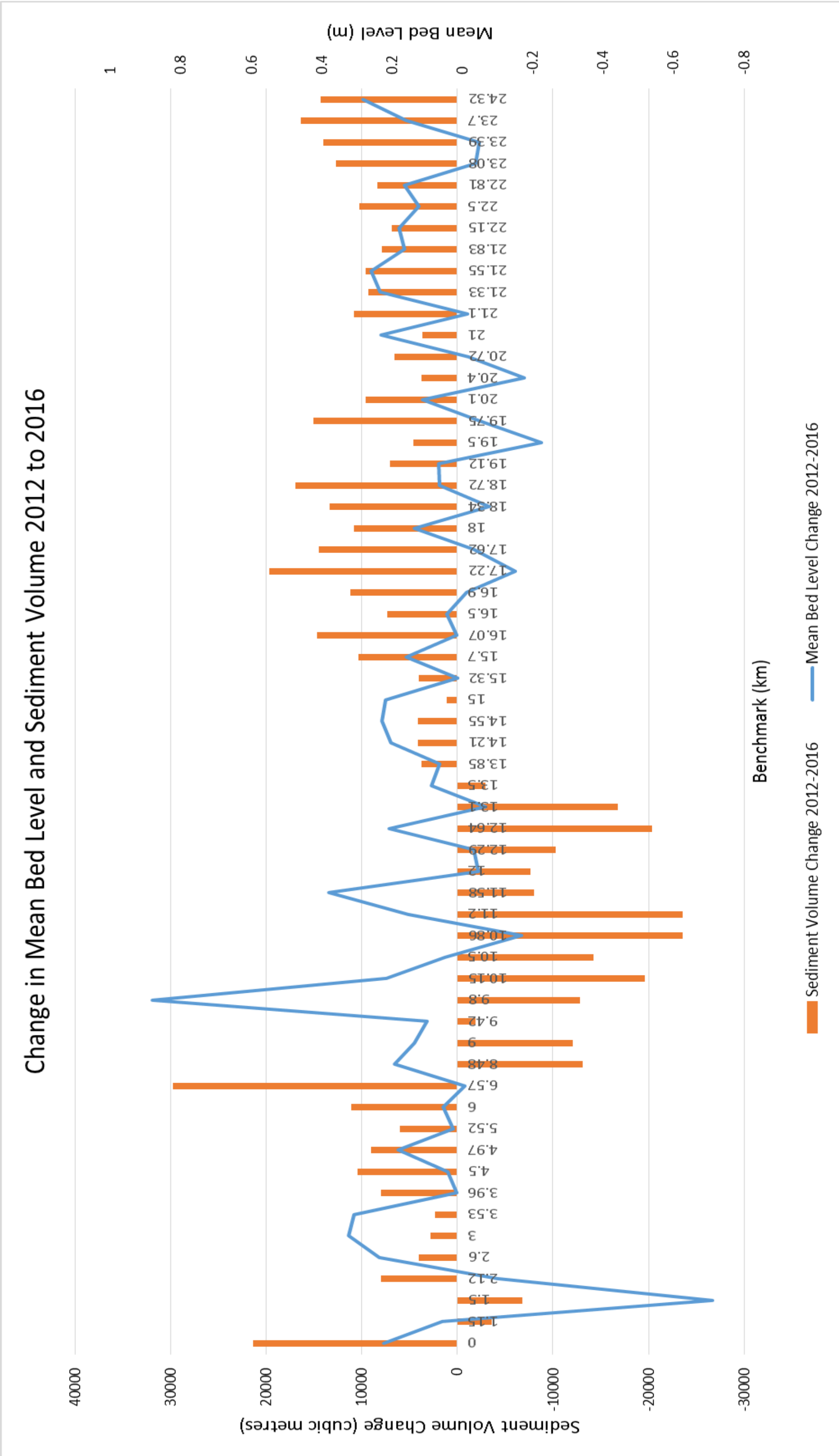


Figure 6.14. Sediment volume change and mean bed level change.

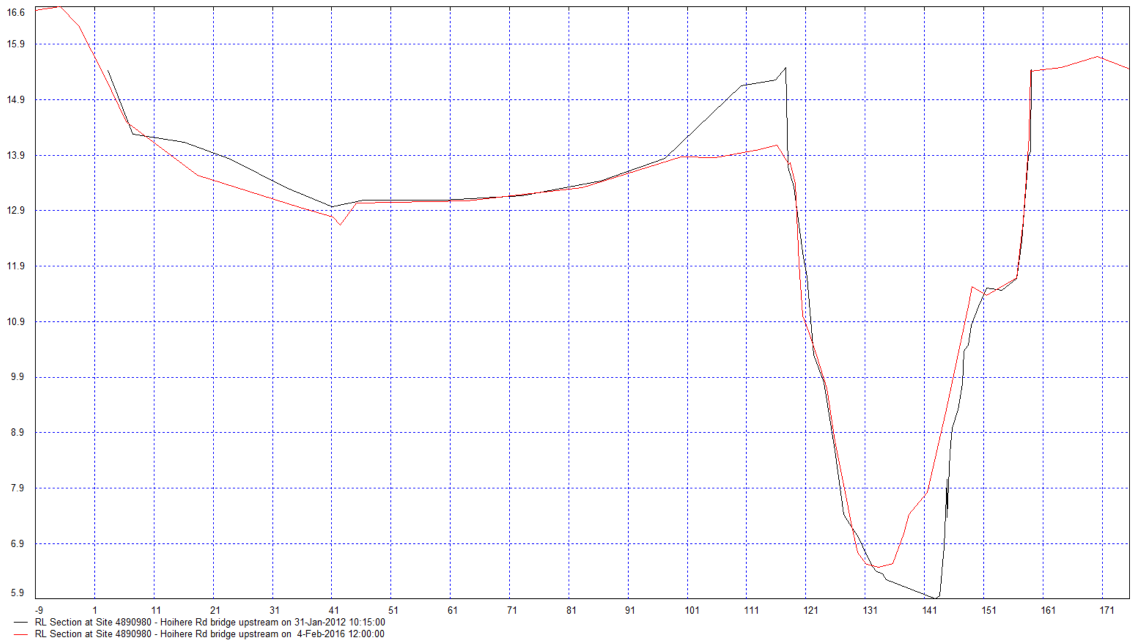


Figure 6.15. 2012 and 2016 cross section overlay at benchmark 9.8.

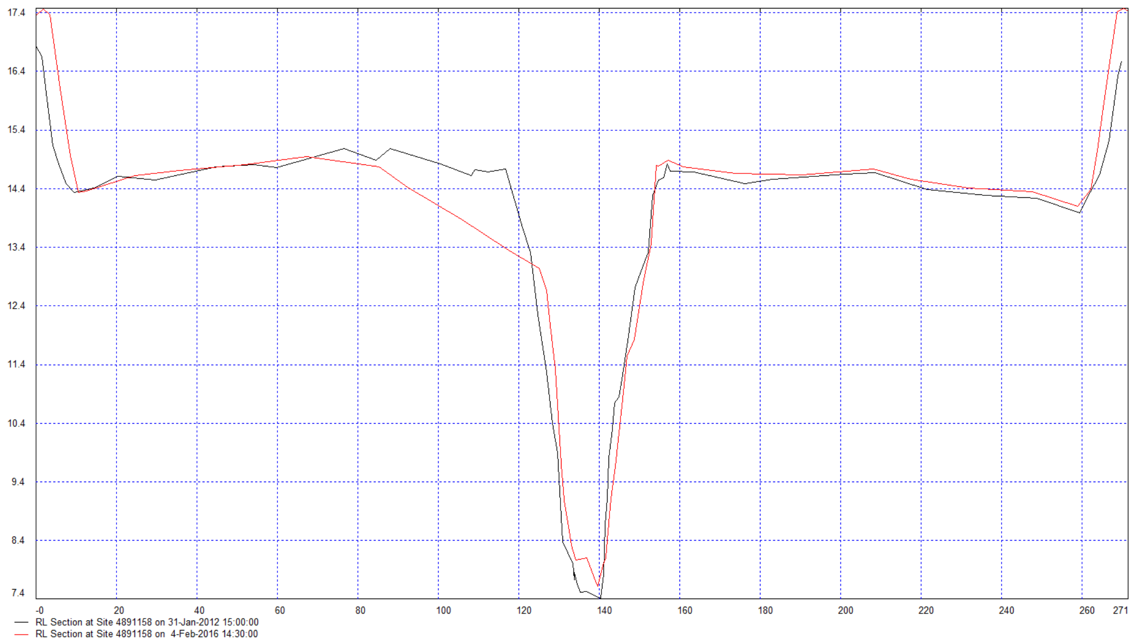


Figure 6.16. 2012 and 2016 cross section overlay at benchmark 11.58.

7. Overall Changes in the Silt Phase

When considering the results of the silt phase of the Ōroua River it is observed that the rates of sedimentation significantly vary across this phase of the river, where a large majority of the silt phase displays a significant increase in the sediment volume overall, however there is also a section which displays a significant loss of sediment. A majority of the silt phase of the river is showing a trend of aggradation on the berms and a narrowing of the channel.

Overall, the silt phase, which extends from the Kopane Bridge to the Manawatū River confluence, has seen an overall increase in the sediment volume, with only two sections displaying a loss of sediment. The results show that the silt phase has aggraded by an estimated 188,600 Cubic metres from 2012 to 2016, which equates to about 47,150 per annum.

Based on the results, an observation can be made that significant aggradation has occurred along this section of the river. It is most noticeable from just below the Kopane Bridge to just above Raupo Road, where from the cross sectional analysis it is observed that significant aggradation is occurring on the berms of the river between the stopbank toes, and the channel is also largely narrowing. This sedimentation that is occurring could affect the flood carrying capacity of the river, as the high rates of sedimentation are likely to reduce the flood carrying capacity of the river channel.

The results also displayed that a section of the silt phase had been affected by significant degradation. The degradation that was observed, was determined to be largely from the construction works that had happened along this part of the river, which included upgrading the stopbank network, where silt was removed from the berms to aid with the stopbank construction and recontouring of the river channel.

The aggradation of sediment on the berms could affect the geomorphology of the river and also lead to a reduction of the flood carrying capacity of the river. The silt phase of the Ōroua River has also been subjected to a lot of physical construction works which could also have an effect on sedimentation affects within the river. It is recommended that LiDAR surveys should be used to provide a more accurate analysis of the rates of sedimentation changes within the silt phase of the Ōroua River.

It is recommended that further investigation needs to be done around ways to mitigate the rates of sedimentation that are occurring within the Ōroua River catchment, because if these sedimentation rates continue it will have a detrimental effect on the flood carrying capacity of the river. The Ōroua River needs to be resurveyed in five years. This needs to be done to get an understanding on whether sedimentation rates are continuing to increase, and whether mitigation measures are successful if any are implemented during that period.

8. Gravel Extraction

Historically, gravel has been extracted from the Ōroua River for a range of purposes including commercial uses in construction as well as for river management purposes. For the purpose of this gravel resource study the gravel extraction records dated back to 2012 haven been used. This extraction record is being used because this gravel study is observing the changes from 2012 to 2016, so the same extraction record will be used to analyse whether the gravel extraction that has occurred since 2012 has had a noticeable effect on the gravel resource.

From 2012 to 2016, there has been six current consents for gravel extraction of the Ōroua River. Three of these consents expired during this study period, with the two Horizons Regional Council global consents (103496, Lower Manawatū Scheme and 102541, Pohangina Ōroua Scheme) and the Manawatū District Council consent remaining current (ATH-2016200840.00). A majority of the gravel extraction that occurred over this period was under the two global consents. A recorded 181,619 cubic metres of gravel has been extracted from the Ōroua River from 2012 to 2016. Figure 8.1, below, shows gravel extraction volumes each year between 2012 and 2016.

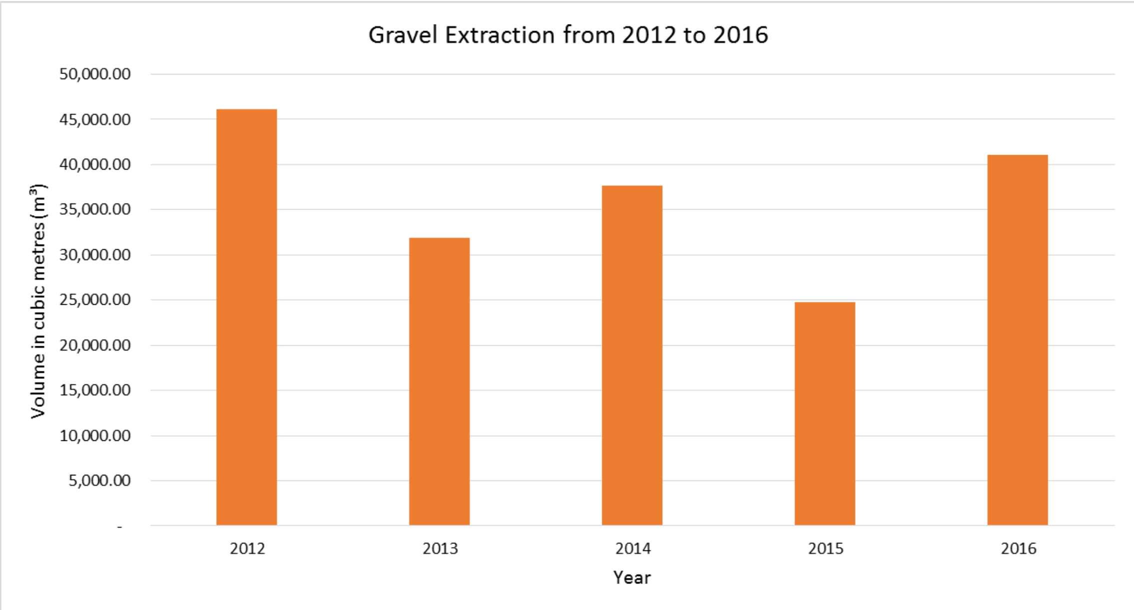


Figure 8.1. Gravel extraction volumes 2012-2016

In Figure 8.1, it is evident that rates of gravel extraction have varied over the years within this time period, with the years displaying extraction rates mainly between 25,000 and 45,000 cubic metres. In the year 2012, gravel extraction was more significant than the other years, with 2015 displaying the least amount of gravel extraction for this time period.

9. Gravel Extraction and the One Plan Reaches

9.1 Summary of Gravel Extraction and the One Plan Reaches

The One Plan breaks the Ōroua River down into two gravel extraction reaches, upstream of Menzies Ford and downstream of Menzies Ford, the location of which can be seen in Figure 9.1, below. The One Plan also outlines the long-term average allocable volumes associated with these reaches, which are outlined in Table 9.1, below. This table outlines the annual allocable volumes for gravel extraction for the two reaches along the Ōroua River.

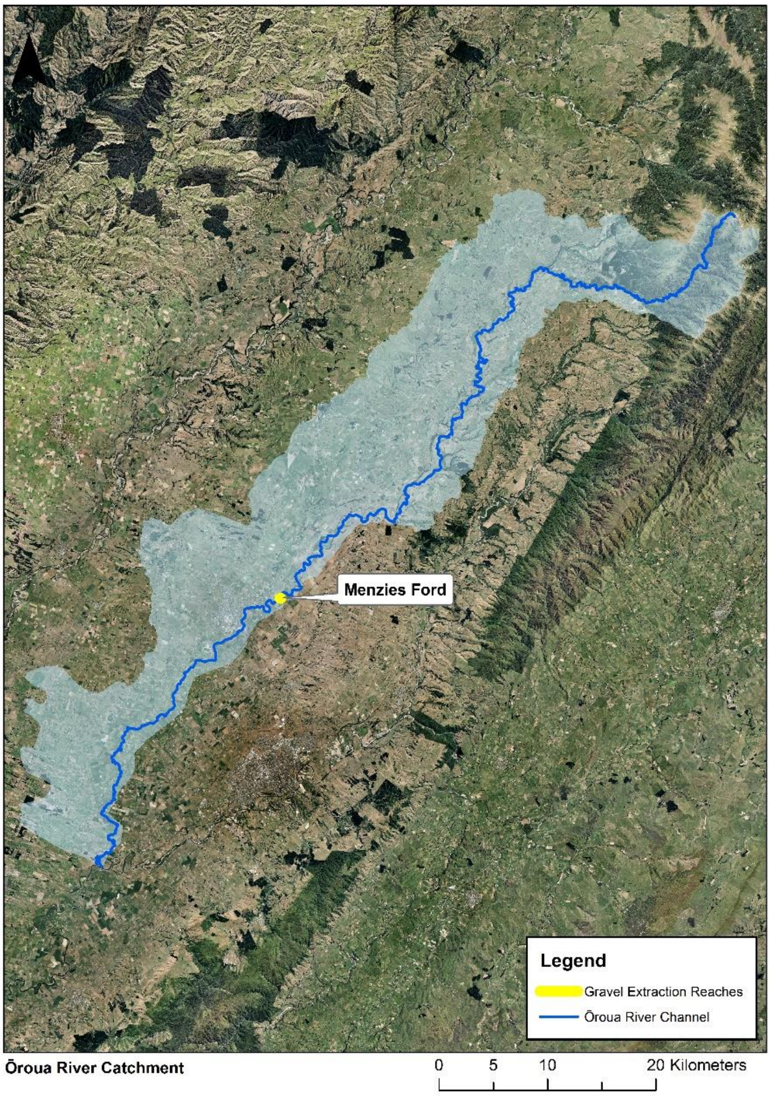


Figure 9.1. Ōroua River showing the location of Menzies Ford.

Table 9.1. Long-term average annual allocable volumes of gravel.

River or Reach	Volume (m^3)
Ōroua River	
• Upstream of Menzies Ford	10,000
• Downstream of Menzies Ford	55,000

For the purpose of this study, the One Plan reaches for the Ōroua River as identified above will be simplified into reaches one and two. This is outlined in Table 9.2, below.

Table 9.2. Reach names for this study.

One Plan Reach	Reach Name for this Study
Upstream of Menzies Ford	Reach One
Downstream of Menzies Ford	Reach Two

Since the establishment of the One Plan, gravel extraction consents are granted in association with the One Plan Reaches. The extraction amounts under a consent are then recorded against the One Plan Reaches. This is visually represented in Figure 9.2, below, where what has been extracted each year from 2012 to 2016 has been broken down in terms of the One Plan Reaches.

In Figure 9.2, it is observed that rates of gravel extraction have fluctuated in the One Plan Reaches from 2012 to 2016. It is noticed that a majority of the gravel extraction has been under 25,000 cubic metres per annum. When considering Figure 9.2 gravel extraction occurs at different rates in each of the reaches, each year. However, when the total volume of what has been extracted in each reach of the study period is considered, it is observed that the overall rate of gravel extraction has been similar in each of the One Plan Reaches from 2012 to 2016. In reach one there has been a total recorded extraction volume of 91,523 cubic metres, whereas reach two has seen a total recorded extraction volume of 90,096 cubic metres.

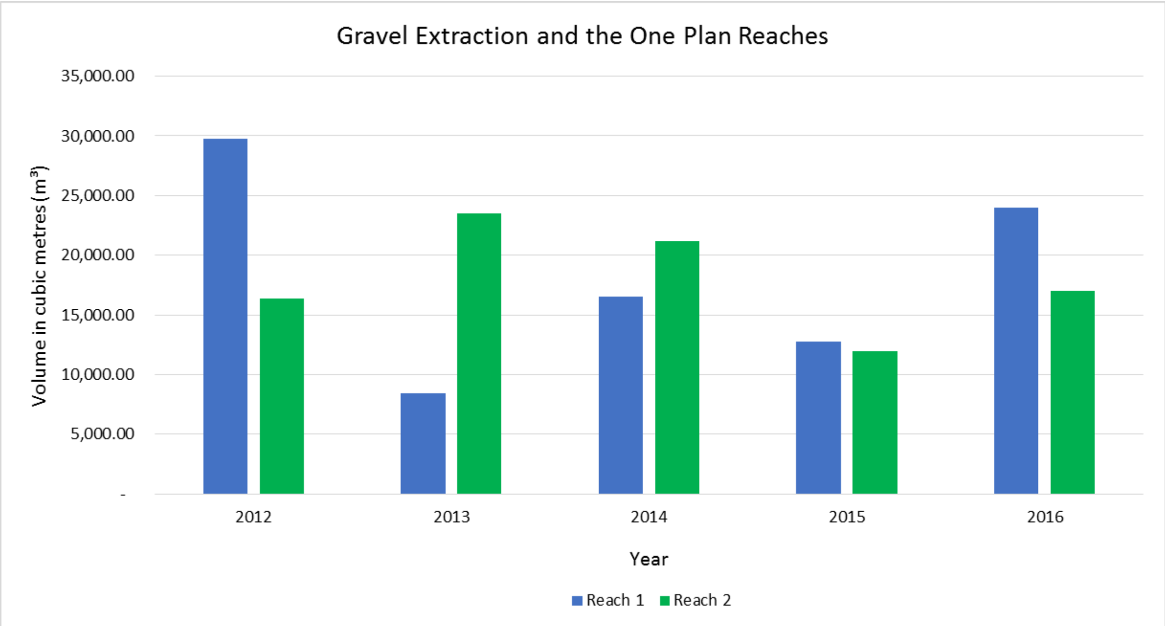


Figure 9.2. Gravel that has been extracted in each of the One Plan Reaches since 2012.

Table 9.3. Summary of extraction rates within the One Plan Reaches.

Year	Reach 1 (m^3)	Reach 2 (m^3)
2012	29,773	16,400
2013	8,456	23,475
2014	16,532	21,170
2015	12,747	12,000
2016	24,015	17,051
Total	91,523	90,096

9.2 Allocation of the One Plan Reaches

In Table 9.4 below, a summary of the gravel consents that were current during the 2012 to 2016 period can be observed. From the table it is noted that consents 102772, 105495, and 106639 expired during this period. The remaining current consents are the only three current consents for gravel extraction within the Ōroua River as at 2019.

During the period from 2012 to 2016 One Plan reach one has been over allocated. Reach one is located above Menzies Ford and has an annual allocable volume of 10,000 cubic metres in the One Plan, Table 9.1. From Table 9.4 it can be seen that during this period this reach has been consented for gravel extraction which exceeds the amount in the One Plan. However, when considering the allocation of gravel extraction consents under the One Plan some factors have to be take into consideration, in particular with Reach one. Considerations that need to be made are that consents 102541 (Horizons consent) and 105495 (NOTE: Consent ATH-2016200840.00 replaced 105495 when it expired), were issued before the One Plan came into effect, so these extraction volumes were determined before the table of long term average annual allocable volumes for gravel extraction existed. Since the implementation of the One Plan Reach one is considered to be over allocated.

Reach one is also outside of the study area as the cross sectional surveys taken along the Ōroua River do not include Reach one. This means that it is not known how the gravel resource is being affected within reach one of the One Plan, and whether or not the long term average annual allocable volume is still appropriate.

Reach two of the One Plan, which is located downstream of Menzies Ford has an annual allocable volume of 55,000 cubic metres in the One Plan, Table 9.1. From Table 9.4 it can be observed that over the period from 2012 to 2016 this reach was considered to be over allocated in terms of the One Plan. However, this is difficult to quantify as consent 102541 spans over part of reach two from the confluence with the Kiwitea Stream to Menzis Ford, and part of reach one from Menzies Ford to 500 upstream of the Apiti Road Bridge at Kimbolton. However, when analysing the locations of where the gravel is mainly extracted under this consent it was observed that a majority of the extraction under consent 102541 takes place within reach one of the One Plan. This leads to the conclusion that Reach two is unlikely to be over allocated as a majority of the gravel extraction under this consent takes place in Reach one. It can also be observed that from 2016 onwards the amount allocated under consent 103496 (Horizons global consent), reduced from 50,000 cubic metres to 15,000 cubic metres.

Currently, at 2019, reach one is over allocated according to the One Plan specifications, and Reach two has not yet reached its allocation limit.

Table 9.4. Overview of Ōroua River Gravel Extraction Consents.

Consent Number	Year Issued	Year Expires	Allocated Volume per annum (m³)	Status 2019	One Plan Reach
103496	2006	2026	Extract up to 50,000 for ten years and thereafter up to 15,000	Current	Reach Two
102541	2004	2023	30,000	Current	Reach One/Two
102772	2004	2014	3,000	Expired	Reach Two
105495	2011	2016	10,000	Expired	Reach One
106639	2013	2013	1,200 (once off)	Expired	Reach One
ATH-2016200840.00	2016	2021	10,000	Current	Reach One

10. Overall Change in the Gravel Resource from 2012 to 2016

Overall, it can be concluded that the gravel volume for the Ōroua River gravel reach has aggraded since 2012. However, when considering the observed volumetric changes in the gravel resource combined with the gravel extraction volumes that have been recorded, an increased understanding can be gained about the condition of the gravel supply rates within the Ōroua River. This is because when these two variables are combined an estimation as to what the gravel volume may have looked like without extraction can be obtained.

To stay within the scope of this study Reach one, which is upstream of Menzies Ford will have to be excluded when considering the overall change in the gravel resource from 2012 to 2016. This is because the gravel extraction that has occurred within this reach is outside of the scope of this study. This Reach is considered to be outside the scope of the study because the cross sectional survey data does not cover this Reach of the Ōroua River. Therefore, no meaningful conclusions could be drawn from analysing this Reach of the Ōroua River.

In Table 10.1 below, a summary of the volumes can be observed. When combining the total gravel volume change and the gravel extraction quantities, as displayed below in Table 10.1, the net gravel volume change worked out to be an estimated 275,750 cubic metres, which equates to an estimated 68,900 cubic metres per year of aggradation, in the Ōroua River gravel reach.

Table 10.1. Summary of gravel volumes.

	2012-2016 (m^3)
Total Volume Change	94,133.75
Extraction Volume	181,619
Net Gravel Volume	275,752.75
Net Gravel Volume per annum	68,938.19

This overall summary has been further broken down below into the One Plan Reaches, so an understanding of the volumetric changes can be observed in each of the extraction reaches.

Table 10.2. Summary of gravel volumes within the One Plan reaches.

	One Plan Reaches (m^3)	
	Reach One	**Reach Two**
Total Volume Change	Unknown	94,133.75
Extraction Volume	91,523	90,096
Net Gravel Volume	Unknown	184,229.75
Net Gravel Volume per annum	Unknown	46,057.44

As mentioned above, Reach one is outside the scope of this study, which is confirmed in Table 10.2, where it can be observed that no information can be obtained on the change in gravel volume. This table represents how the gravel resource has been affected from 2012 to 2016, where the total volume change represents the inferred gravel supply rate to the Reach, which can be observed in Figure 5.1. The extraction volume includes what has been extracted in each Reach from 2012 to 2016. The net gravel volume is the total volume change and extraction volume added together. This gives an idea of gravel supply rates before extraction has occurred. The net gravel volume per annum is the net gravel volume divided by four years, which gives an estimate of the gravel supply rate to the Reach per year from 2012 to 2016.

From Table 10.2 it can be observed that the inferred rate of gravel supply to One Plan Reach two is considerable, however the extraction quantities that have occurred within this Reach are significant. In the previous study, which is mentioned in Section 11, the gravel volume was considered to be in a degradation state where overall the gravel reach of the river was subject to a loss of gravel. The results from this study show that the gravel reach of the river is recovering where gravel aggradation is occurring.

One Plan Reach two from which gravel is extracted from, covers the Ōroua River from downstream of Menzies Ford to the Manawatū River confluence. However, for the purpose of this study the gravel reach is assessed as being from above the Kiwitea Stream confluence as this is as far as the cross section surveys extend, to just below the Kopane Bridge which is the extent of the gravel reach in this study. From the analysis, it has been determined that the gravel reach of the Ōroua River is recovering as aggradation has occurred from 2012 to 2016. When the total volume change is compared with what has been extracted it is observed that considerable aggradation of the gravel resource has occurred even though the river has been subjected to substantial gravel extraction.

When these observations are compared with the One Plan, annual allocable volume for this Reach, which is 55,000 cubic metres, it is observed that the amount that could be extracted under the One Plan each year has not been extracted each year over this study period, as a total recorded volume of 90,096 cubic metres has been extracted from 2012 to 2016.

However, even though the gravel extraction rates have not been met each year it doesn't mean to say that they should be met each year. This conclusion has been drawn through consideration of the changes in the gravel resource. When considering the net gravel volume per annum it has been estimated that the overall gravel resource has aggraded by around 46,000 cubic metres per annum from 2012 to 2016 (excluding gravel extraction). This leads to the recommendation that the One Plan average annual allocable volume of 55,000 cubic metres might not be appropriate for this Reach as the gravel resource is not considered to be aggrading by this much per annum. It is recommended that 45,000 m^3 could be considered a more appropriate annual allocable volume according to the findings of this report. However, it is difficult to draw a meaningful conclusion around the appropriateness of the One Plan allocable volume for Reach two because the extent of the cross section surveys do not cover the entire reach so it is not known how the gravel resource is being affected above the Kiwitea Stream confluence to Menzies Ford.

It is recommended that the length of the surveyed Reach of the Ōroua River, should be extended further upstream of the Kiwitea confluence to include the rest of Reach two and Reach one of the One Plan. The survey should be extended to a point upstream of Ōroua Valley Road, as indicated in Figure 10.1, below. This is because currently no meaningful conclusions can be drawn about how the gravel resource in the rest of Reach two is being affected or in Reach one upstream of Menzies Ford, which has gravel extraction annual allocation limit of 10,000 cubic metres under the One Plan. This should be implemented when the next cross sectional survey is carried out along the Ōroua River. It is recommended that the Ōroua River will have to be reassessed in the 2020-2021 season to see how the gravel resource is being affected.

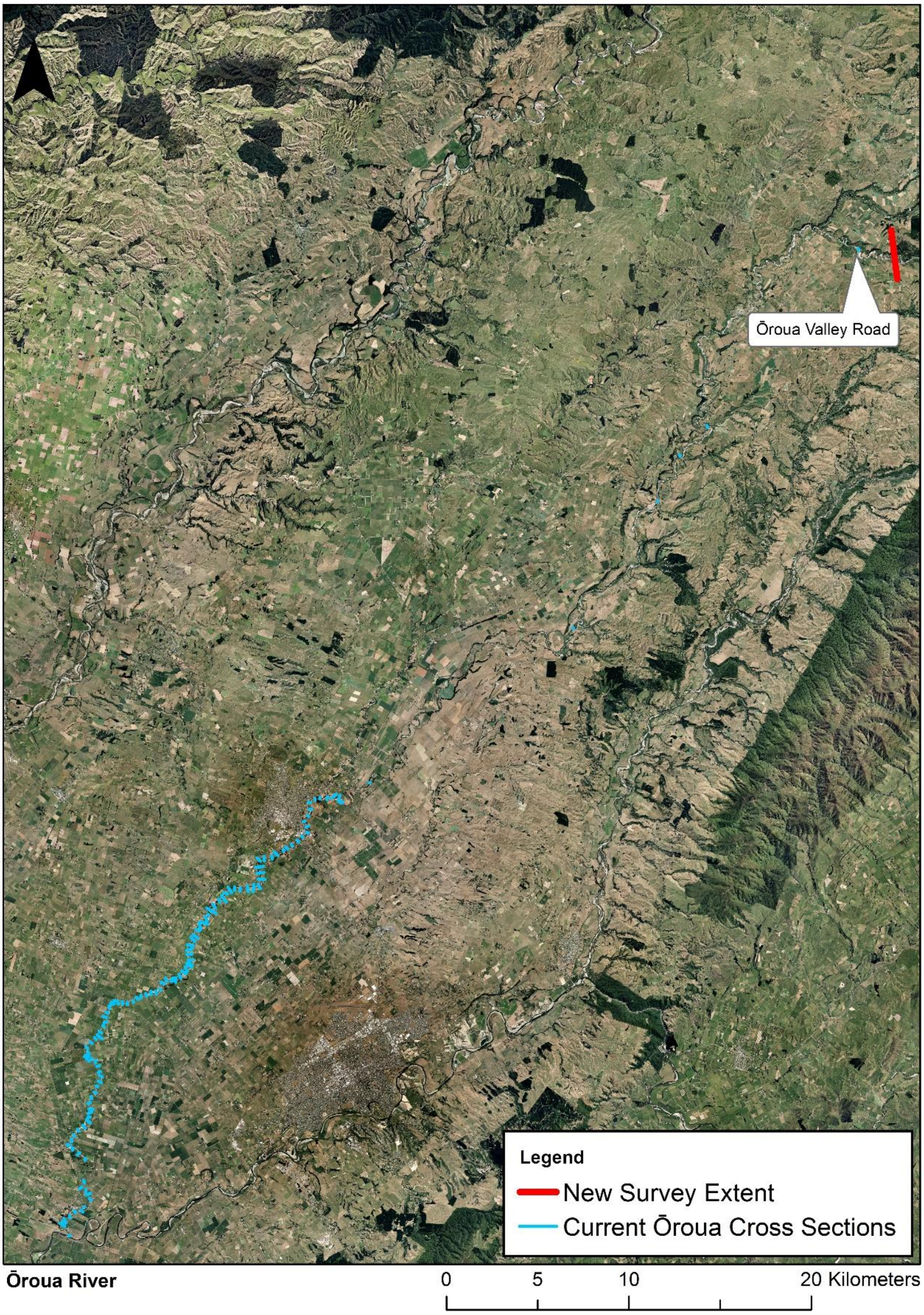


Figure 10.1. Showing current cross section survey extent and the new recommended survey extent (cross section surveys should extend up to the red line).

11. 2012 Ōroua River Gravel Resource Study Comparison

The 2012 Gravel Resource Study made a number of conclusions about trends in the gravel resource and fine sediment of the Ōroua River, which are summarised below:

- The volume under the active channel shows aggradation had occurred in the lower half of the Reach, below Kaimatarau Road to the Manawatū confluence.
- The main finding of the 2012 study is that there had been a general trend of degradation of the volume of gravel in the upper half of the Reach from Kaimatarau Road to a point just upstream of the confluence with the Kiwitea Stream.
- The 2012 study found that there was approximately 900,000 cubic metres more material beneath the active channel than there was in 1998, the material is thought to have consisted of a higher proportion of fine sediment.
- This study found that it was particularly important to monitor the levels of aggradation in the lower half of the Reach, below Kaimatarau Road, as a continuation in this trend could lead to a loss of flood carrying capacity in the river channel.

The following looks at whether these trends have continued or changed.

In the 2012 study, it was observed that aggradation occurred in the lower half of the Reach from Kaimatarau Road to the Manawatū River confluence (22.5 km to 0 km benchmark), where this part of the Ōroua River aggraded by an estimated 1,200,000 m^3, which equates to around 85,700 m^3 per annum. This study considers this section to be a part of the silt phase of the river. From the results of the analysis of this gravel resource study it has been estimated that this part of the Reach has continued to aggrade and has aggraded by an estimated amount of 157,000 m^3, which is around 39,250 m^3 per annum. The results from the 2012 study and the results from this study are difficult to compare with any accuracy, as the offsets used when calculating the results for the 2012 study will be different to some of the offsets used to obtain the results in this study. Different offsets have been used because in this study, the silt phase is quantified between the toe to toe of the stopbanks. Therefore, only an overall conclusion can be drawn that this section of the river is continuing to aggrade.

The 2012 study concluded that there is a general trend of degradation of the volume of gravel from Kaimatarau Road to a point upstream of the confluence with the Kiwitea Stream, where an estimated 280,000 m^3 of material was lost from this section of the Ōroua River. For this study, the location from Kaimatarau Road to just upstream of the confluence with the Kiwitea Stream includes some of the silt phase of the river and the gravel reach of the river. Therefore, the silt phase is to be excluded, as the gravel volume is what is being assessed for this comparison, the change in gravel volume will be taken from just below the Kopane Bridge to just upstream of the confluence with the Kiwitea Stream. The results from this study show that this part of the Ōroua River, which is considered to be the gravel reach, has aggraded by an inferred rate of 94,100 m^3. However, since some of the offsets that have been used in the previous study will be different to the offsets used in this study, a direct comparison between the two volumes can't be made. Different offsets have been used in this study, because since the last study there have been some changes in the cross section channel shape. It can only be concluded that overall that gravel volume is starting to increase along this section of the Ōroua River.

The overall finding of the previous study found that form the Manawatū River confluence to above the Kiwitea Stream confluence, the Ōroua River, overall, aggraded by an estimated 900,000 cubic metres beneath the active channel from 1998 to 2012, which equates to 64,280 per annum. The findings from this study suggest that overall the Ōroua River has aggraded by an estimated 280,000 m^3 along the entire study length, which equates to 70,000 per annum. However, the result from this study includes the volume beneath the active channel from the gravel reach and the volume from the toe to toe of the stopbanks for the silt phase, so a direct comparison between the two volumes can't be made. It can be assumed that overall the study section of the Ōroua River is continuing to aggrade at a similar rate to the previous study from 2012.

The last conclusion from the 2012 study points out the need to monitor the levels of aggradation in the lower half of the Reach, below Kaimatarau Road, as a continuation of this trend could lead to a loss of flood carrying capacity in the river channel. This study outlines that the silt phase of the river is considered to be from just below the Kopane Bridge to the Manawatū River confluence, and overall the results show that rates of sedimentation have continued to increase. It is estimated that this part of the river has aggraded by 188,600 m^3. This significant aggradation of sediment could reduce the flood carrying capacity of the river, so it is recommended that mitigation measures need to be further investigated to reduce the rates of sedimentation within this part of the river, in particular ways to reduce sedimentation on the berms between the stopbanks.

12. Conclusions

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

- Overall, between 2012 and 2016 the gravel volume is estimated to have aggraded by 94,100 cubic metres across the gravel reach, which equates to around
23,525 cubic metres per annum.
- Mean bed level has increased across a majority of the gravel reach largely in the order of magnitude 0 to 0.2 m.
- There is a correlation between the gravel volume and mean bed level of the gravel reach, where generally as the gravel volume increases and decreases, the mean bed level increases and decreases as well.
- Overall, between 2012 and 2016 the silt phase has seen a significant increase in sediment volume with an estimated aggradation of 188,600 cubic metres, which equates to round 47,150 cubic metres per annum.
- Mean bed level has increased across a majority of the silt phase largely in the order of magnitude of 0 to 0.2 m.
- The consistent trend along the silt phase of the Ōroua River is aggradation on the berm land and a narrowing of the river channel.
- From 2012 to 2016 there was six consents for gravel extraction of the Ōroua River, three of which expired during this study period, with three remaining current as of 2019.
- From 2012 to 2016, 181,619 cubic metres of gravel has been extracted from the river channel.
- Gravel extraction has occurred at similar rates in Reaches one and two of the One Plan, however no survey information is available for reach one so it is not known how the gravel resource has been affected in this reach.
- Reach one of the One Plan is outside the scope of this study because the cross sectional survey data does not cover this Reach of the Ōroua River. Therefore no meaningful conclusions could be drawn from this Reach.
- Reach two of the One Plan is aggrading within the gravel reach, however the One Plan allocable volume of 55,000 cubic metres per annum is not considered to be appropriate for this Reach and should be reduced to 45,000 cubic metres for sustainable gravel management.
- When the findings of the 2012 gravel study are compared to the results of this gravel study, it is observed that since the 2012 study the degrading gravel reach is starting to replenish its gravel resource. It was also observed that the Reach from Kaimatarau Road to the Manawatū River confluence is continuing to aggrade.

13. Recommendations

- The entire Ōroua River should be resurveyed up to the new survey extent in the 2020-2021 season so that the gravel reach and silt phase of the river can be reassessed. The extent of the survey reach should be increased as it is not known how the gravel resource is being affected in reach one and part of Reach two of the One Plan.
- Sediment volume in the silt phase of the river has continued to increase significantly, so it is recommended that mitigation measures or solutions are sought to reduce the volume of sediment aggradation within this part of the Ōroua River.
- It is recommended that the One Plan average allocable volume of 55,000 cubic metres for Reach two is currently not appropriate as reach two is not considered to be aggrading by this much per annum. It is recommended that 45,000 cubic metres could be considered more appropriate for this reach. This can be revised in the next gravel resource study to see if this trend continues to occur.

14. Appendix A – Locations of Cross Sections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11.58
10.86
9.8


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17.62
17.22
16.9
16.5
16.07
15.7
15.32
15
14.55
14.21
13.85
13.5


N
23.39
23.08
22.81
22.5
22.15
21.83
21.33
21
20.72
20.4
20.1
19.75
19.5
19.12
18.72
18.34
18
17.62
17.22


27.57
27.25
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26.88
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26.37
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25.5
25.05
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24.32
24
23.7
23.39
23.08
22.81
22.5
22.15
21.83
21.65
21.33
21
20.72


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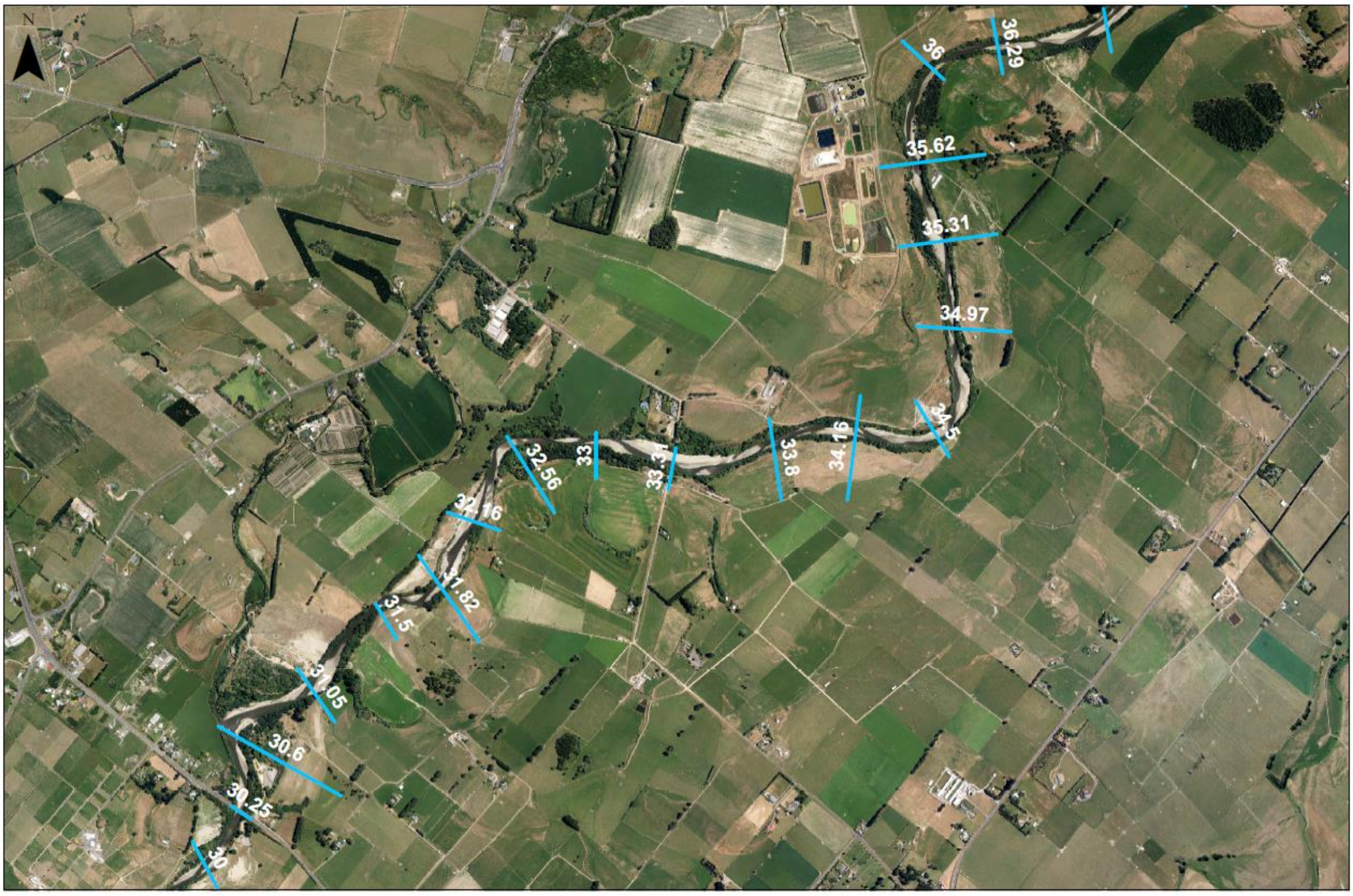
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35.31


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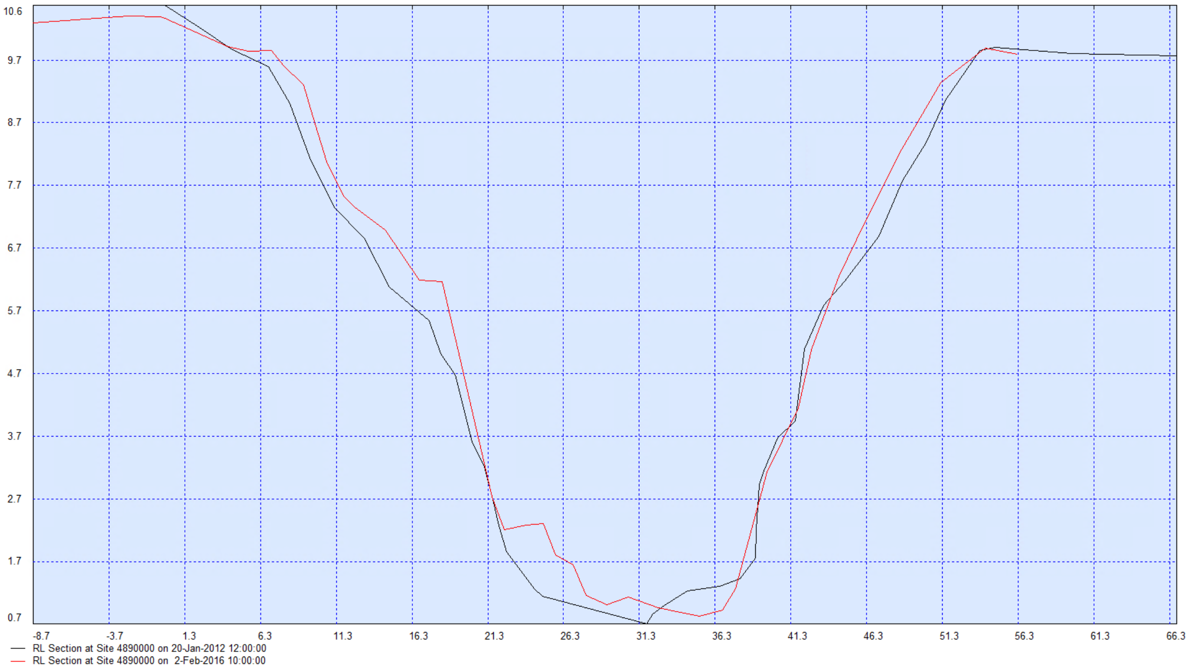
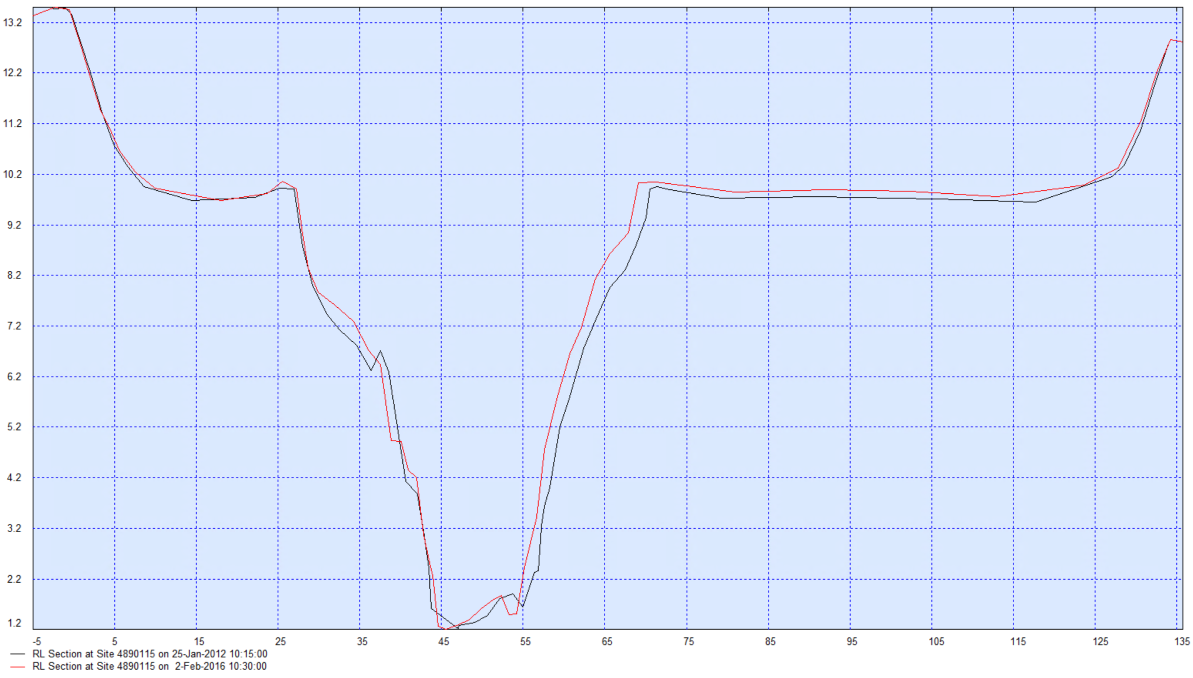
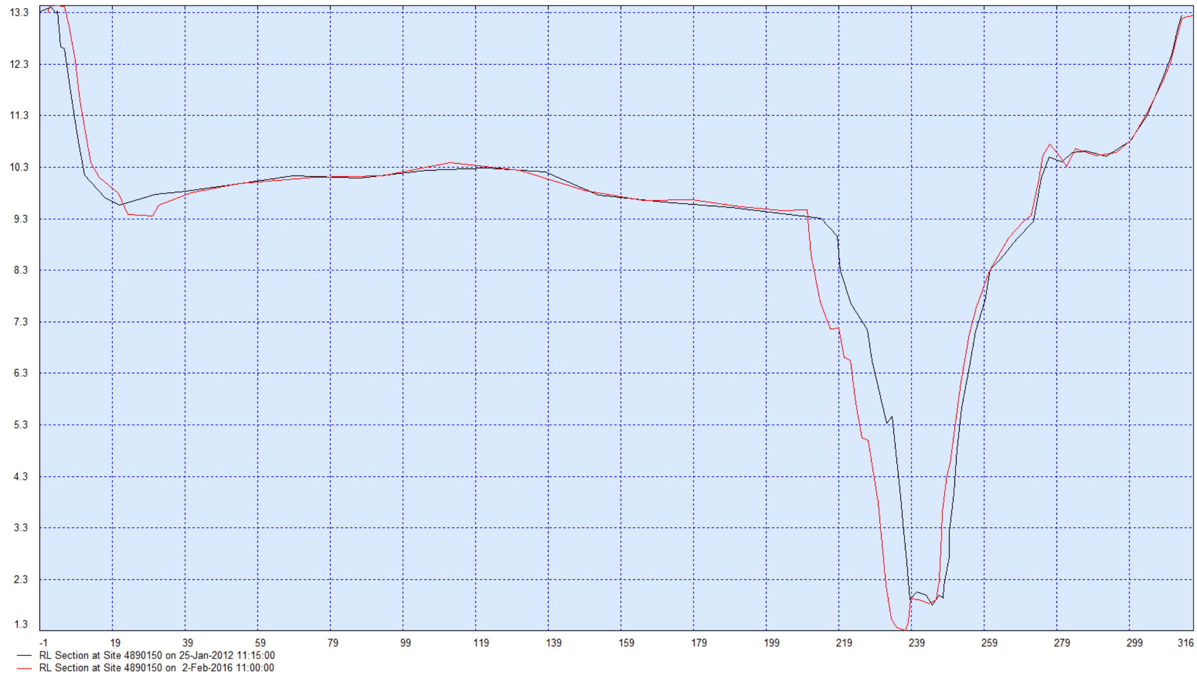
15. Appendix B – Cross Sections



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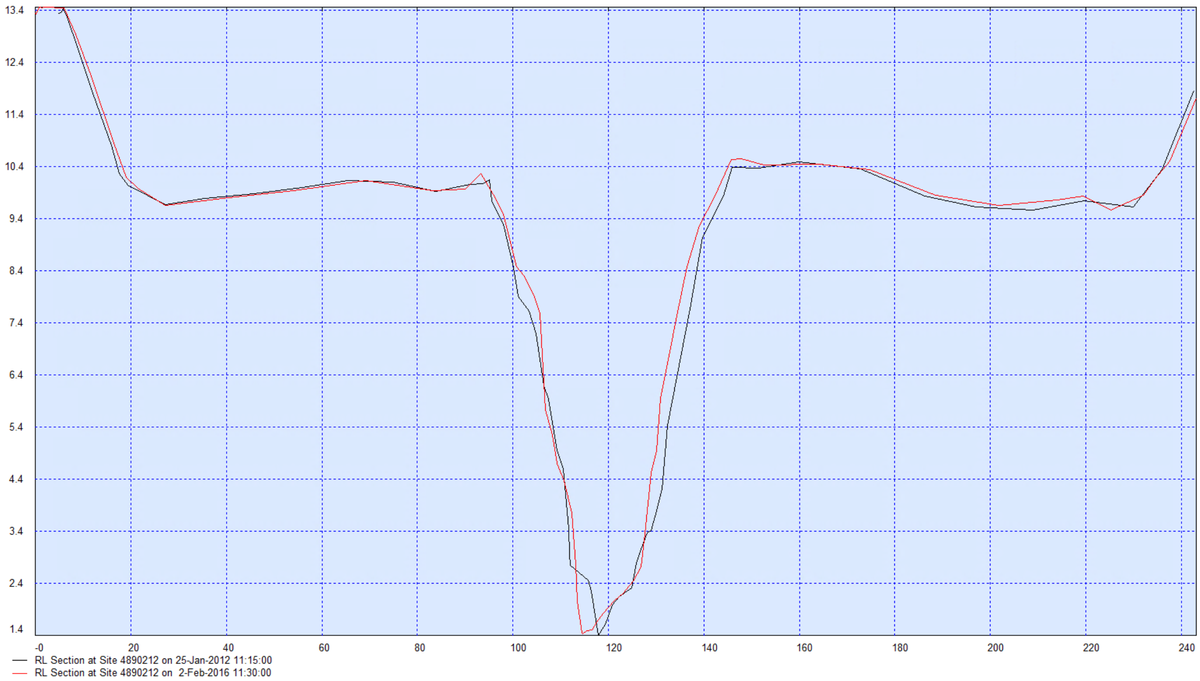
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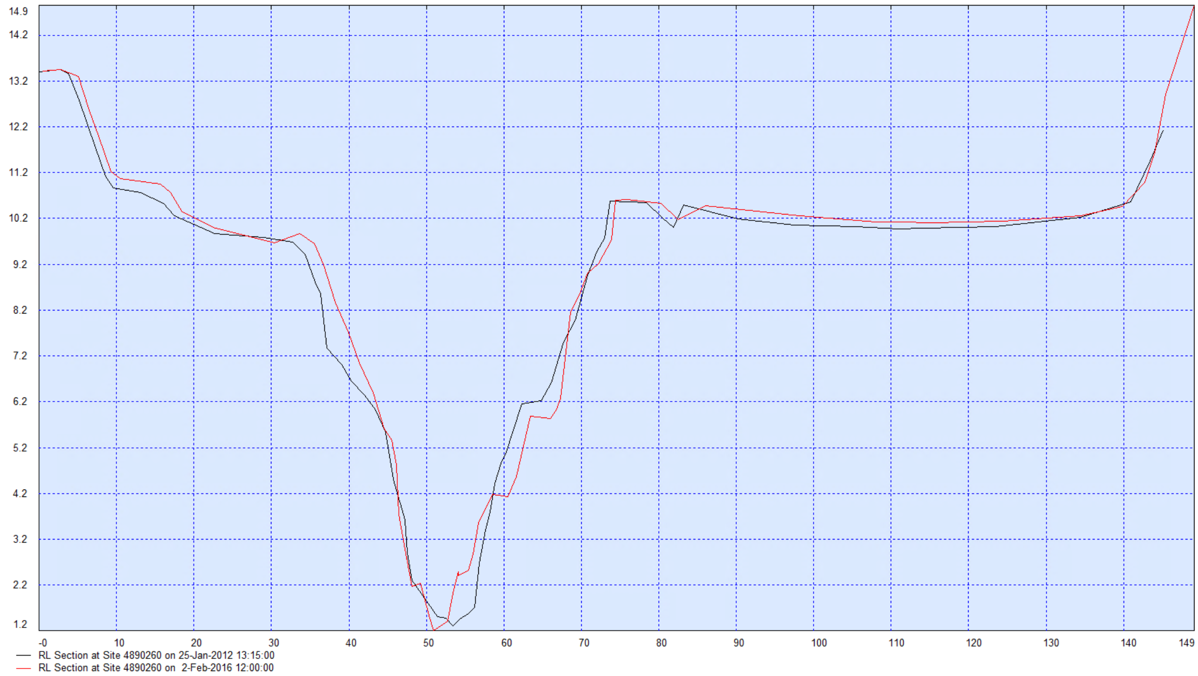
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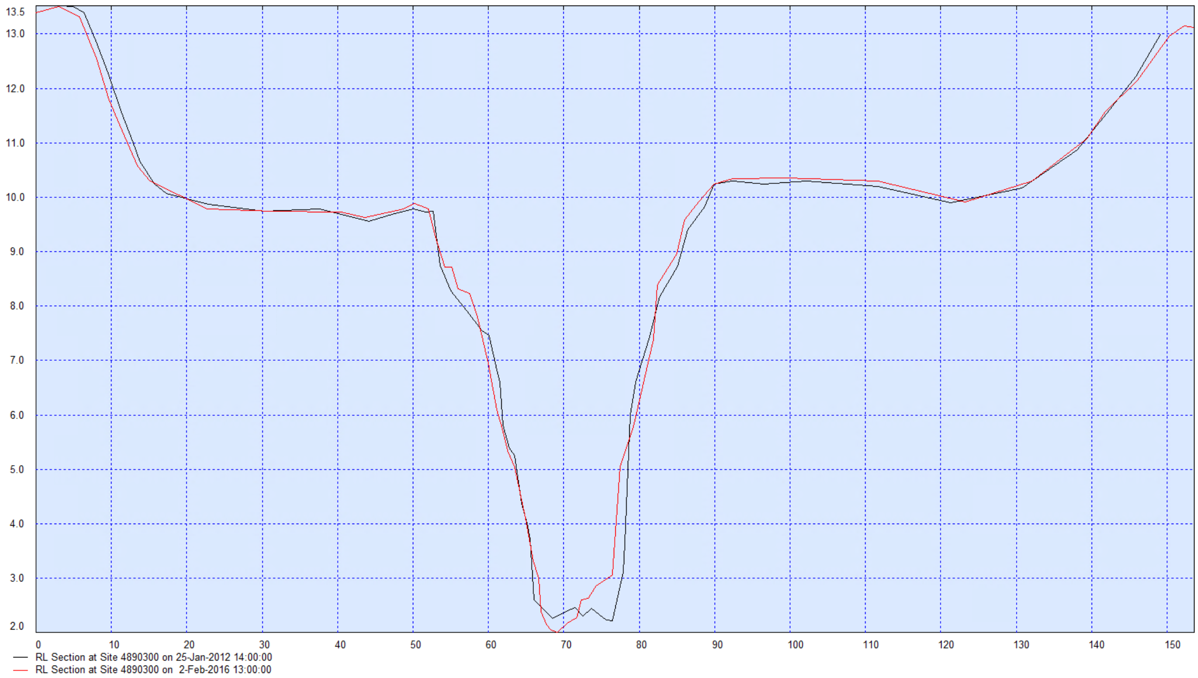
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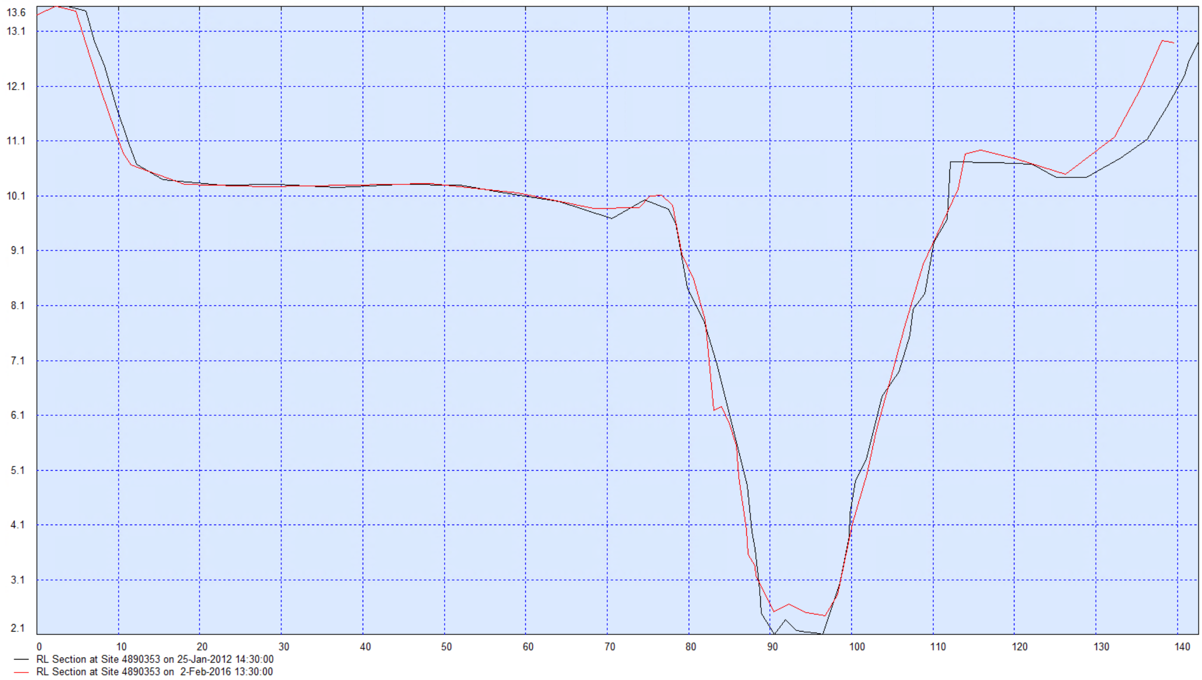
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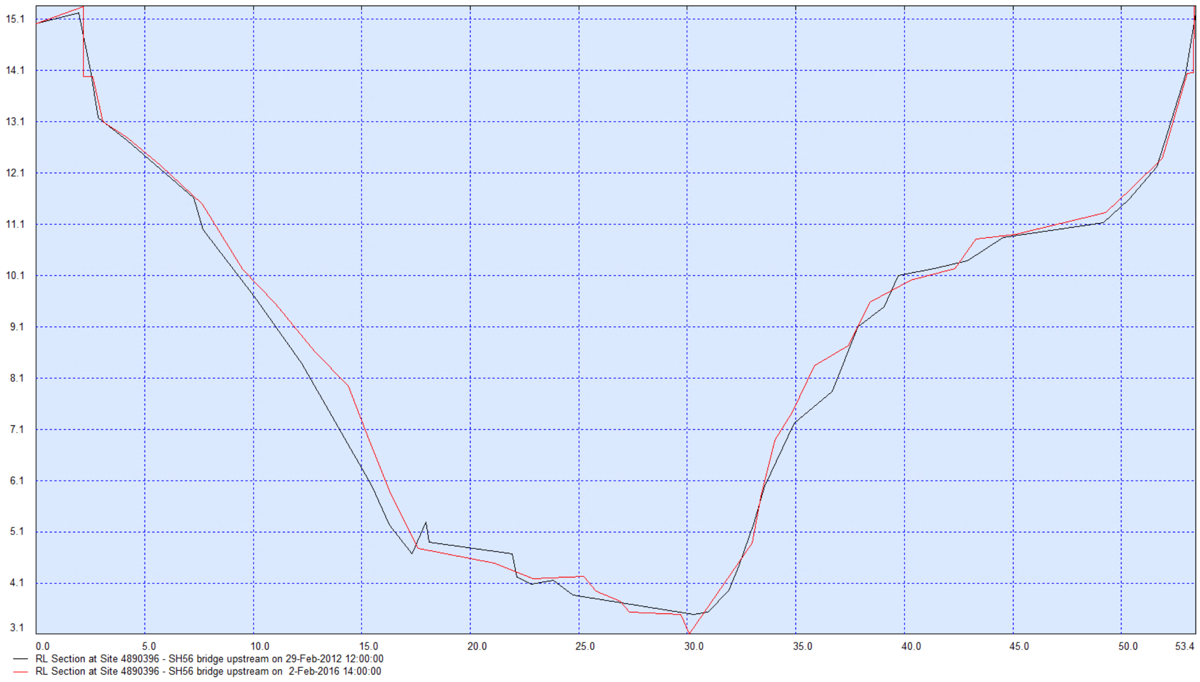
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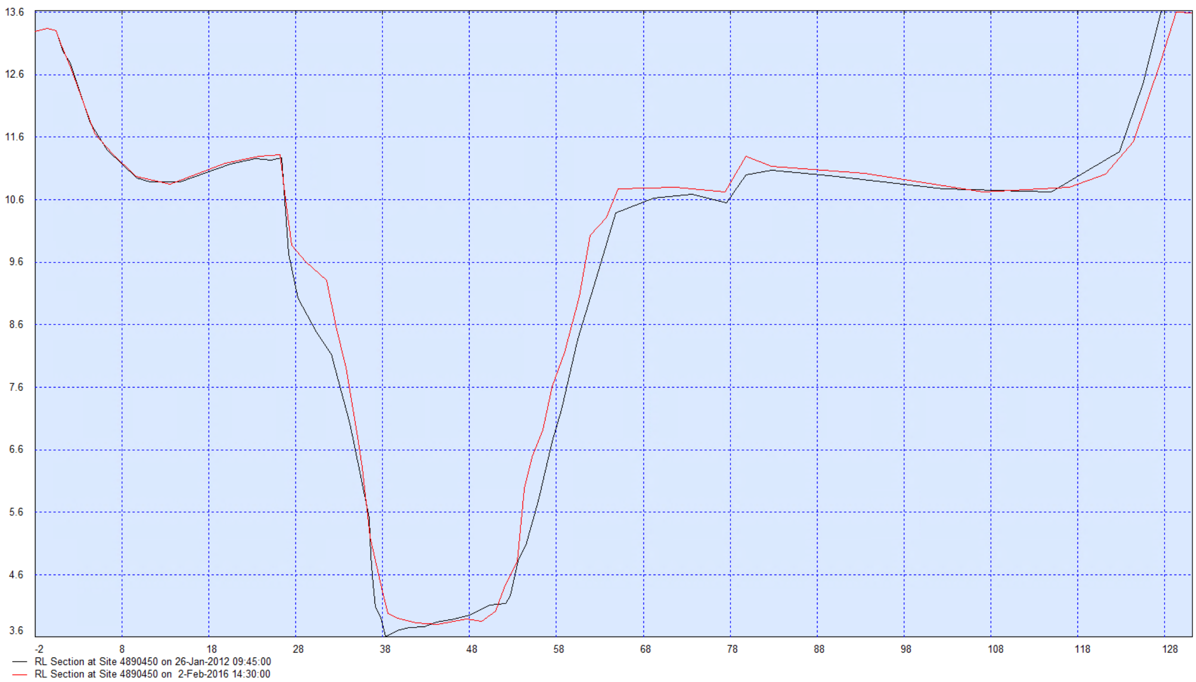
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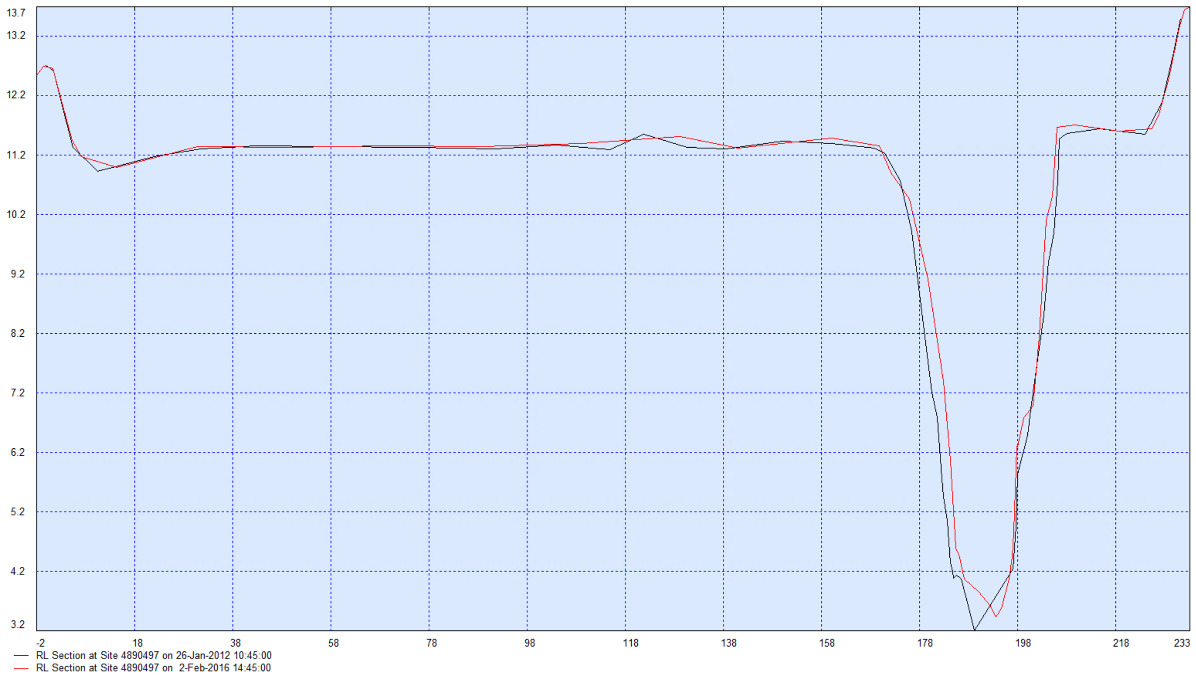
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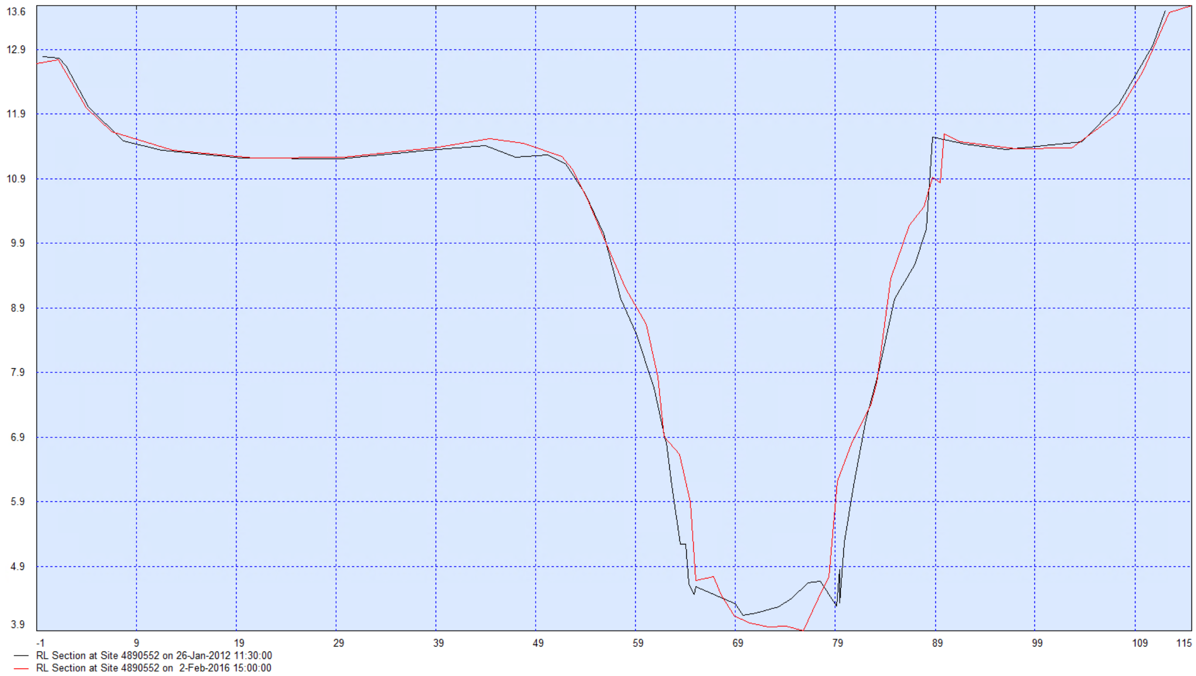
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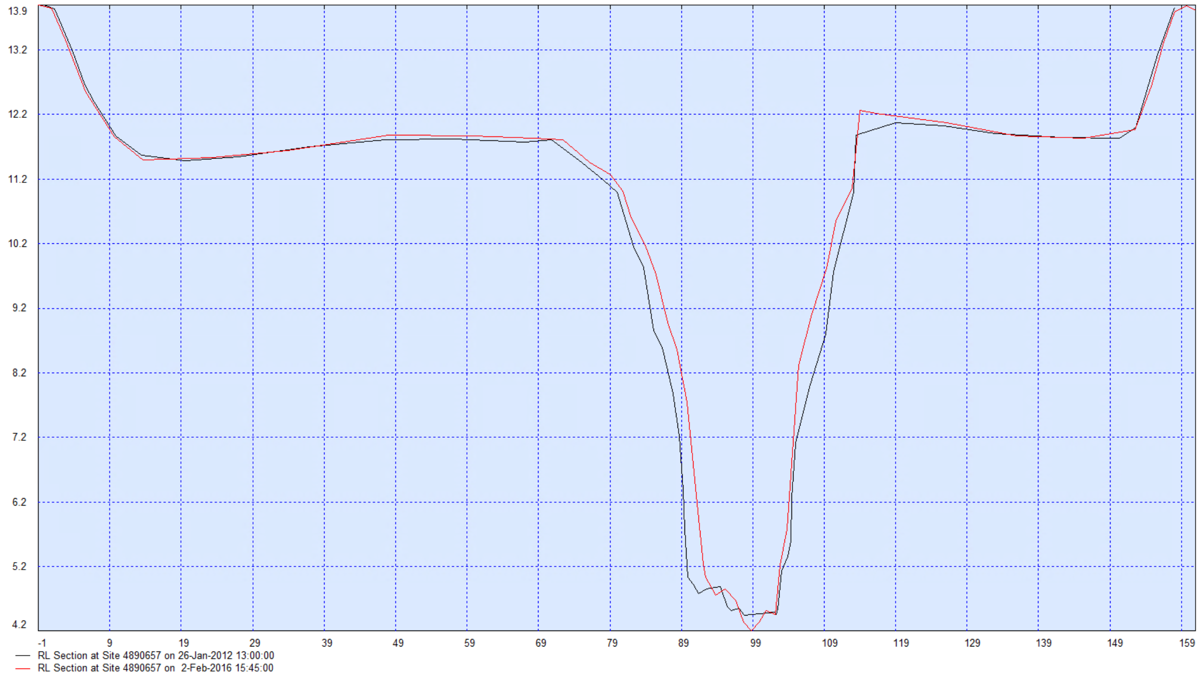
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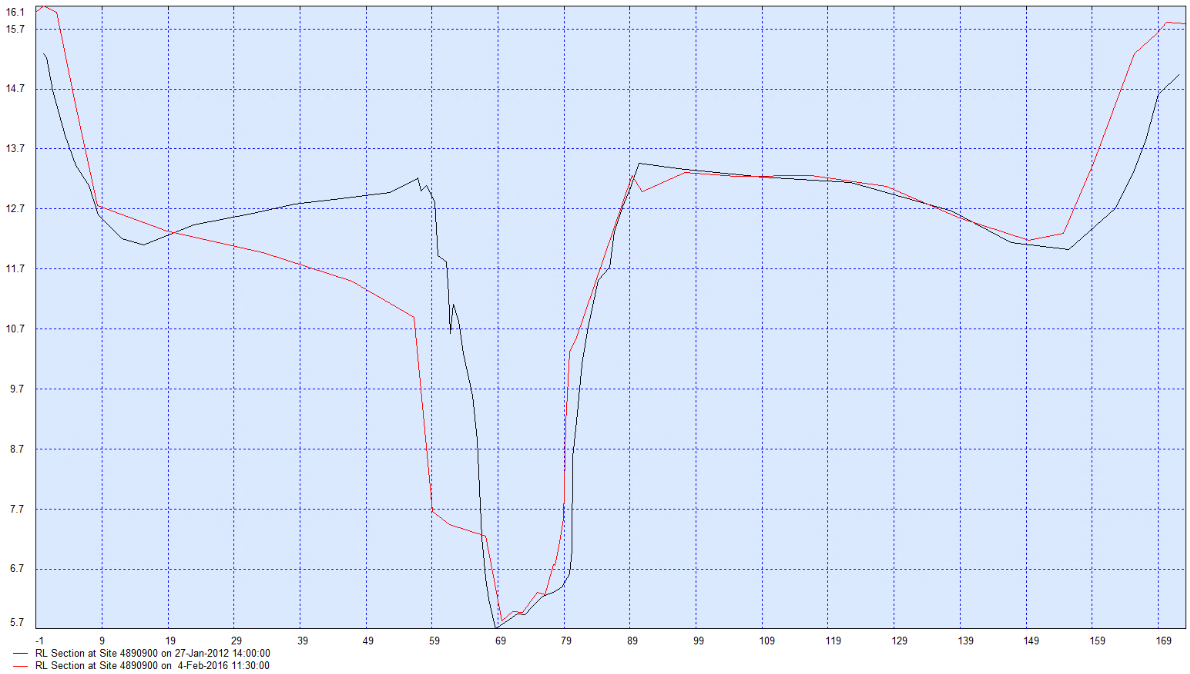
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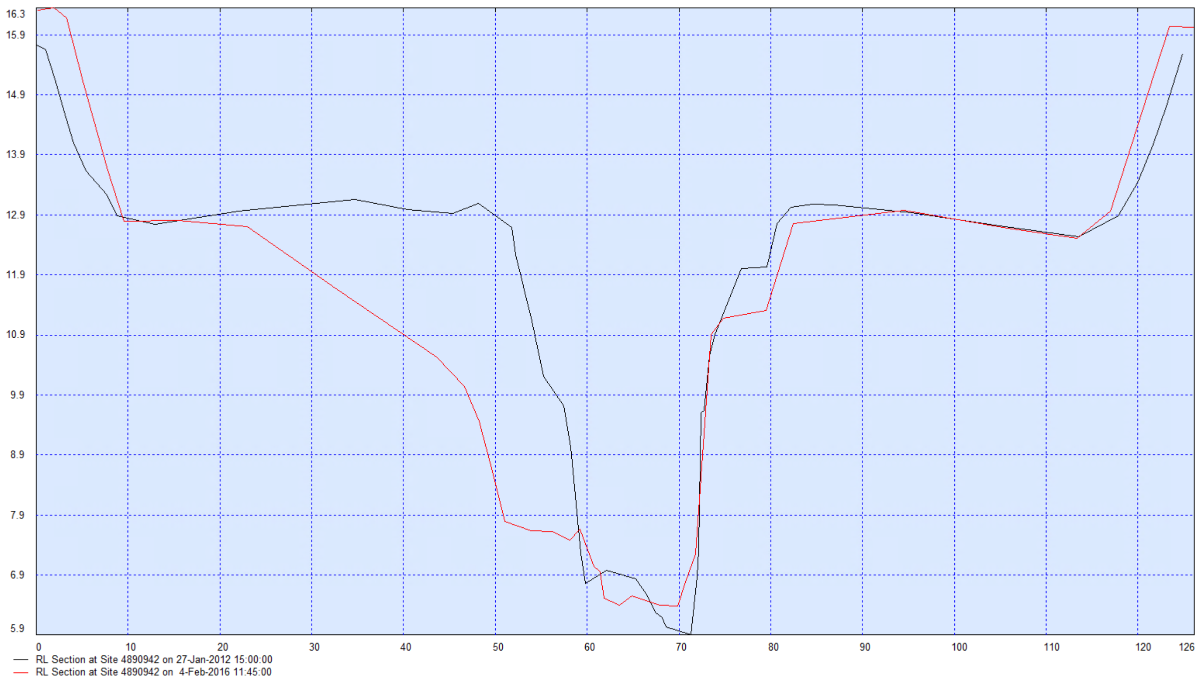
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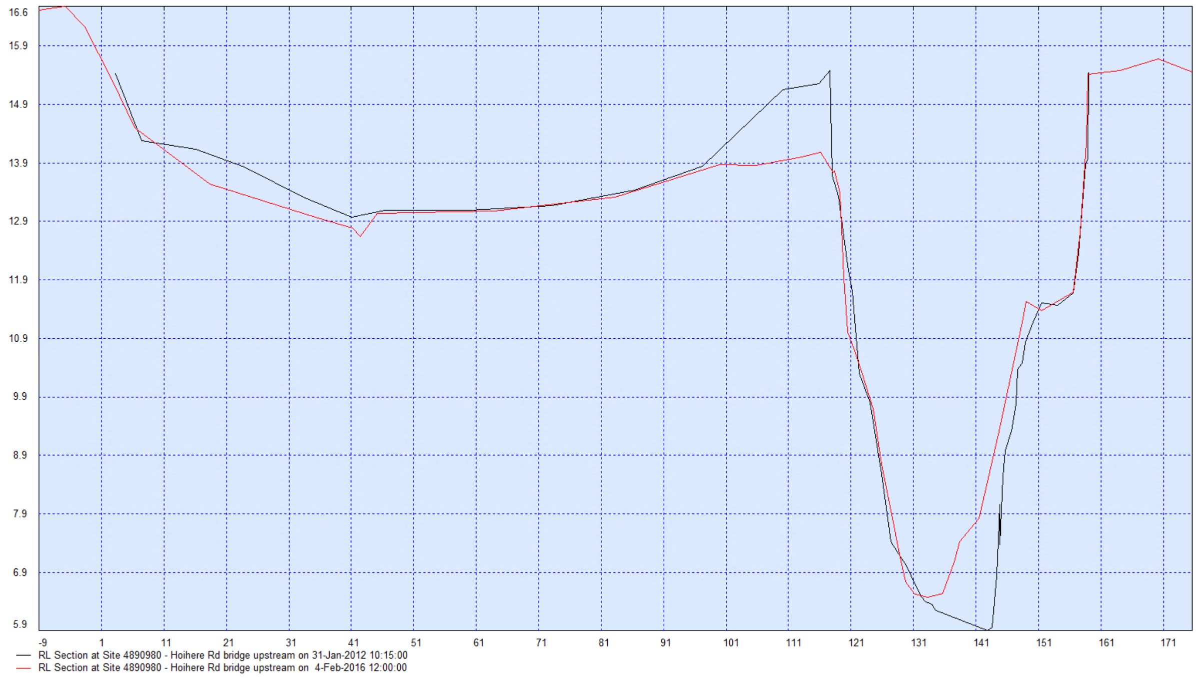
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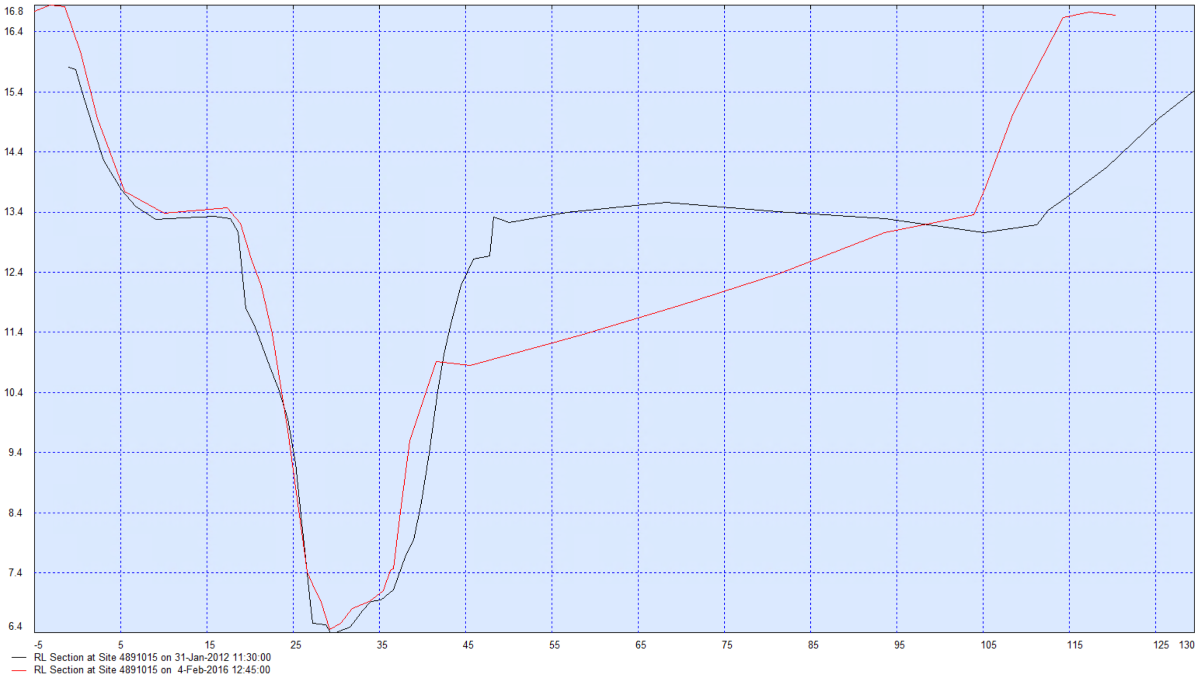
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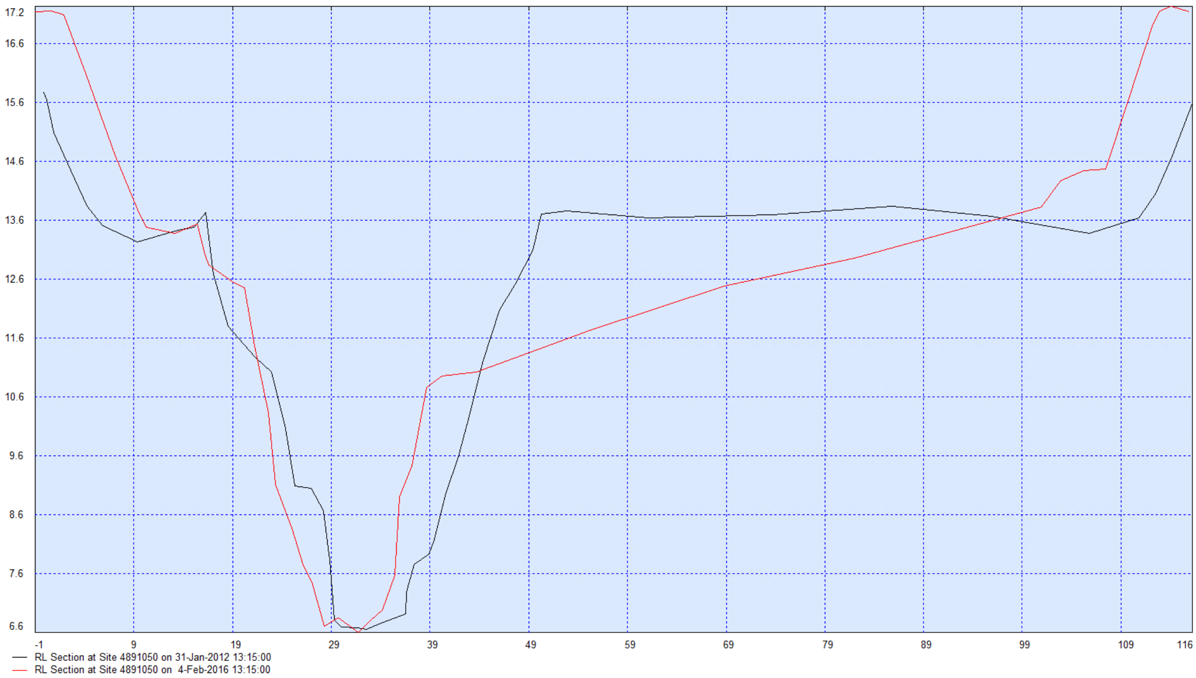
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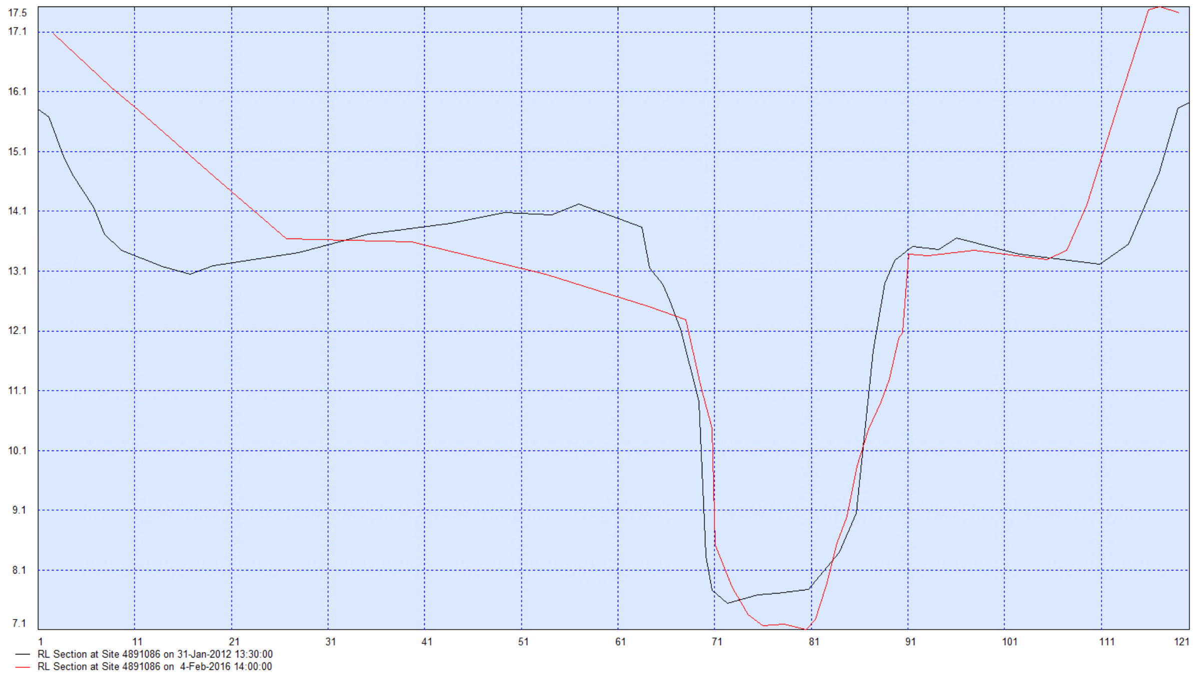
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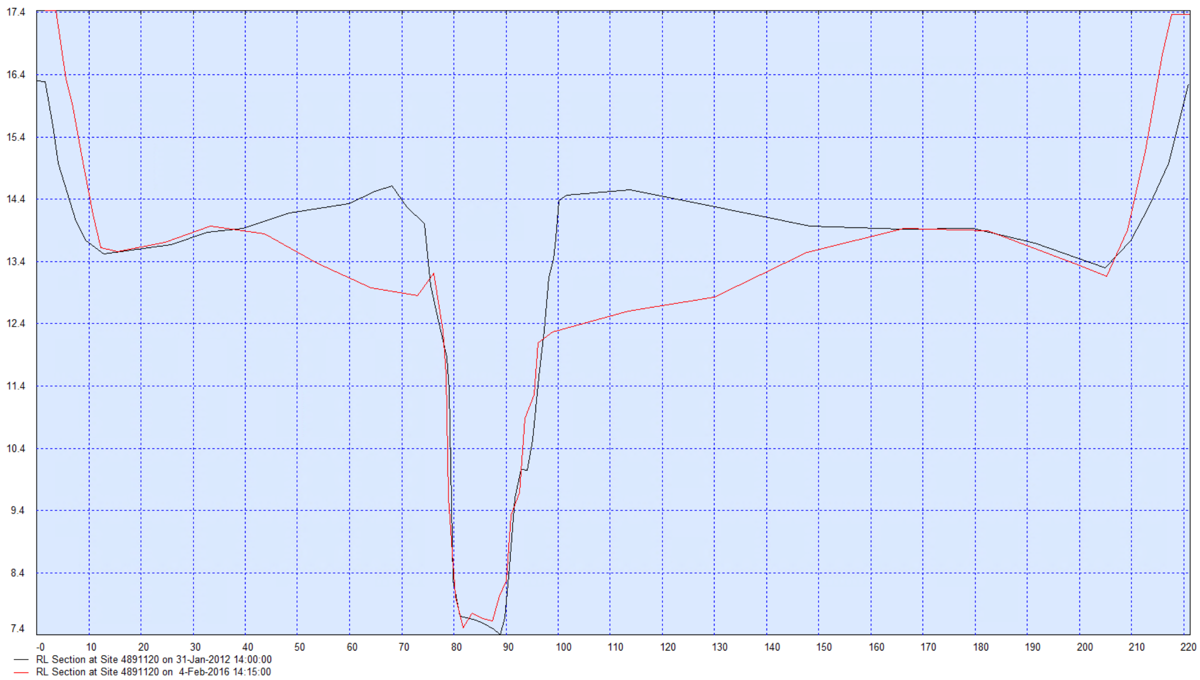

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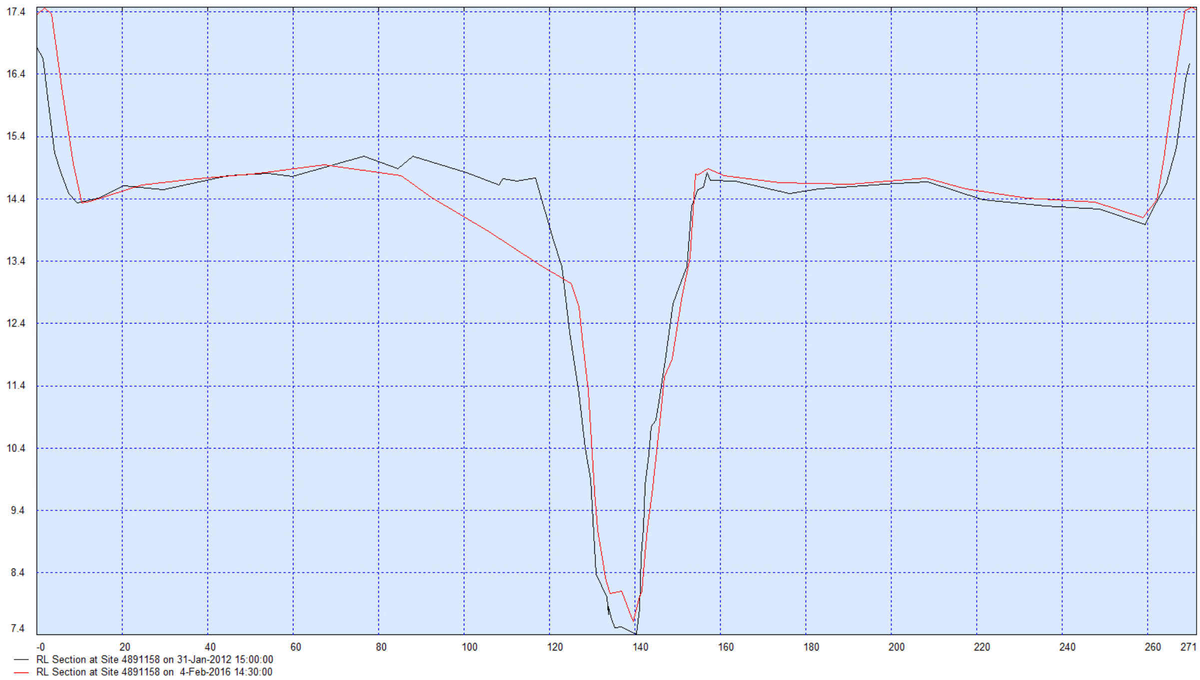

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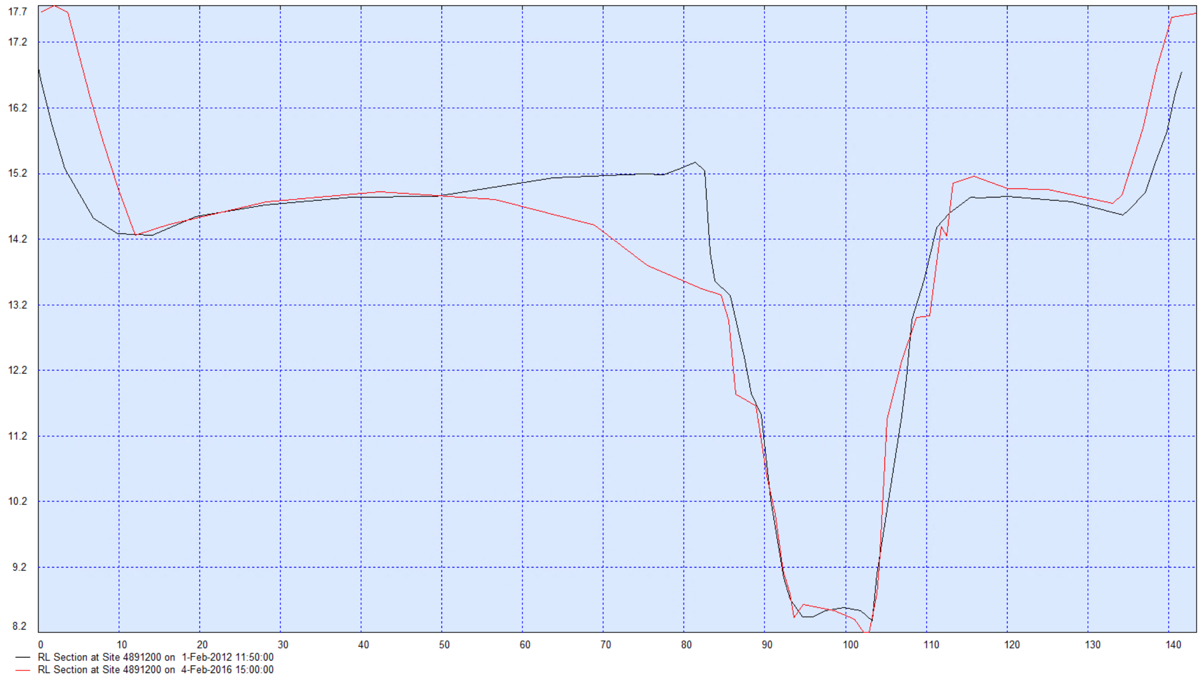
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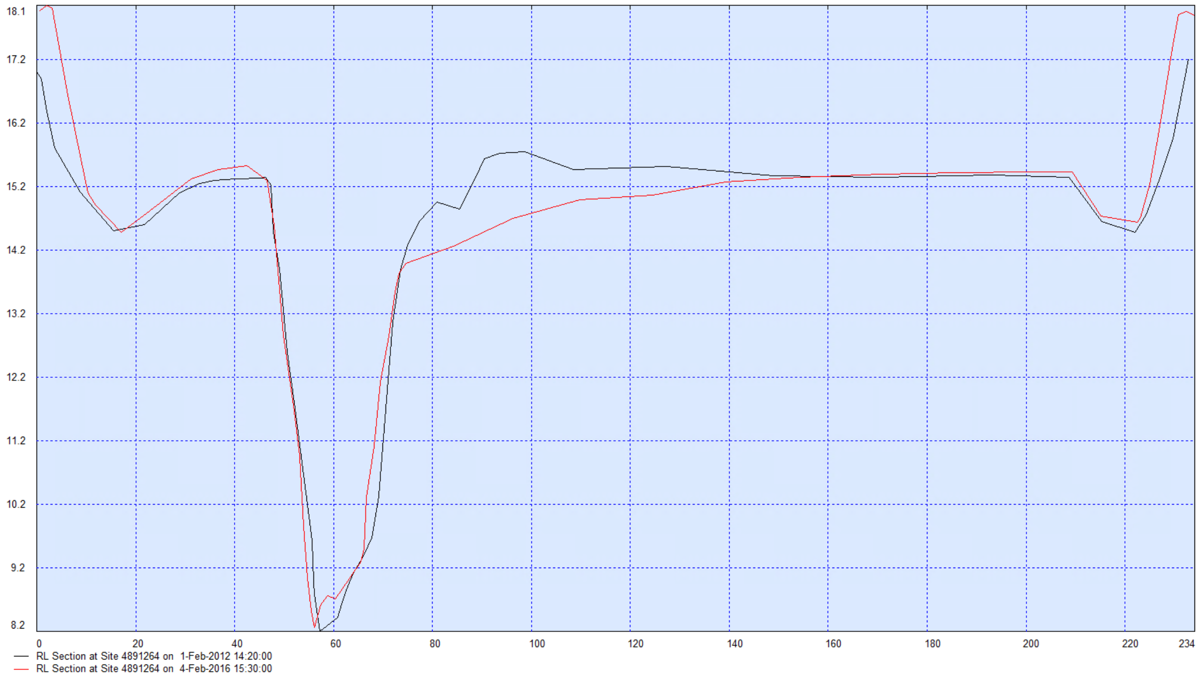
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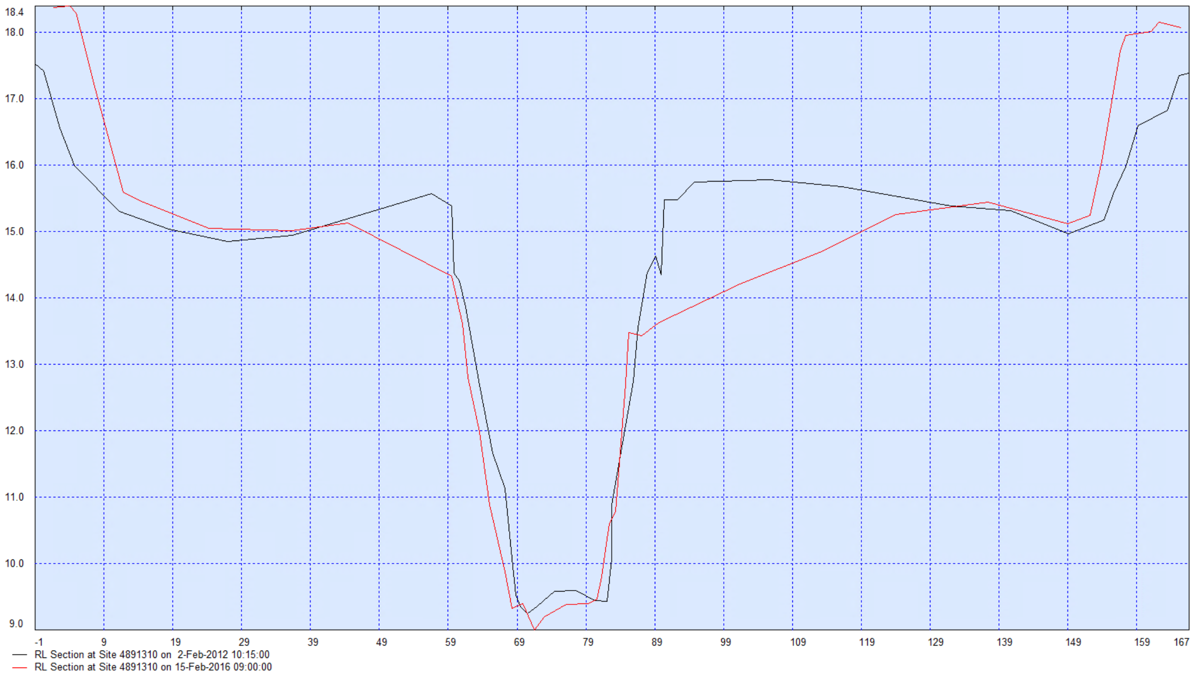
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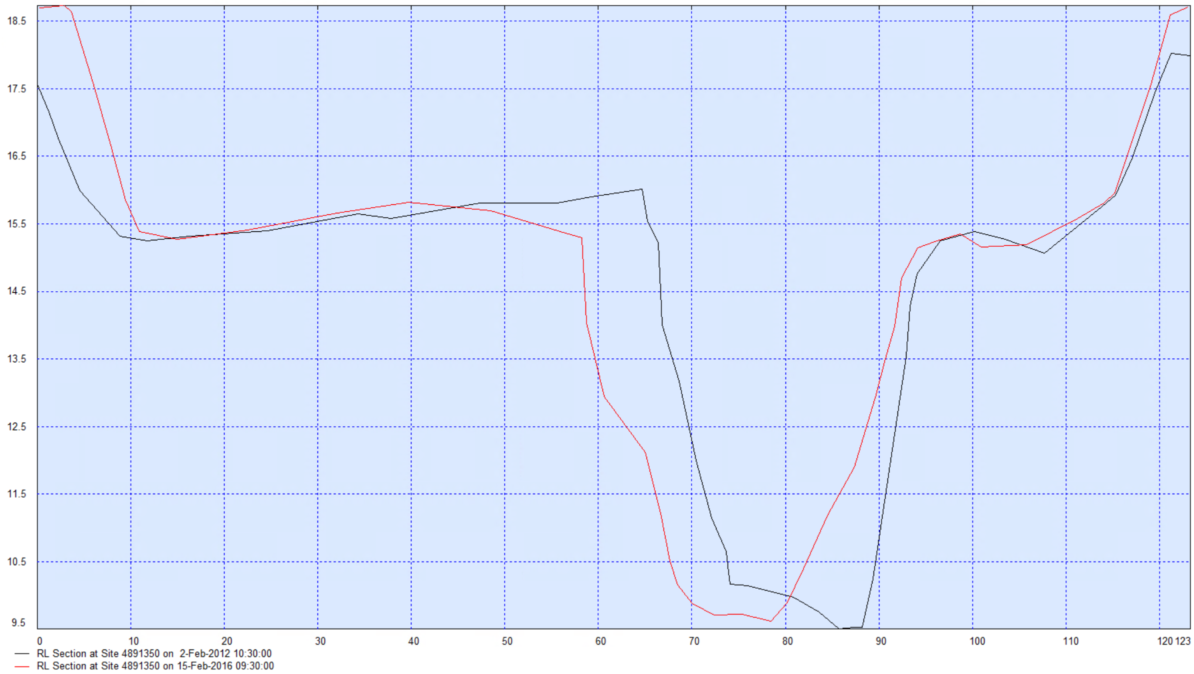
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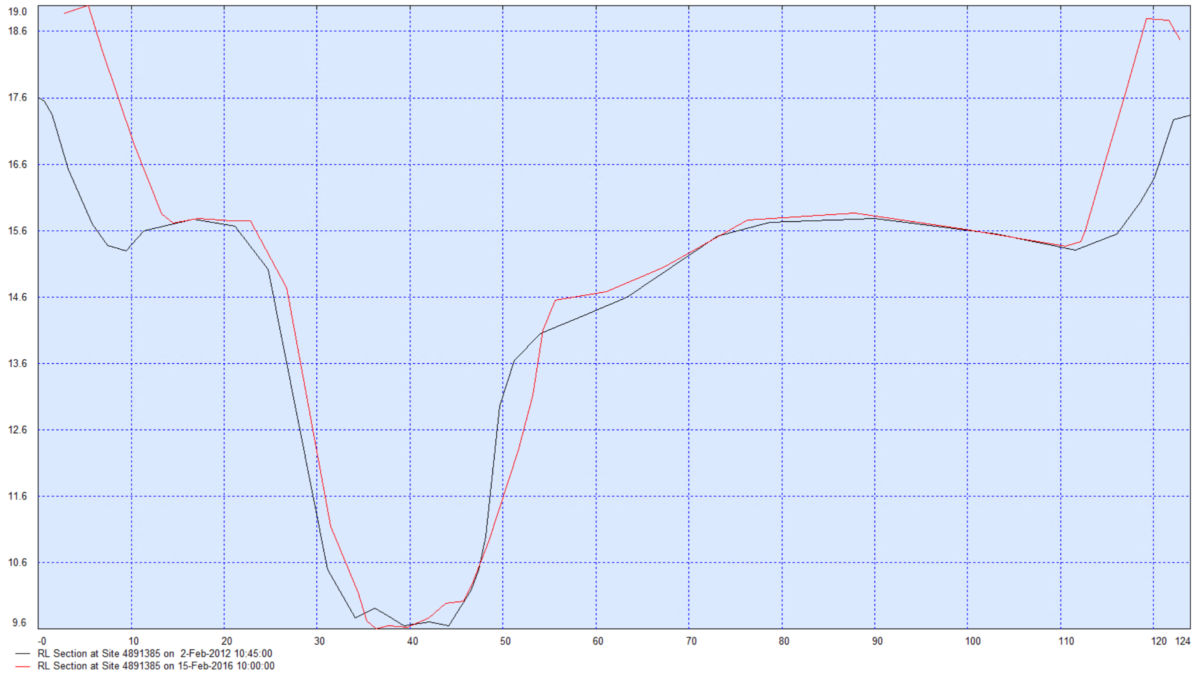
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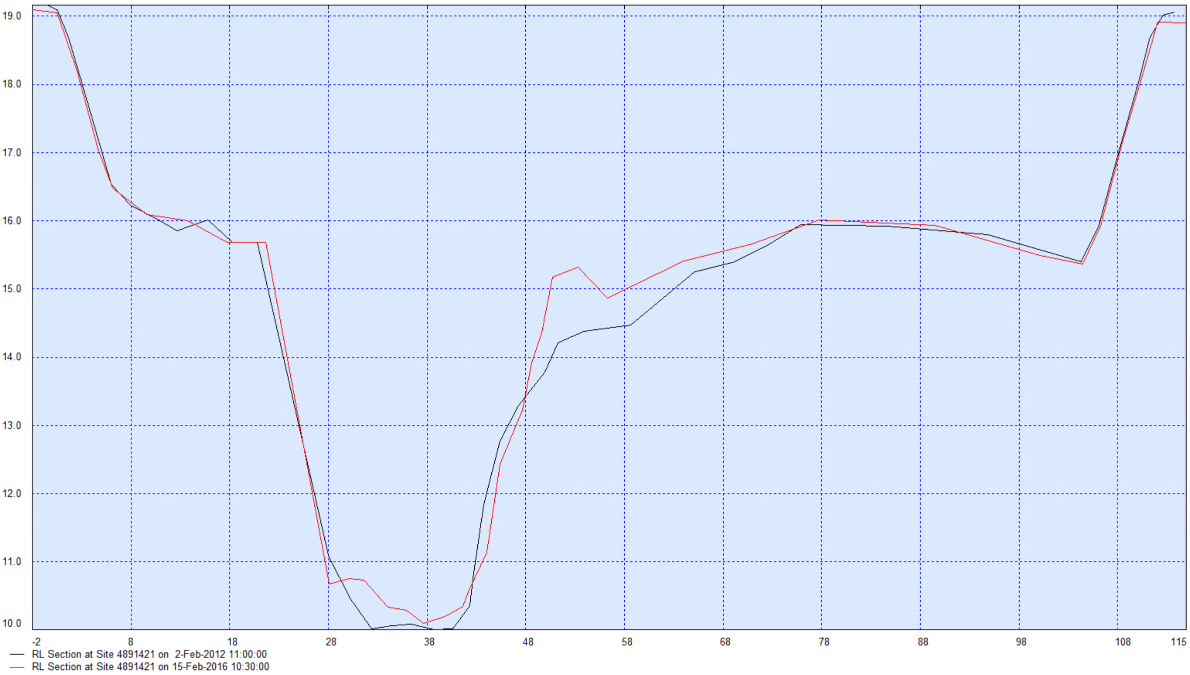
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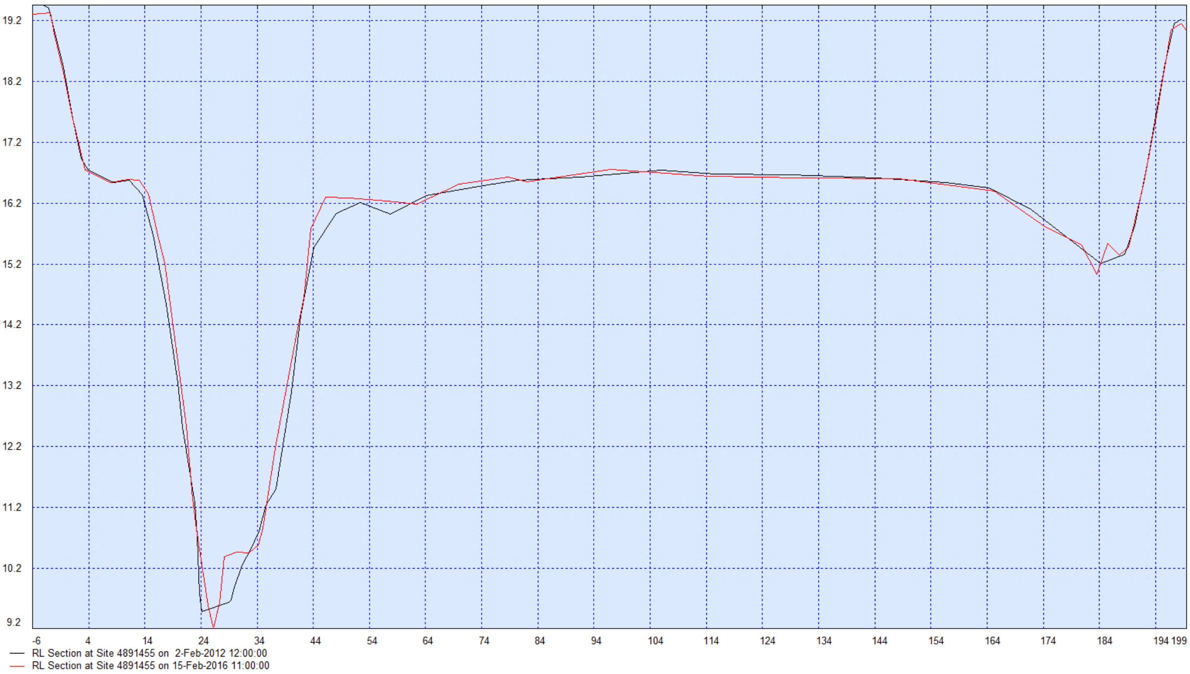
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RL Section at Site 4891455 on 2-Feb-2012 12:00:00
RL Section at Site 4891455 on 15-Feb-2016 11:00:00


19.3
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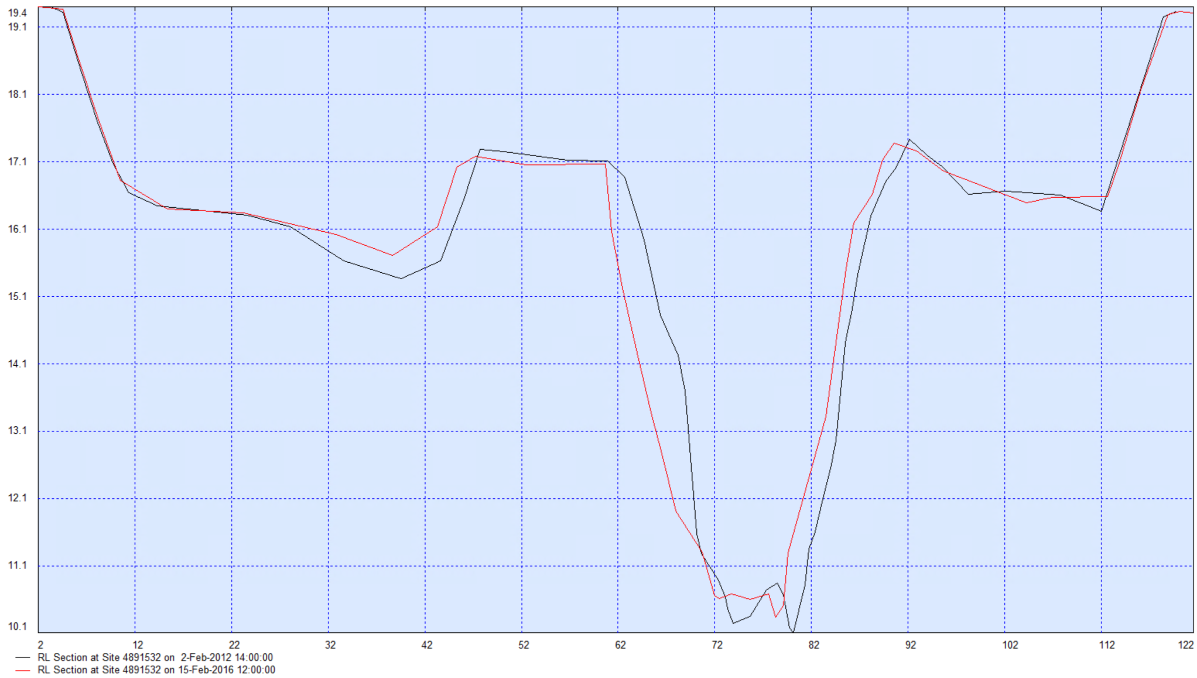
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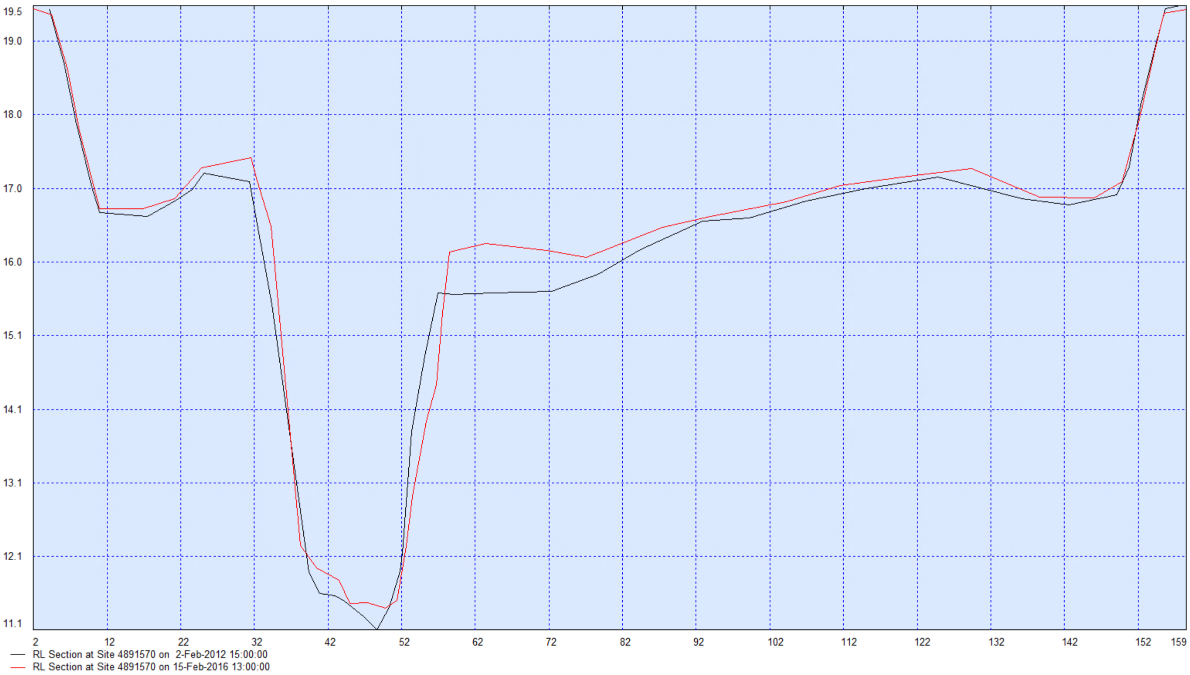
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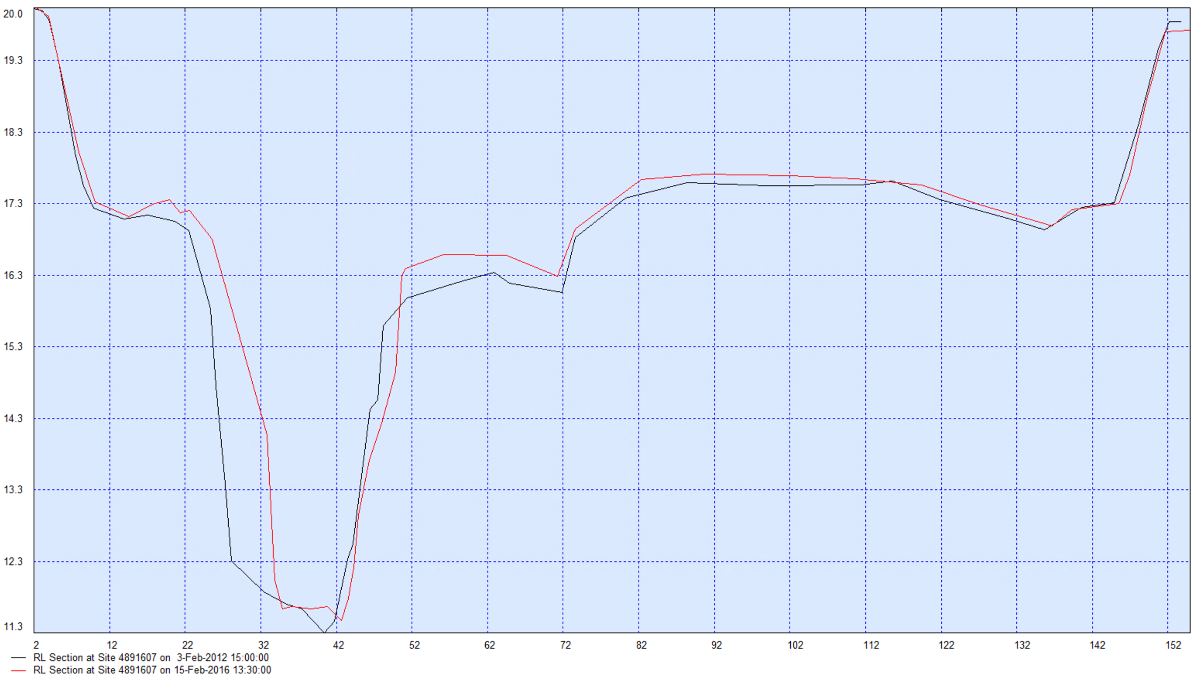
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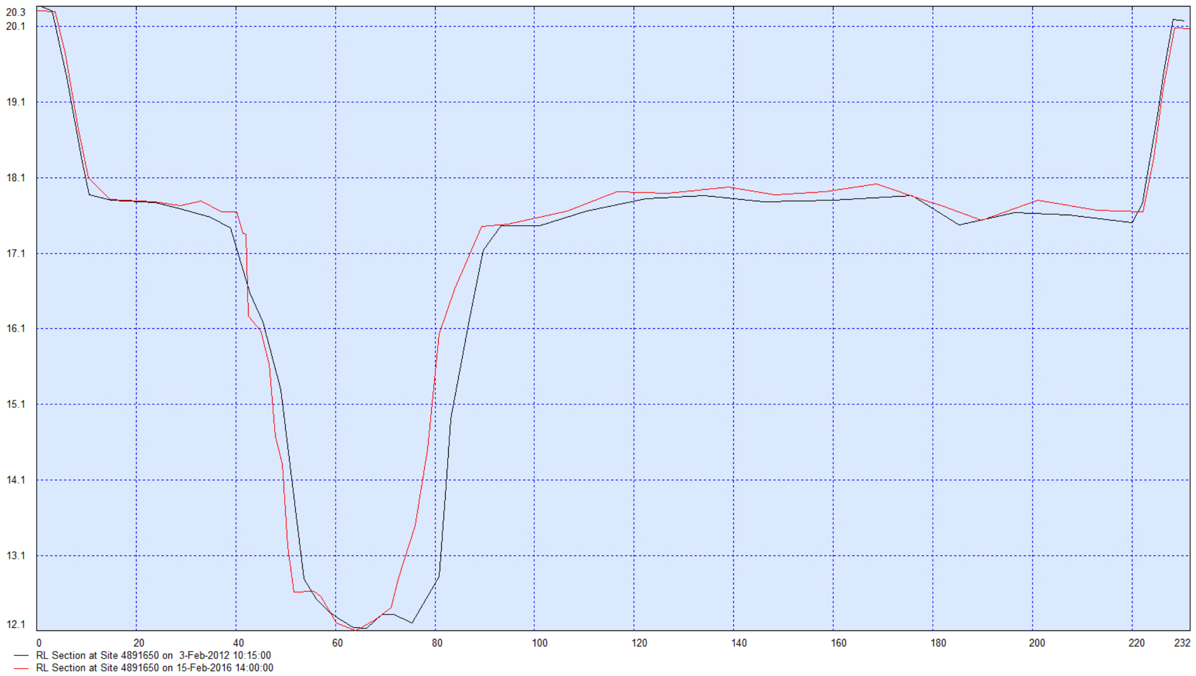
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RL Section at Site 4891650 on 3-Feb-2012 10:15:00
RL Section at Site 4891650 on 15-Feb-2016 14:00:00


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RL Section at Site 4891690 on 3-Feb-2012 10:45:00
RL Section at Site 4891690 on 15-Feb-2016 14:30:00


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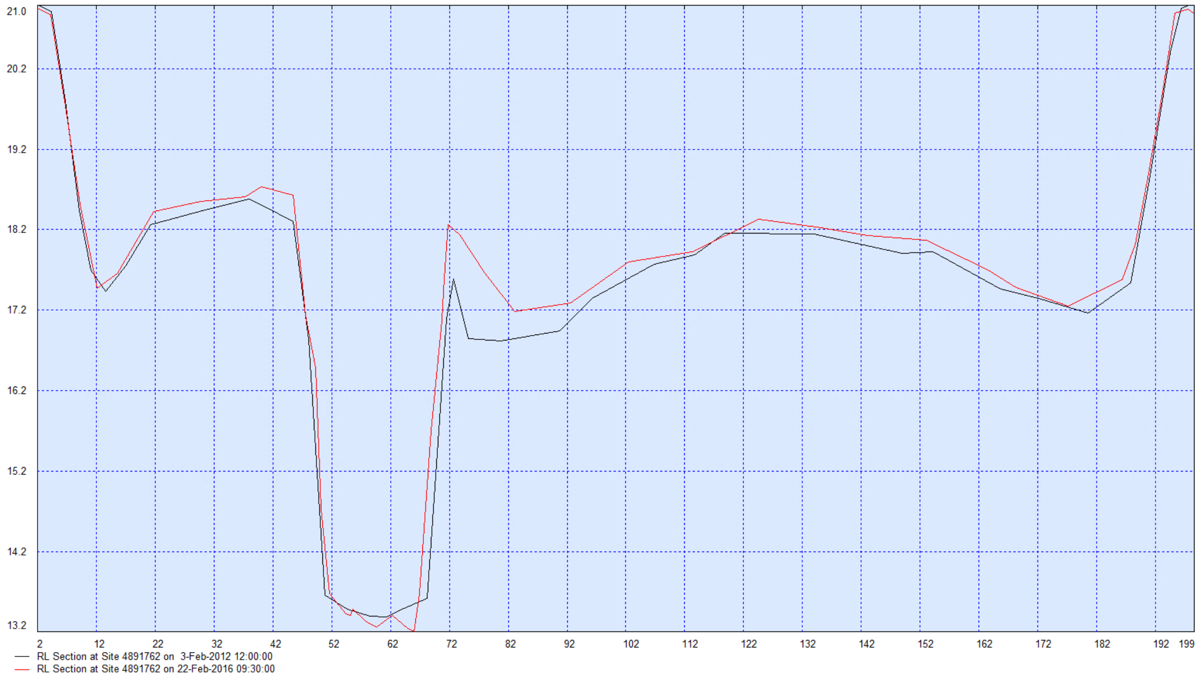
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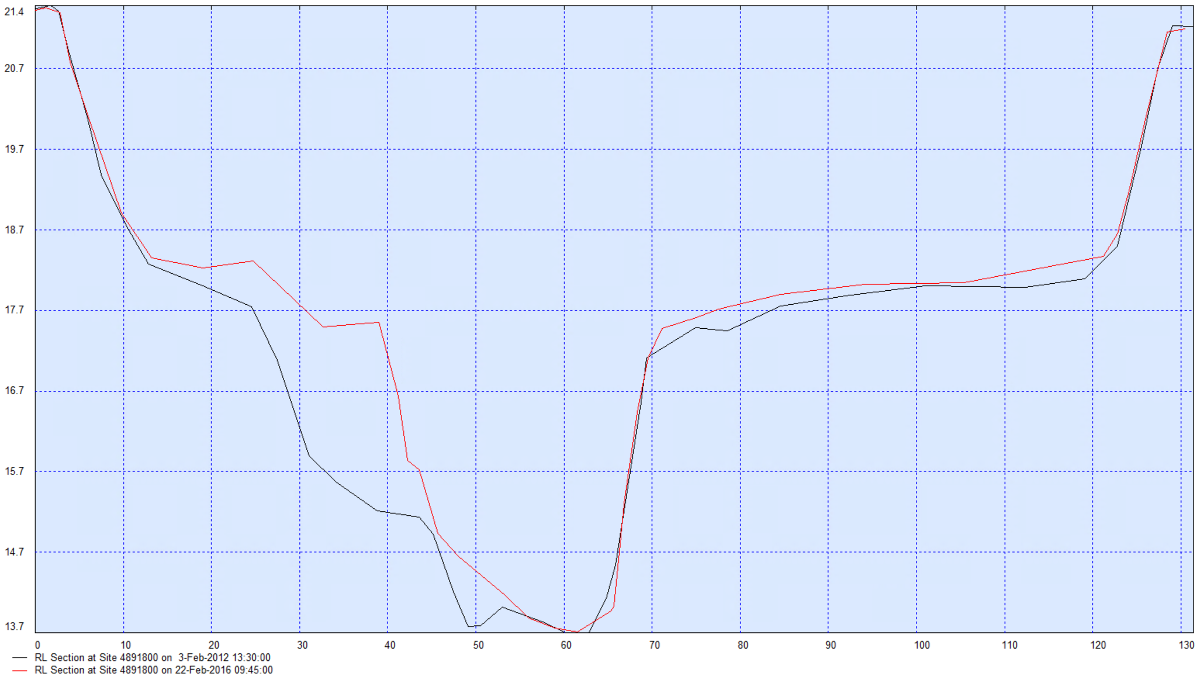
RL Section at Site 4891762 on 3-Feb-2012 12:00:00
RL Section at Site 4891762 on 22-Feb-2016 09:30:00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RL Section at Site 4891800 on 3-Feb-2012 13:30:00
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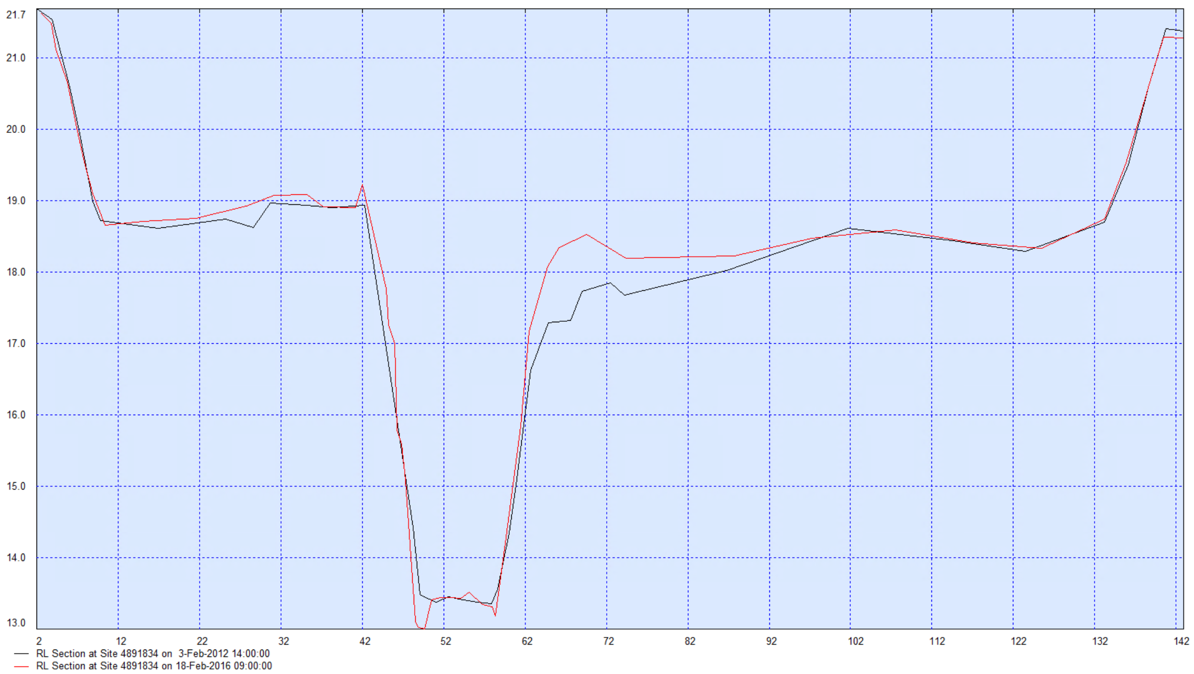
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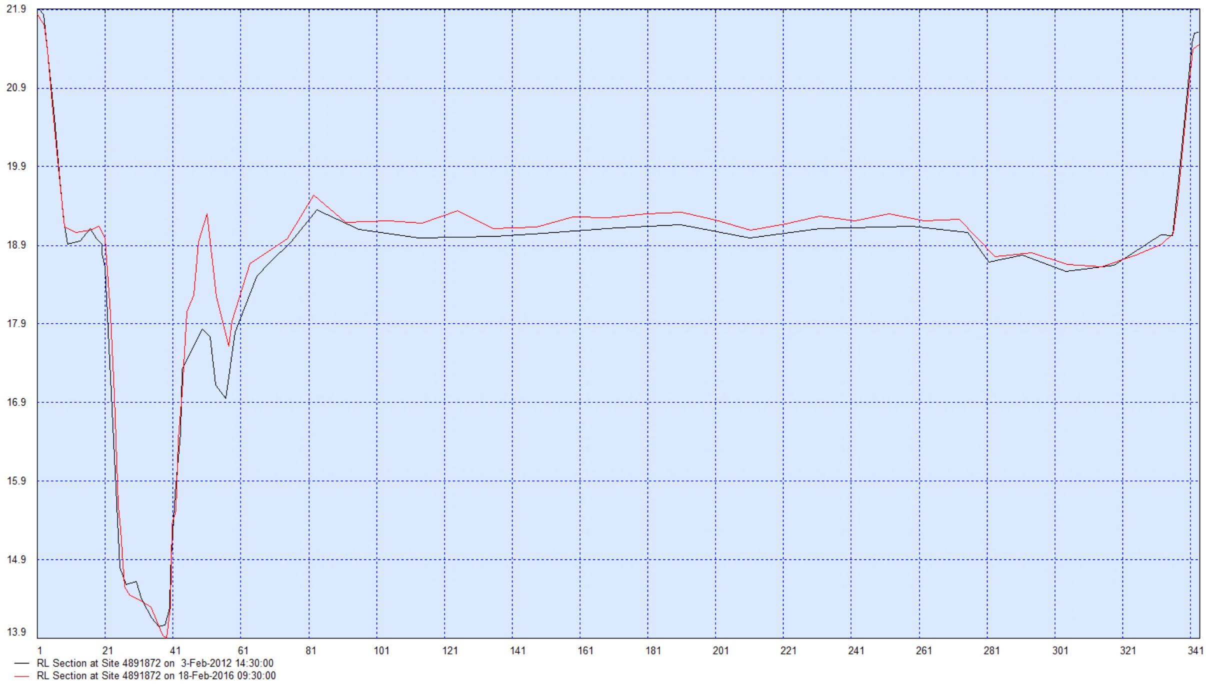
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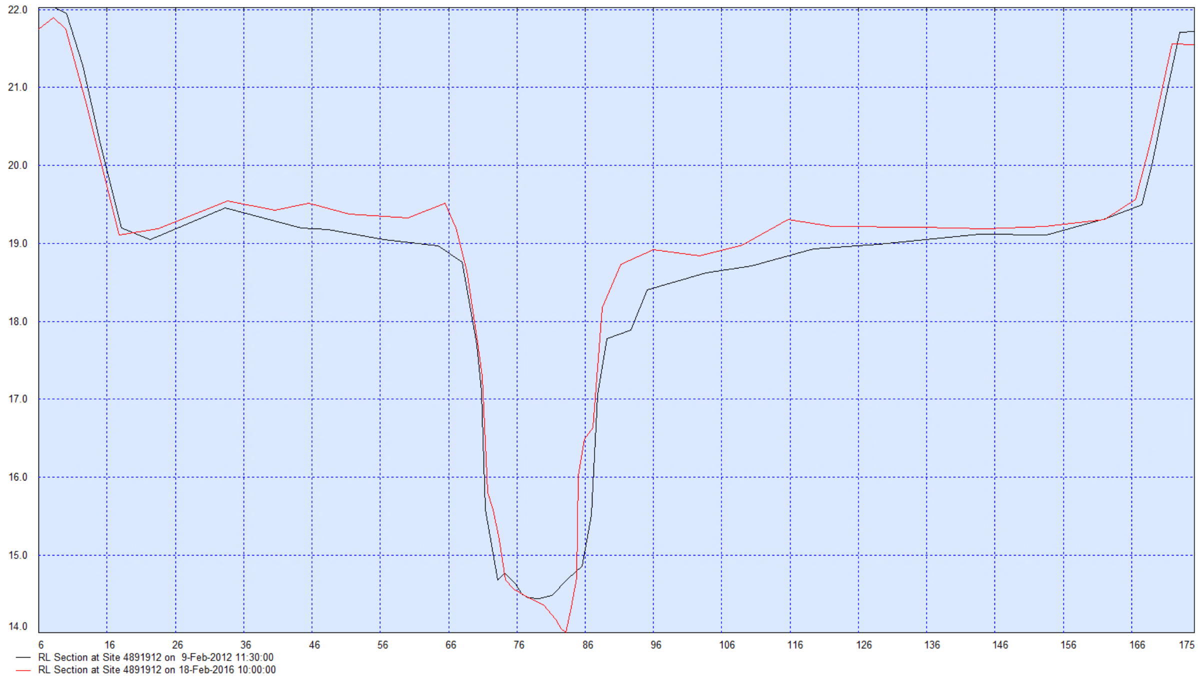
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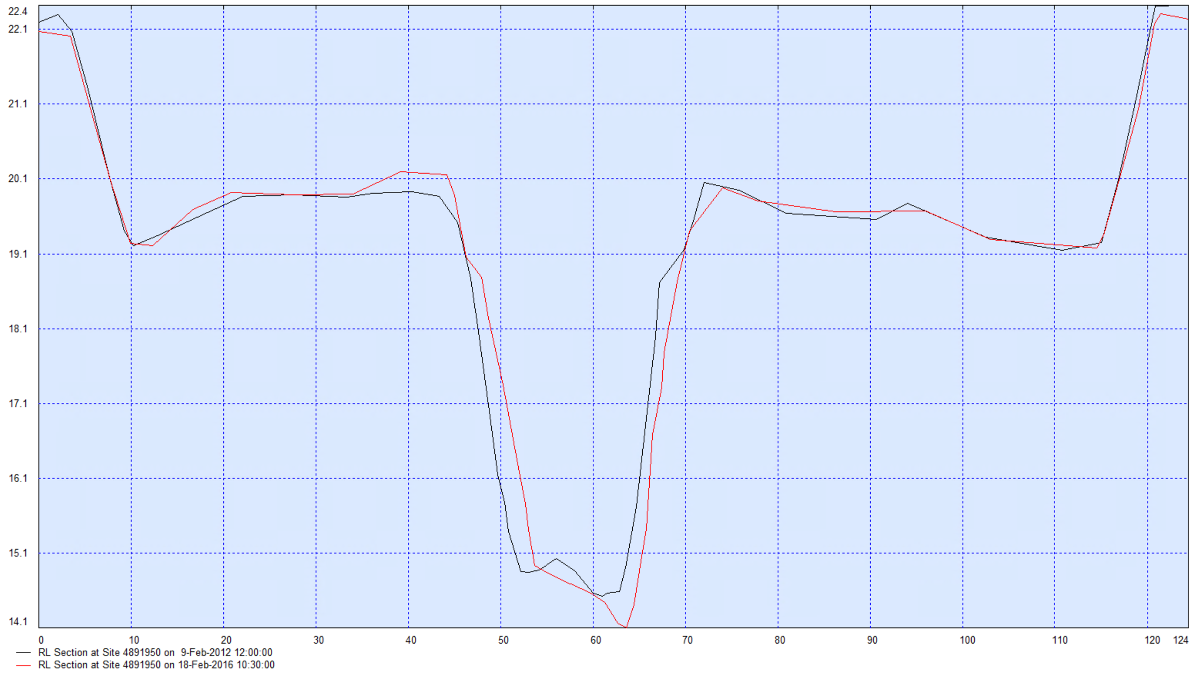
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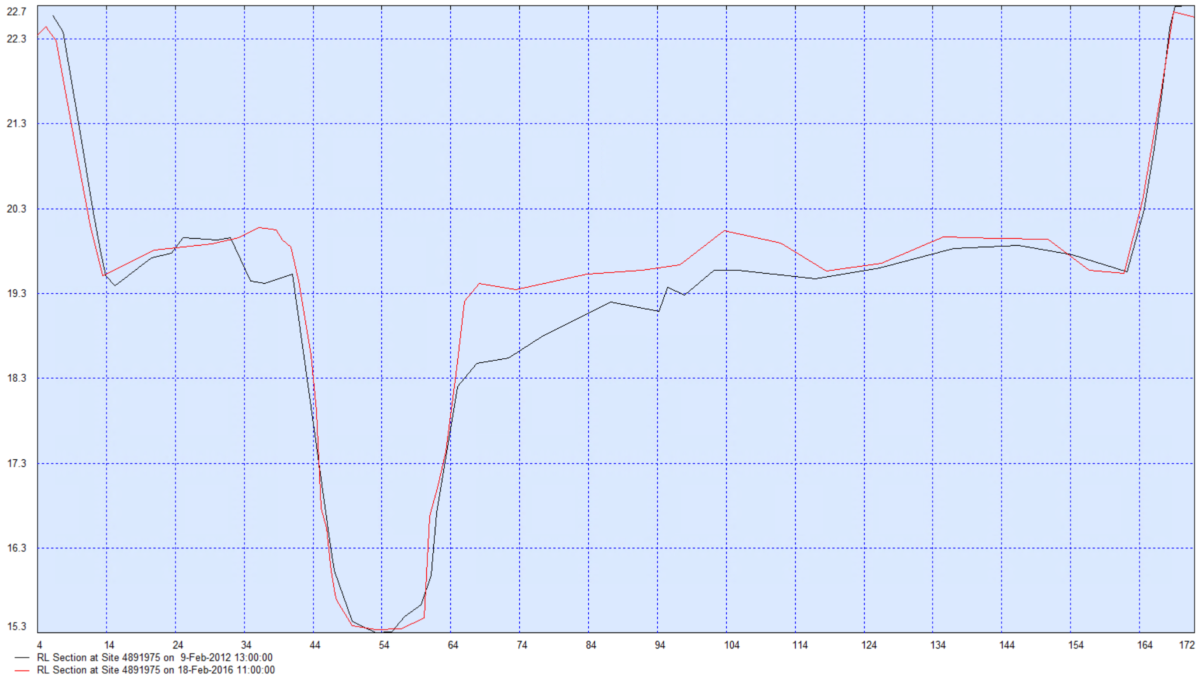
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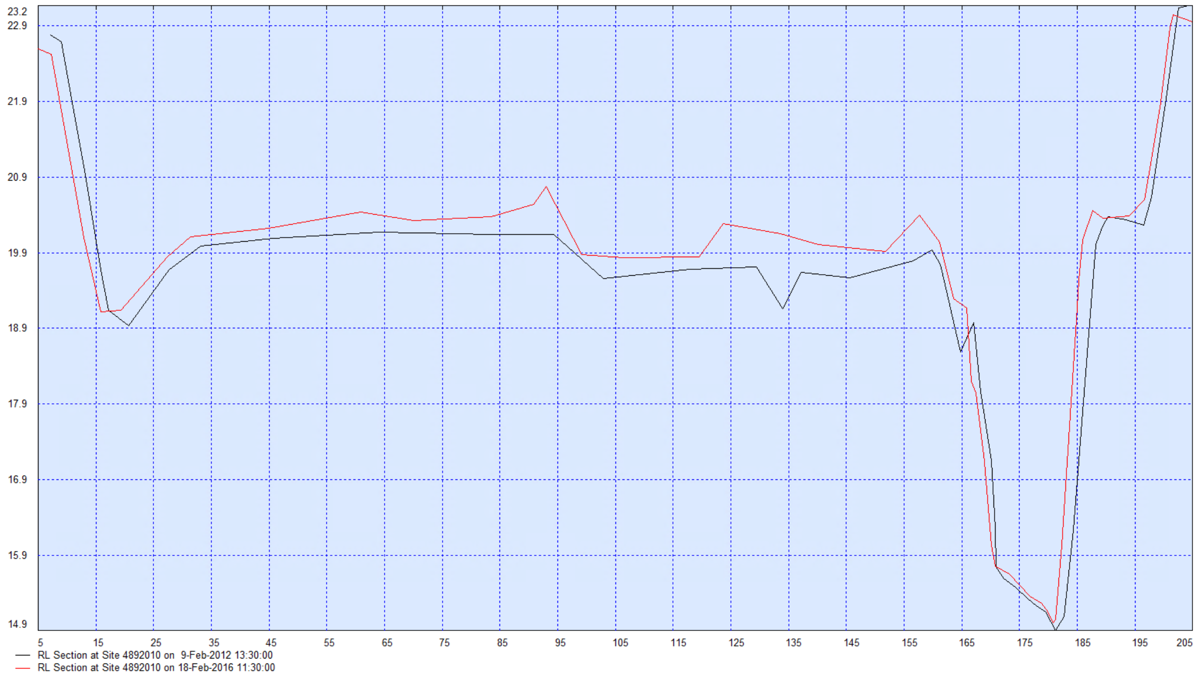
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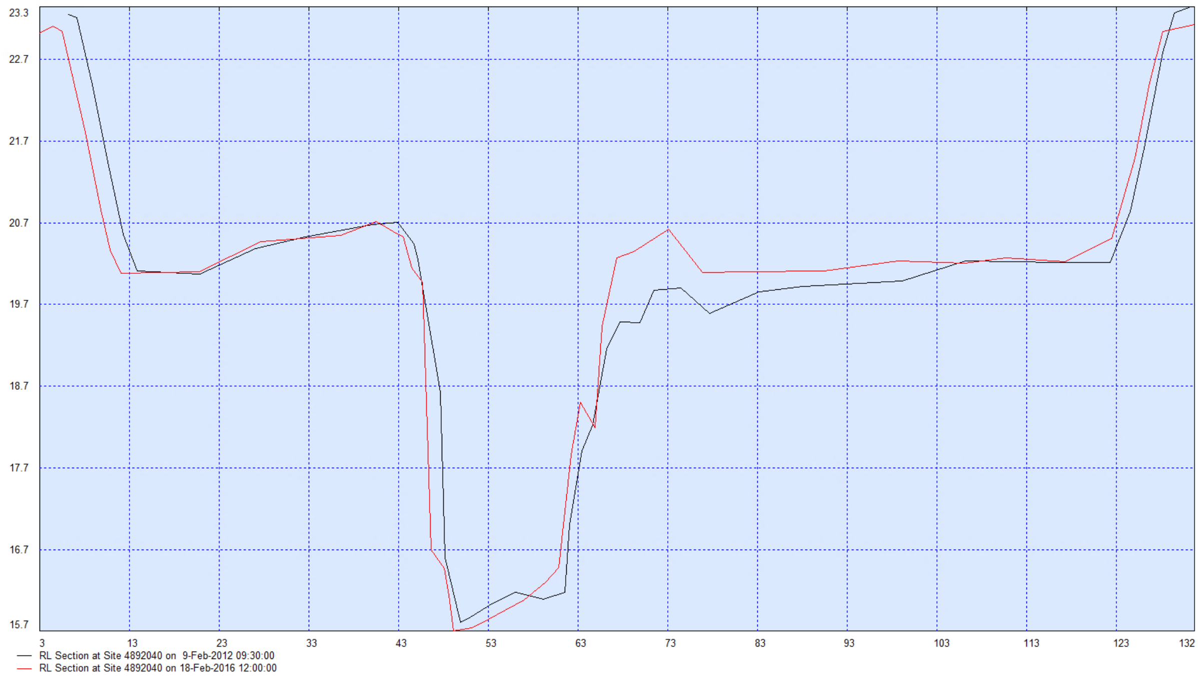
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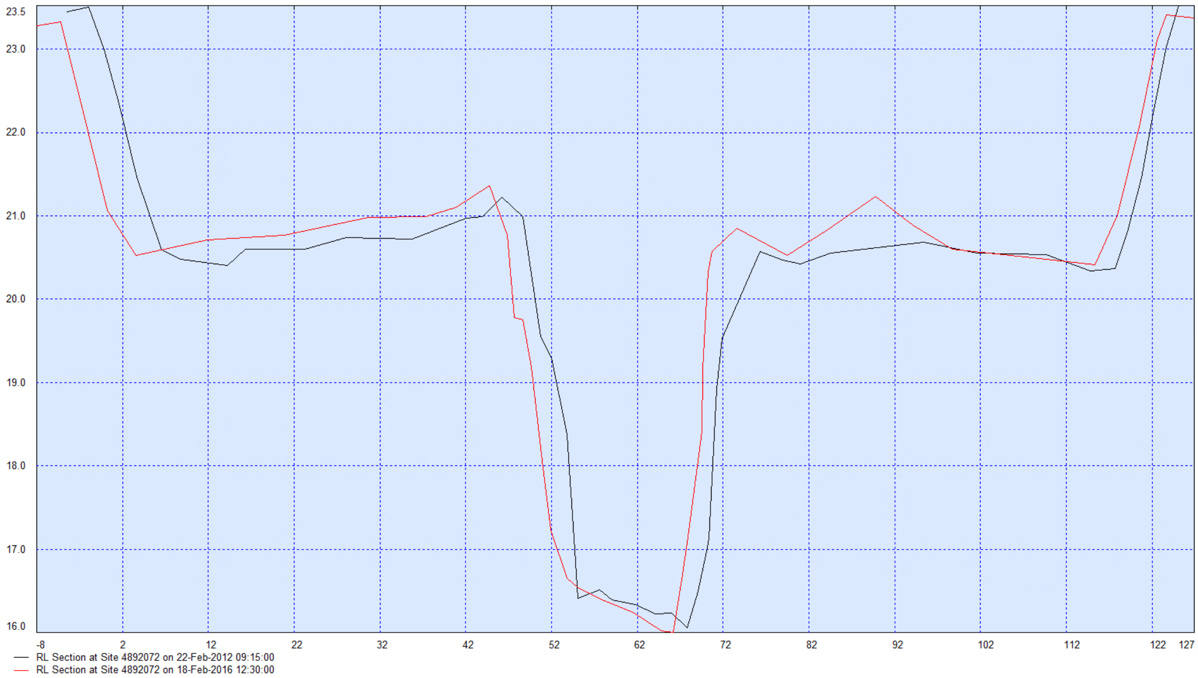
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RL Section at Site 4892072 on 22-Feb-2012 09:15:00
RL Section at Site 4892072 on 18-Feb-2016 12:30:00


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RL Section at Site 4892100 on 21-Feb-2012 14:00:00
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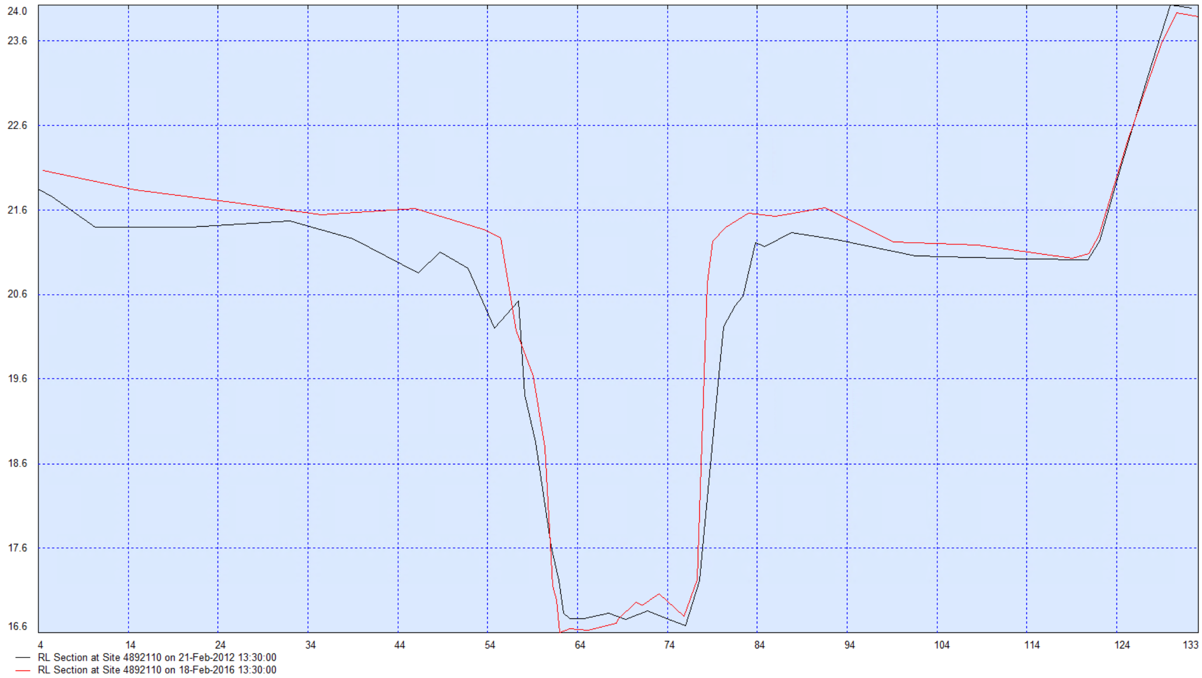
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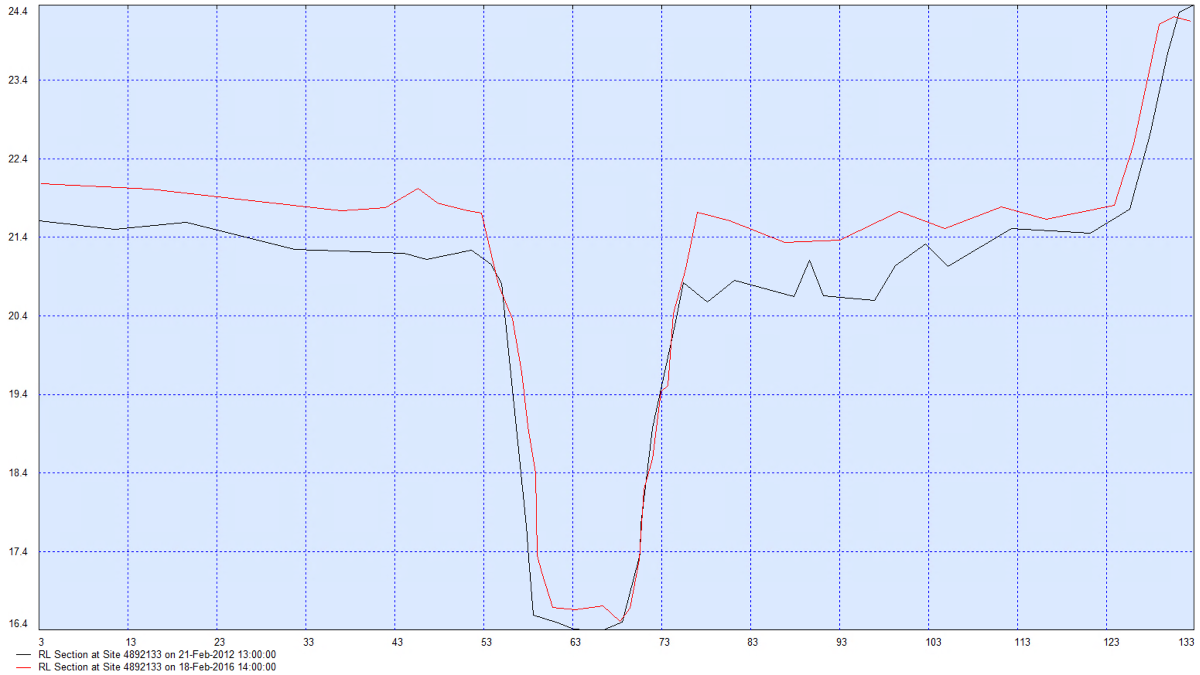
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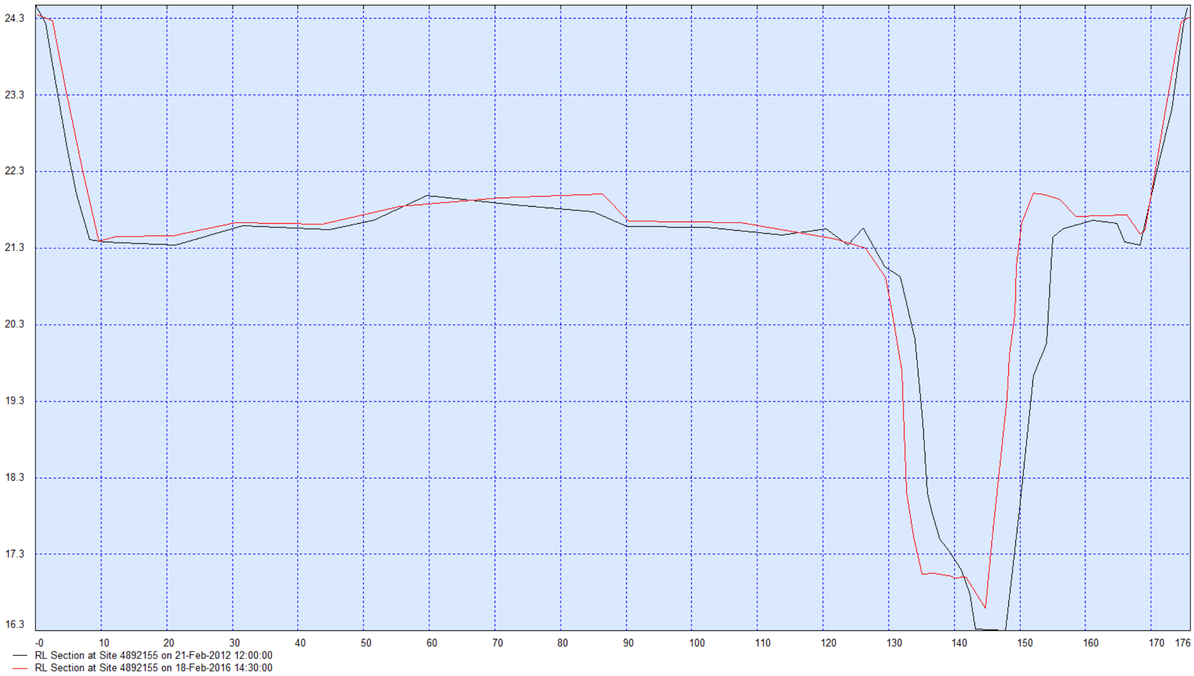
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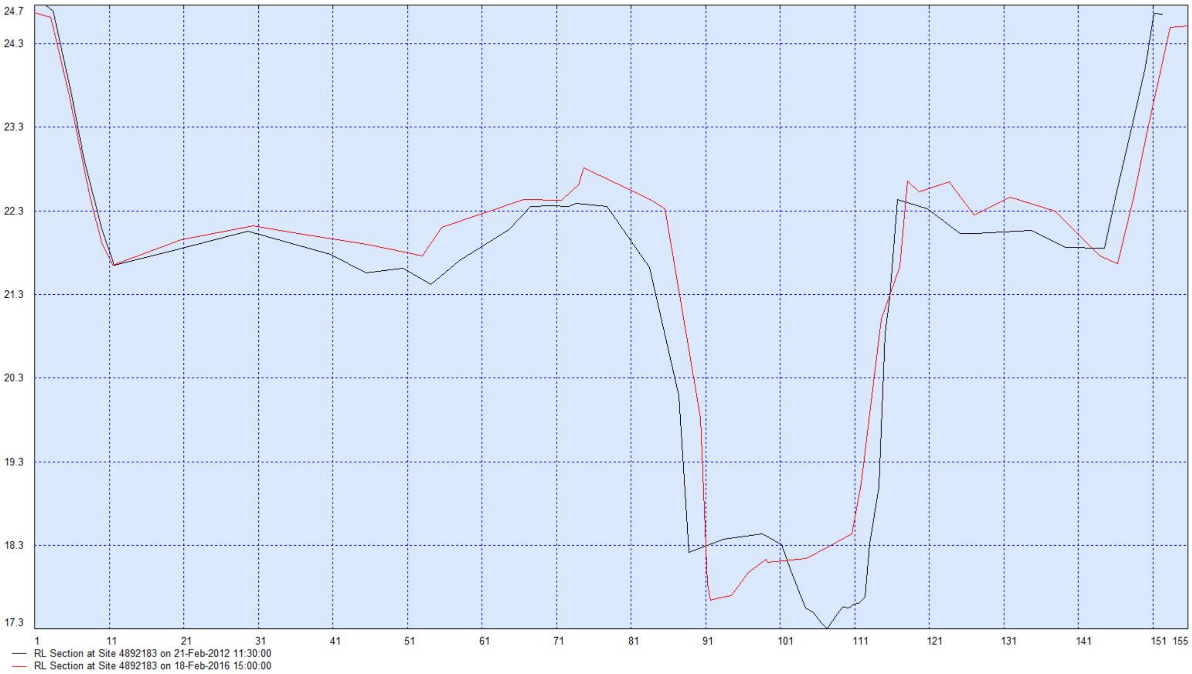
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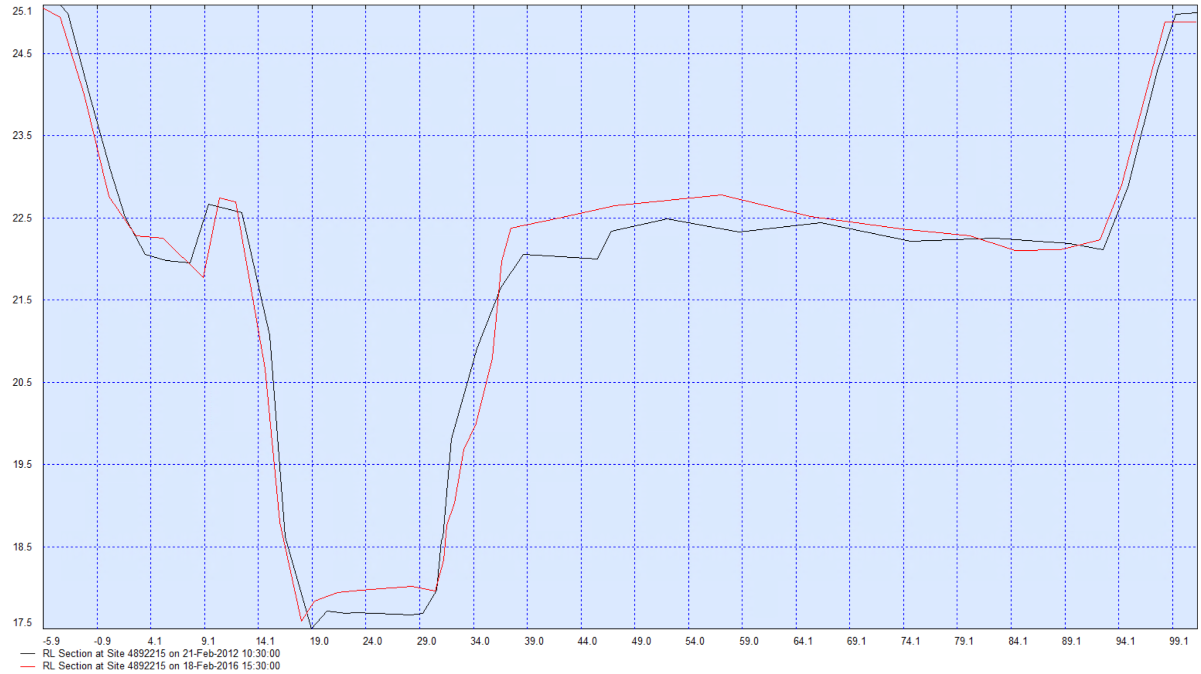
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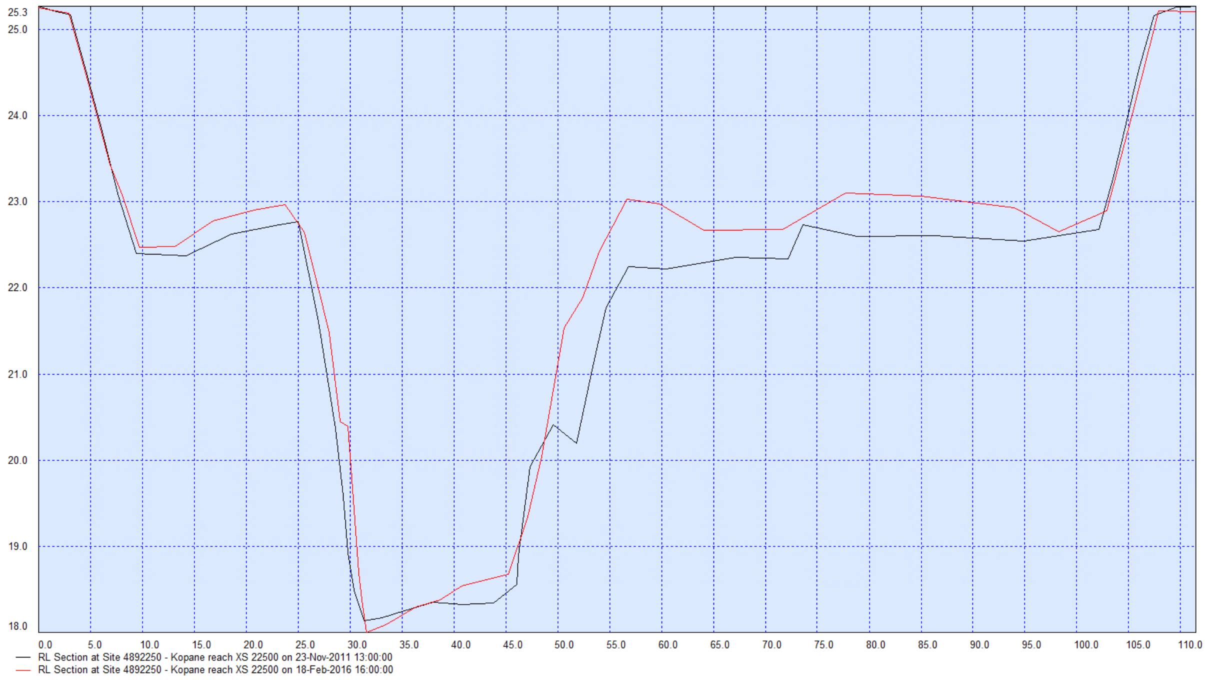
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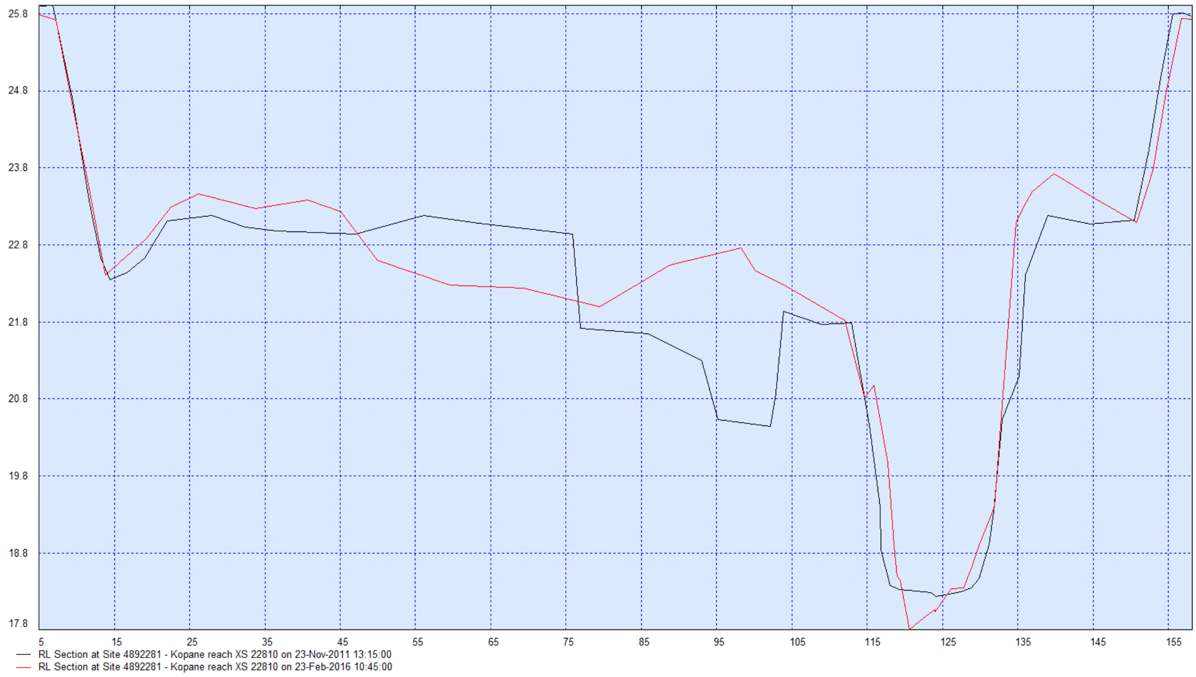
RL Section at Site 4892250 - Kopane reach XS 22500 on 23-Nov-2011 13:00:00
RL Section at Site 4892250 - Kopane reach XS 22500 on 18-Feb-2016 16:00:00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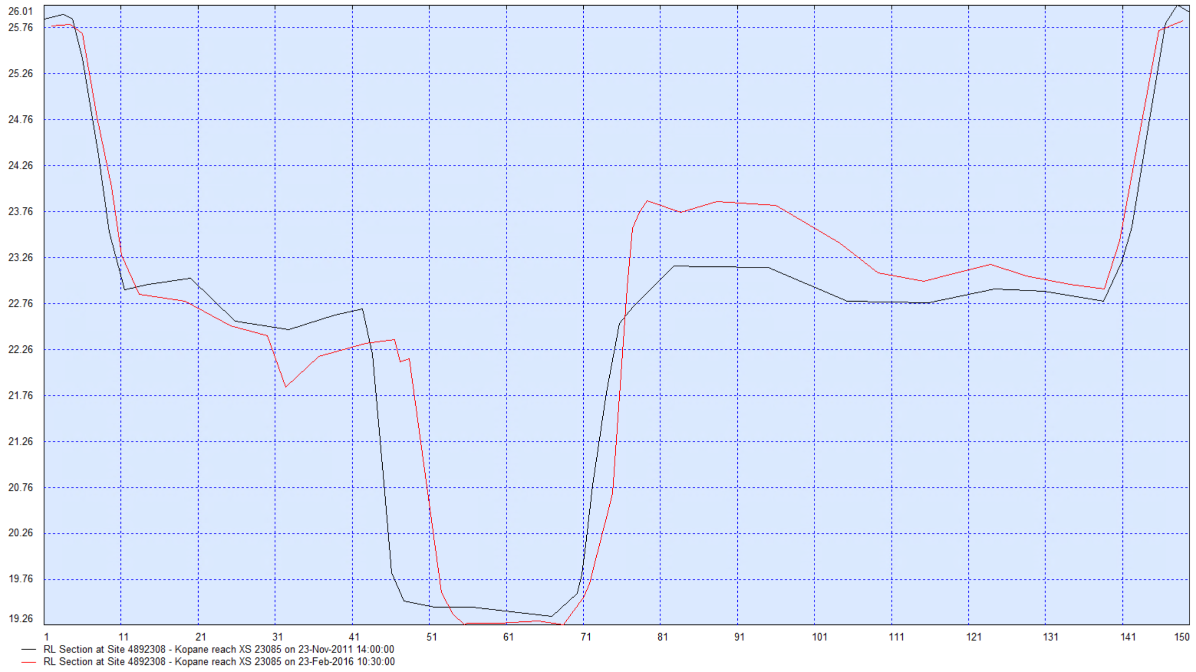
RL Section at Site 4892281 - Kopane reach XS 22810 on 23-Nov-2011 13:15:00
RL Section at Site 4892281 - Kopane reach XS 22810 on 23-Feb-2016 10:45:00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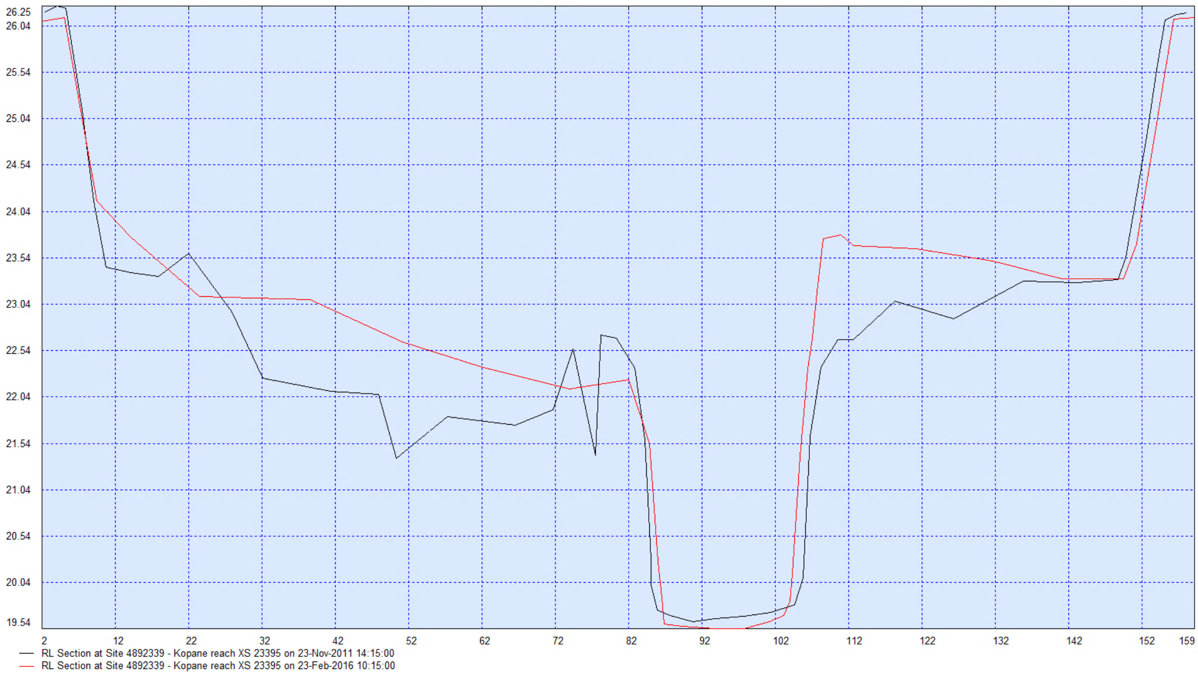
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2 12 22 32 42 52 62 72 82 92 102 112 122 132 142 152 159
RL Section at Site 4892339 - Kopane reach XS 23395 on 23-Nov-2011 14:15:00
RL Section at Site 4892339 - Kopane reach XS 23395 on 23-Feb-2016 10:15:00


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RL Section at Site 4892370 - Kopane reach XS 23700 on 23-Nov-2011 14:30:00
RL Section at Site 4892370 - Kopane reach XS 23700 on 23-Feb-2016 10:00:00


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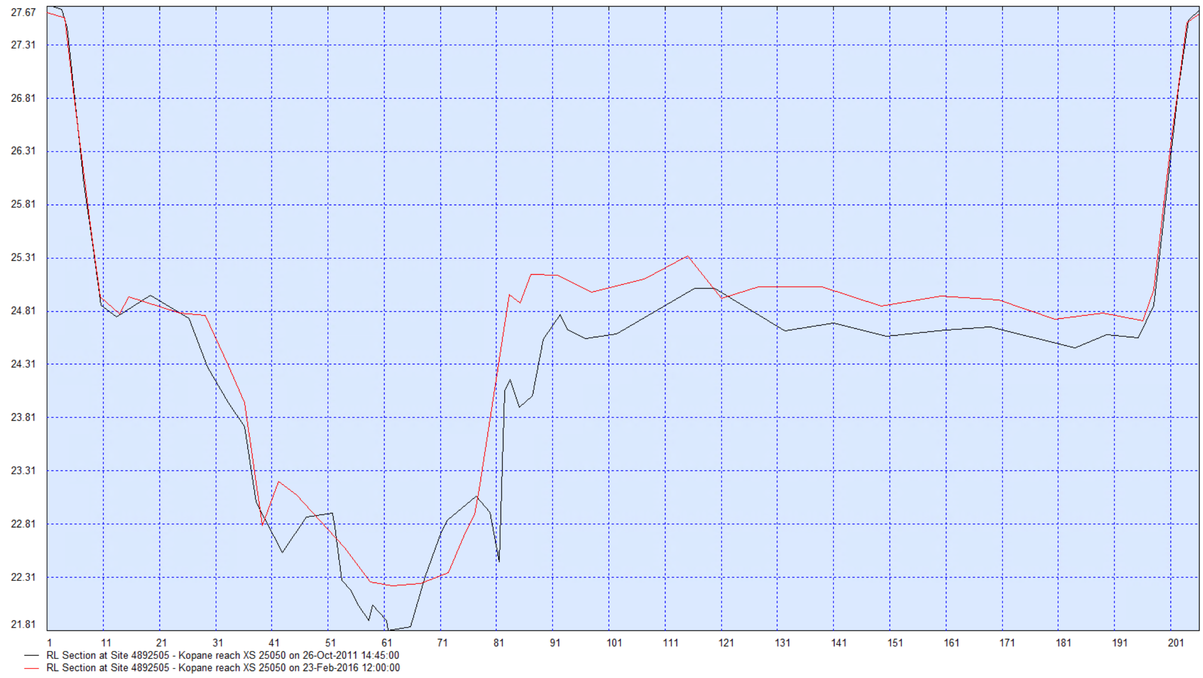
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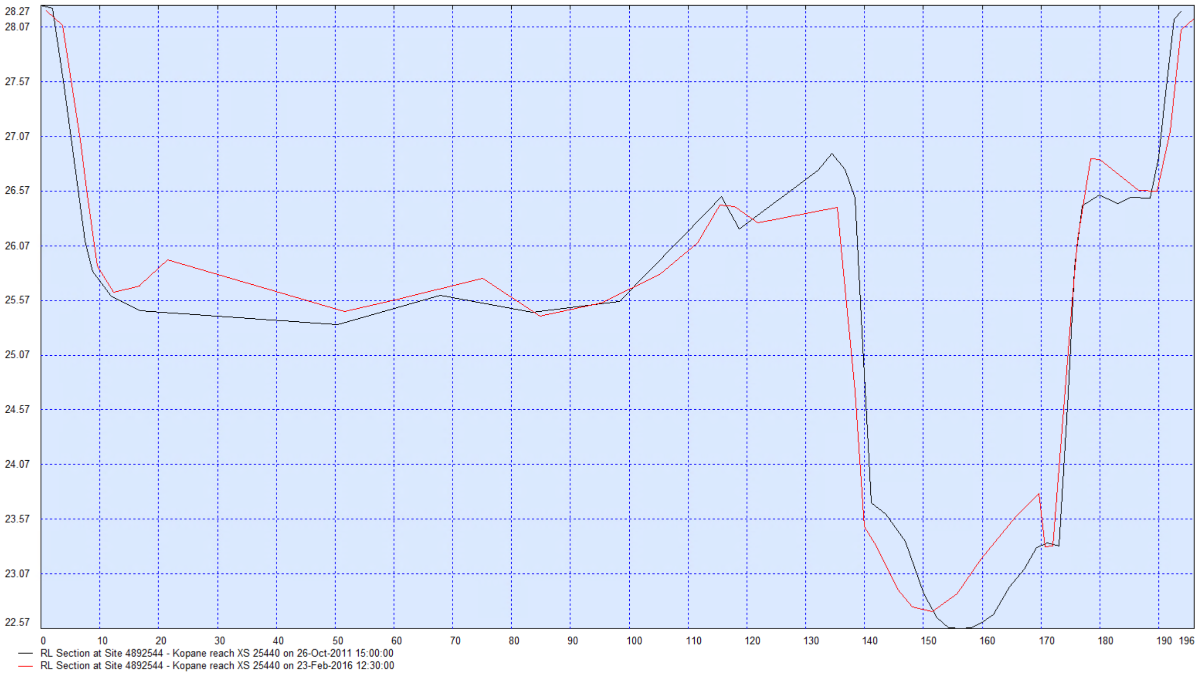
RL Section at Site 4892505 - Kopane reach XS 25050 on 26-Oct-2011 14:45:00
RL Section at Site 4892505 - Kopane reach XS 25050 on 23-Feb-2016 12:00:00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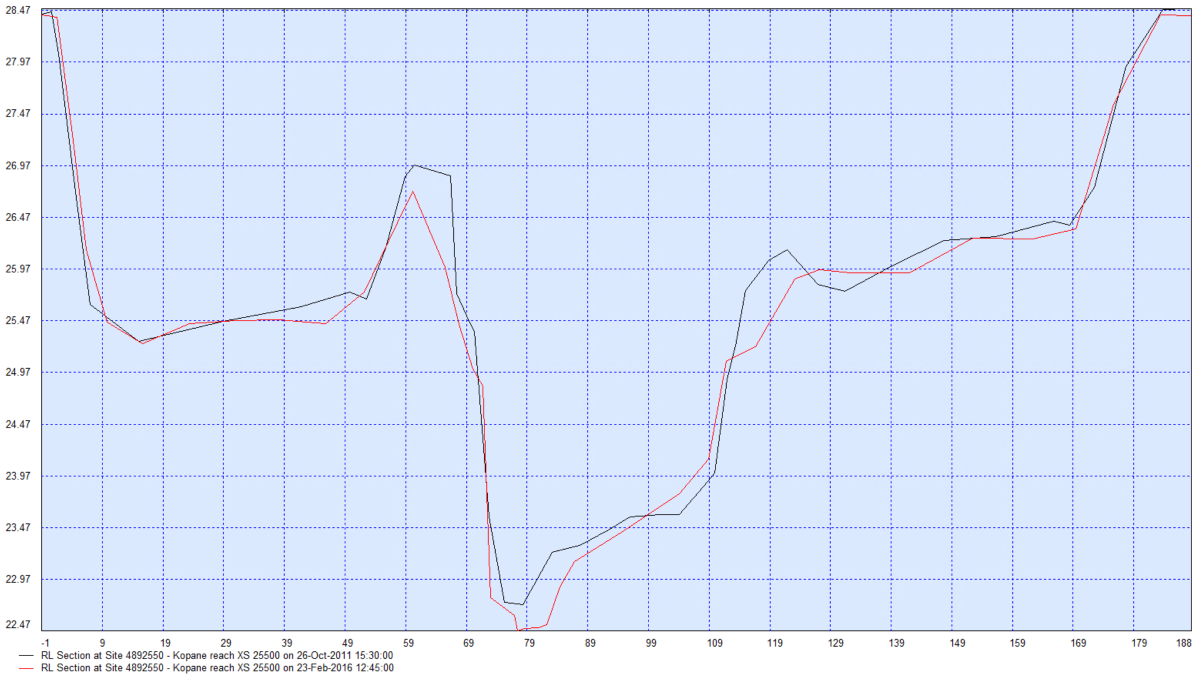
RL Section at Site 4892544 - Kopane reach XS 25440 on 26-Oct-2011 15:00:00
RL Section at Site 4892544 - Kopane reach XS 25440 on 23-Feb-2016 12:30:00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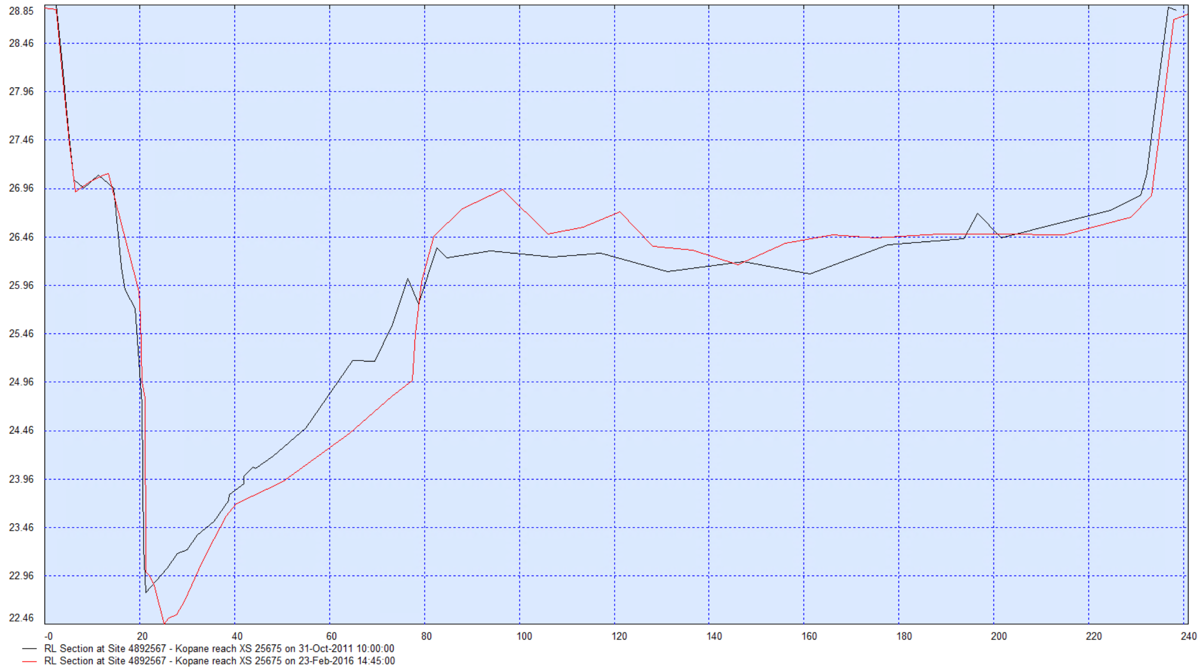
RL Section at Site 4892550 - Kopane reach XS 25500 on 26-Oct-2011 15:30:00
RL Section at Site 4892550 - Kopane reach XS 25500 on 23-Feb-2016 12:45:00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RL Section at Site 4892567 - Kopane reach XS 25675 on 31-Oct-2011 10:00:00
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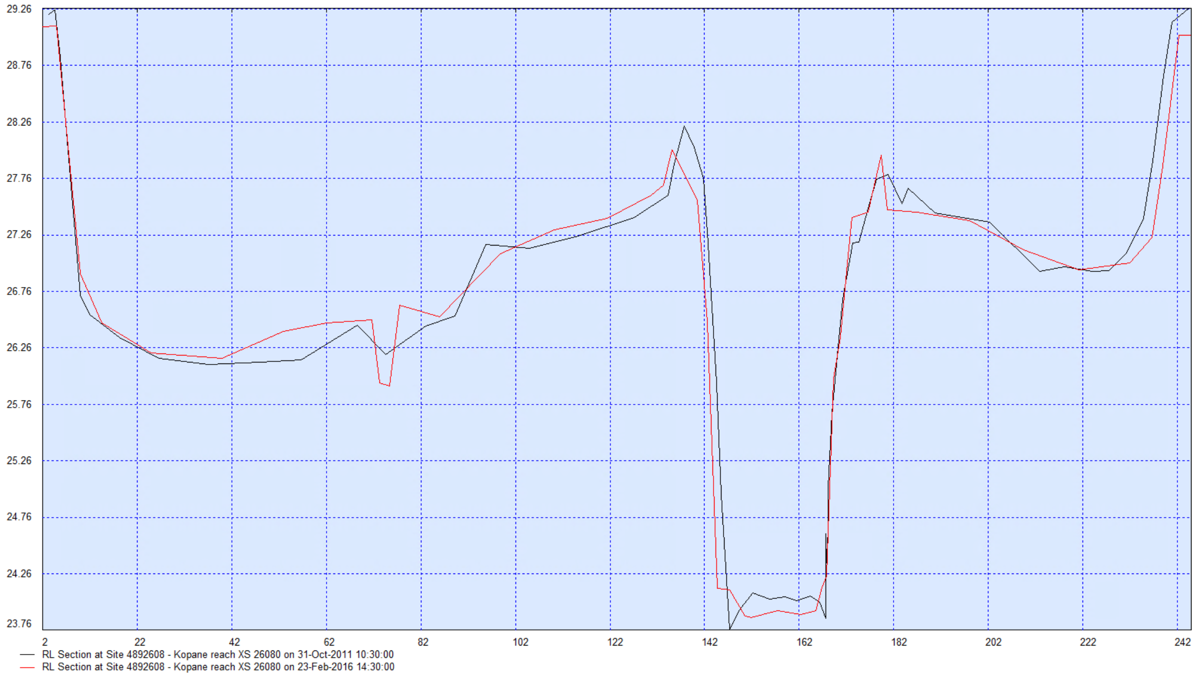
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42
62
82
102
122
142
162
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202
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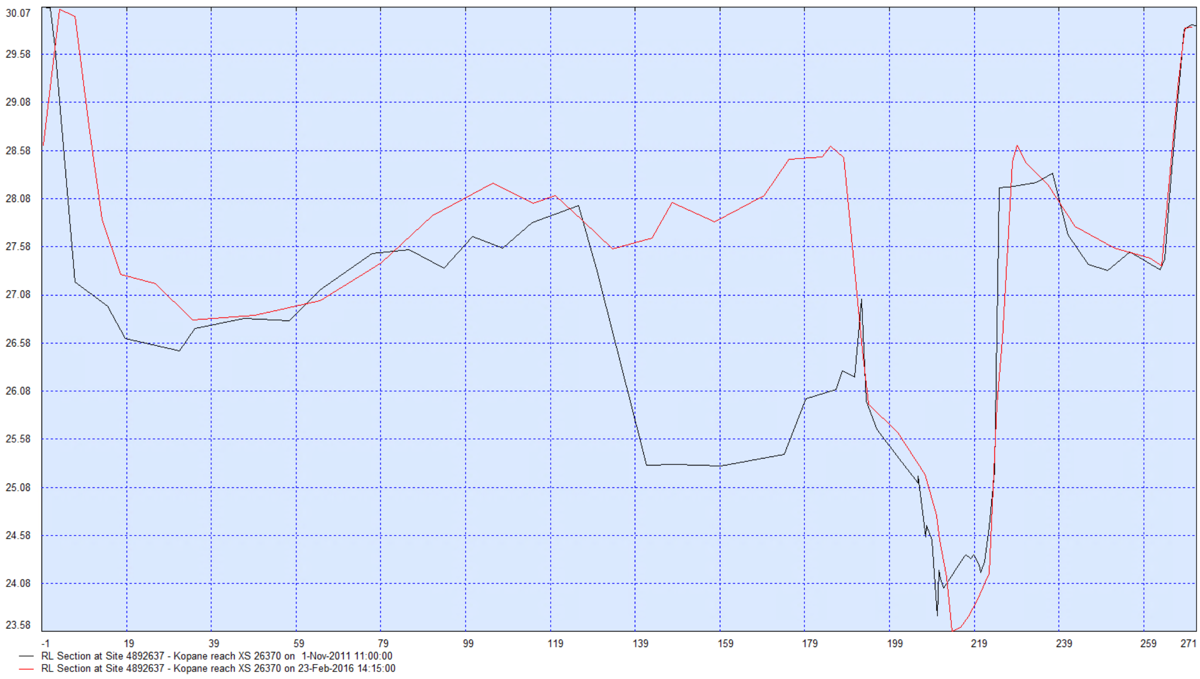
RL Section at Site 4892608 - Kopane reach XS 26080 on 31-Oct-2011 10:30:00
RL Section at Site 4892608 - Kopane reach XS 26080 on 23-Feb-2016 14:30:00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59
79
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159
179
199
219
239
259
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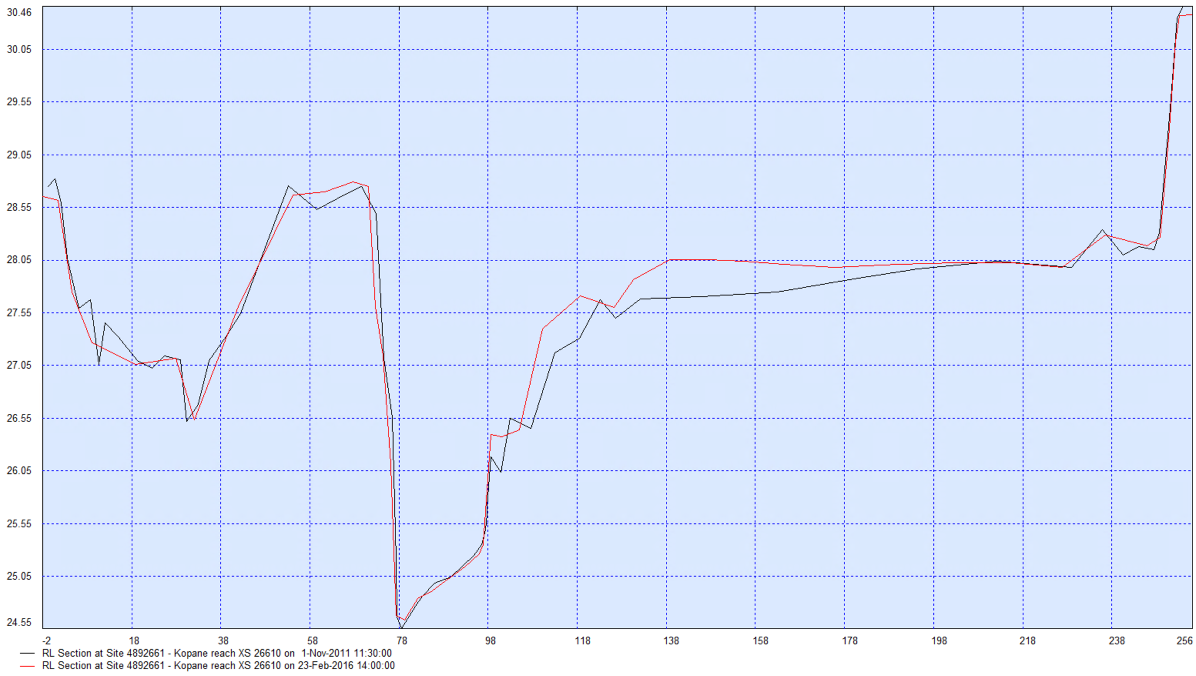
RL Section at Site 4892637 - Kopane reach XS 26370 on 1-Nov-2011 11:00:00
RL Section at Site 4892637 - Kopane reach XS 26370 on 23-Feb-2016 14:15:00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238
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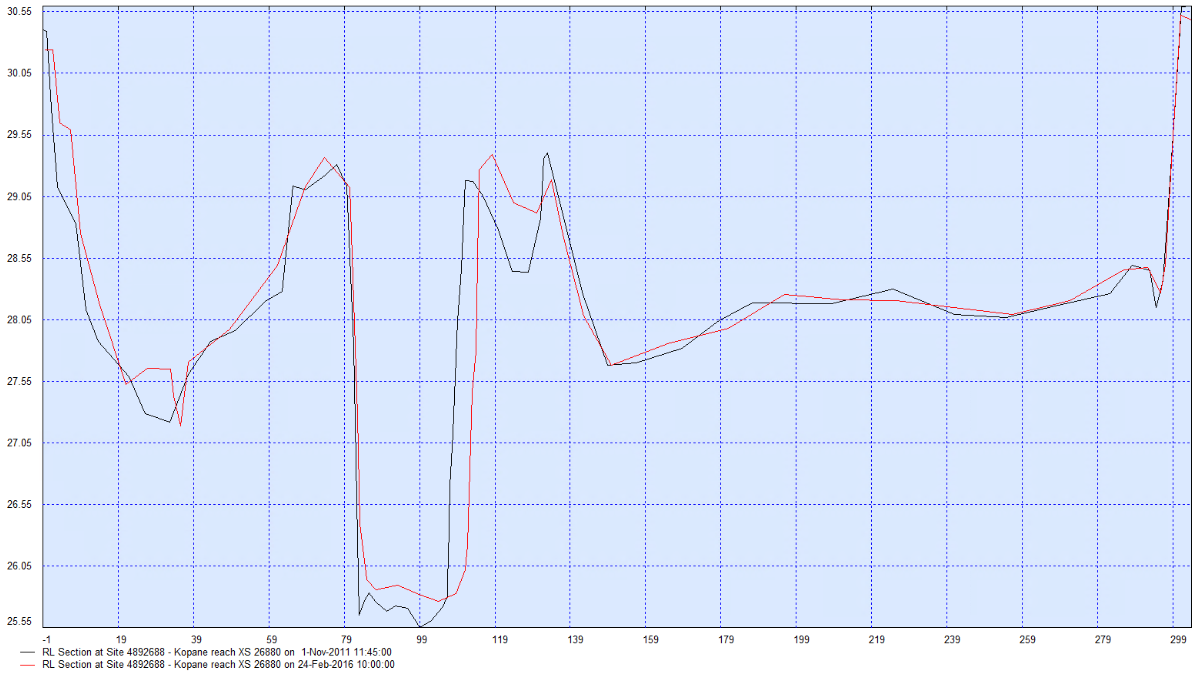
RL Section at Site 4892661 - Kopane reach XS 26610 on 1-Nov-2011 11:30:00
RL Section at Site 4892661 - Kopane reach XS 26610 on 23-Feb-2016 14:00:00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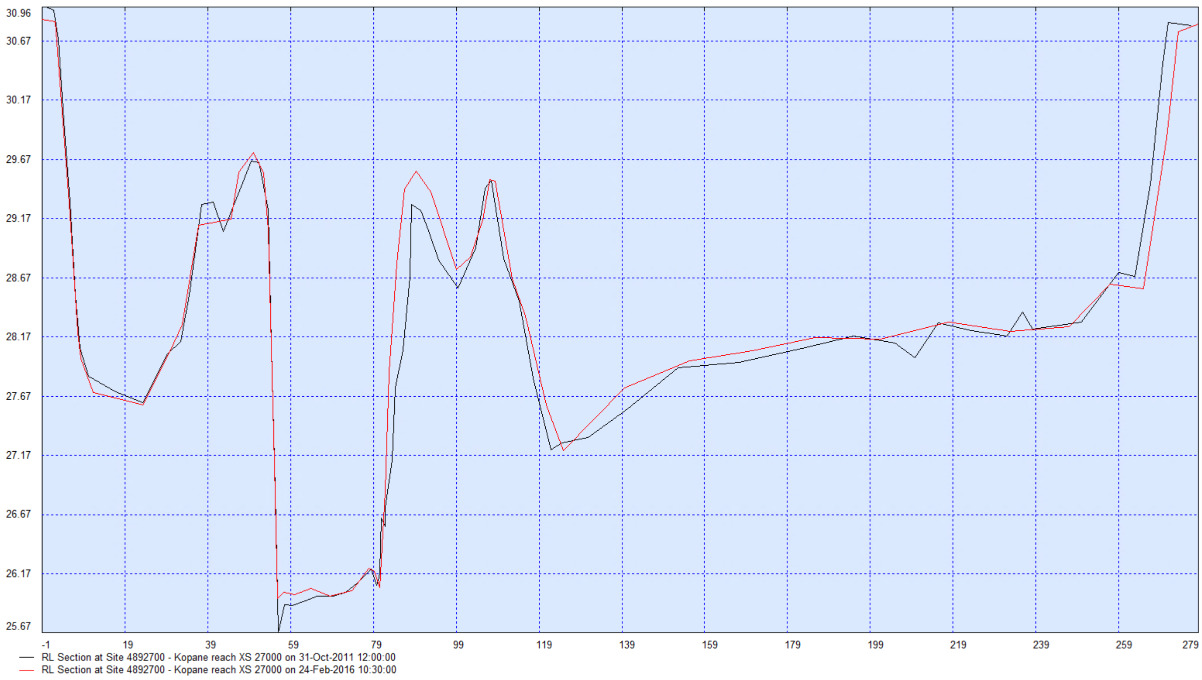
RL Section at Site 4892688 - Kopane reach XS 26880 on 1-Nov-2011 11:45:00
RL Section at Site 4892688 - Kopane reach XS 26880 on 24-Feb-2016 10:00:00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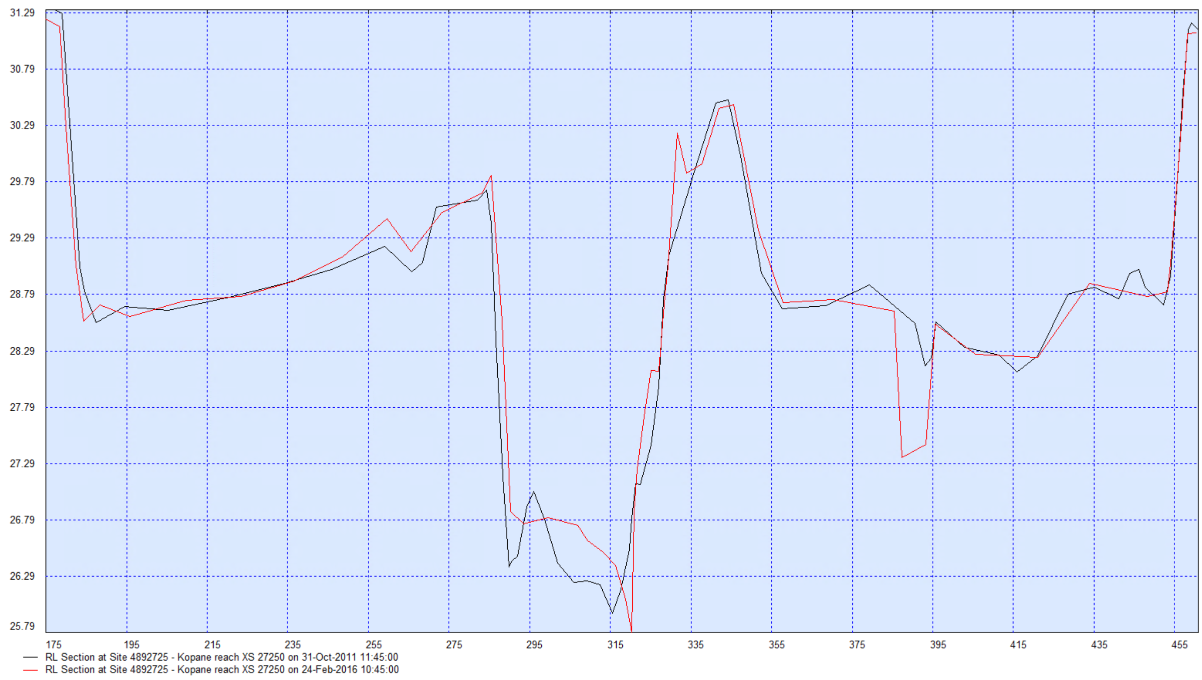
RL Section at Site 4892700 - Kopane reach XS 27000 on 31-Oct-2011 12:00:00
RL Section at Site 4892700 - Kopane reach XS 27000 on 24-Feb-2016 10:30:00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195
215
235
255
275
295
315
335
355
375
395
415
435
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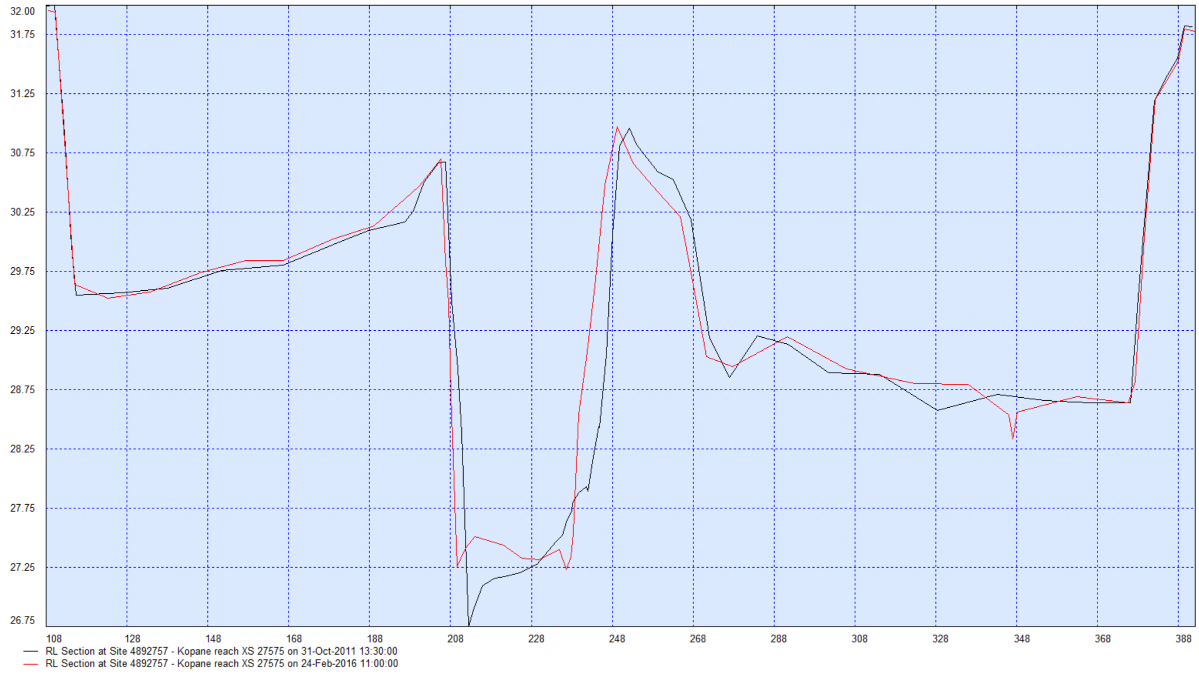
RL Section at Site 4892725 - Kopane reach XS 27250 on 31-Oct-2011 11:45:00
RL Section at Site 4892725 - Kopane reach XS 27250 on 24-Feb-2016 10:45:00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128
148
168
188
208
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248
268
288
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328
348
368
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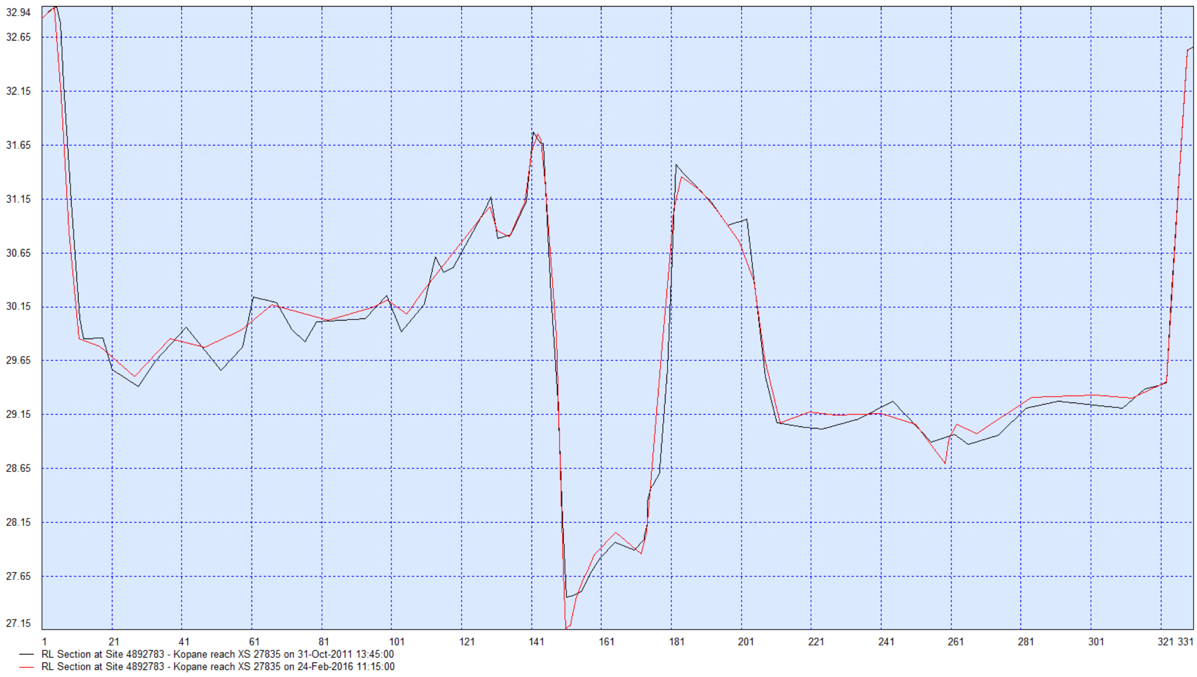
RL Section at Site 4892757 - Kopane reach XS 27575 on 31-Oct-2011 13:30:00
RL Section at Site 4892757 - Kopane reach XS 27575 on 24-Feb-2016 11:00:00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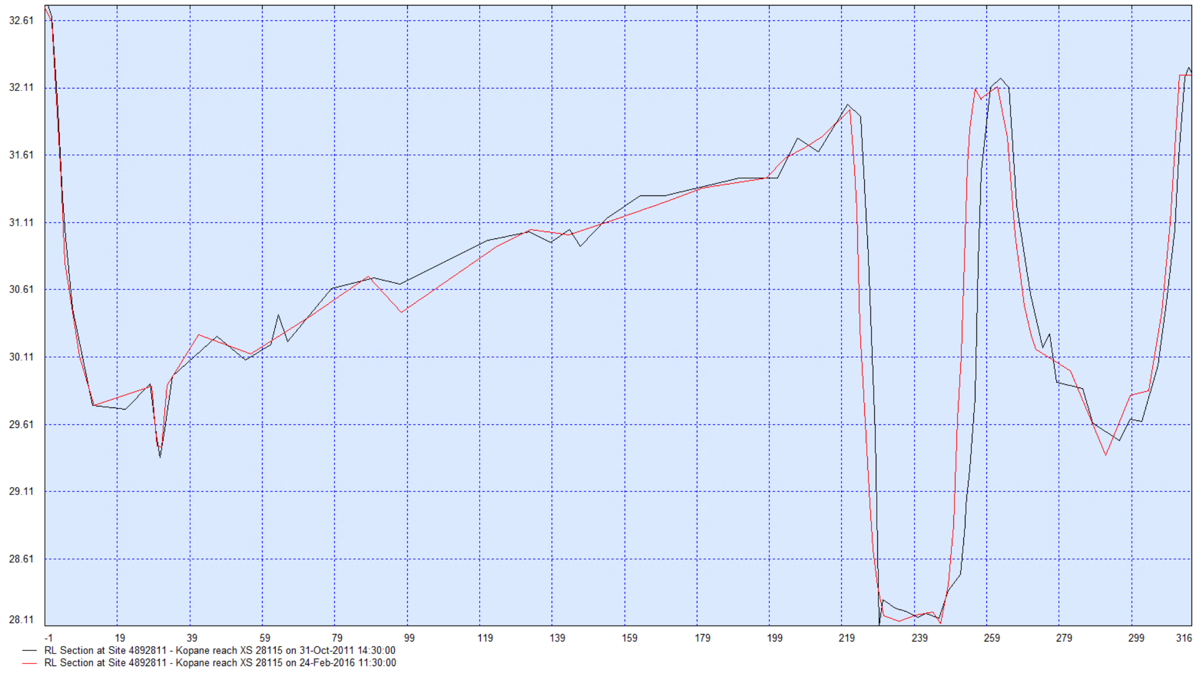
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321 331
RL Section at Site 4892783 - Kopane reach XS 27835 on 31-Oct-2011 13:45:00
RL Section at Site 4892783 - Kopane reach XS 27835 on 24-Feb-2016 11:15:00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79
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119
139
159
179
199
219
239
259
279
299
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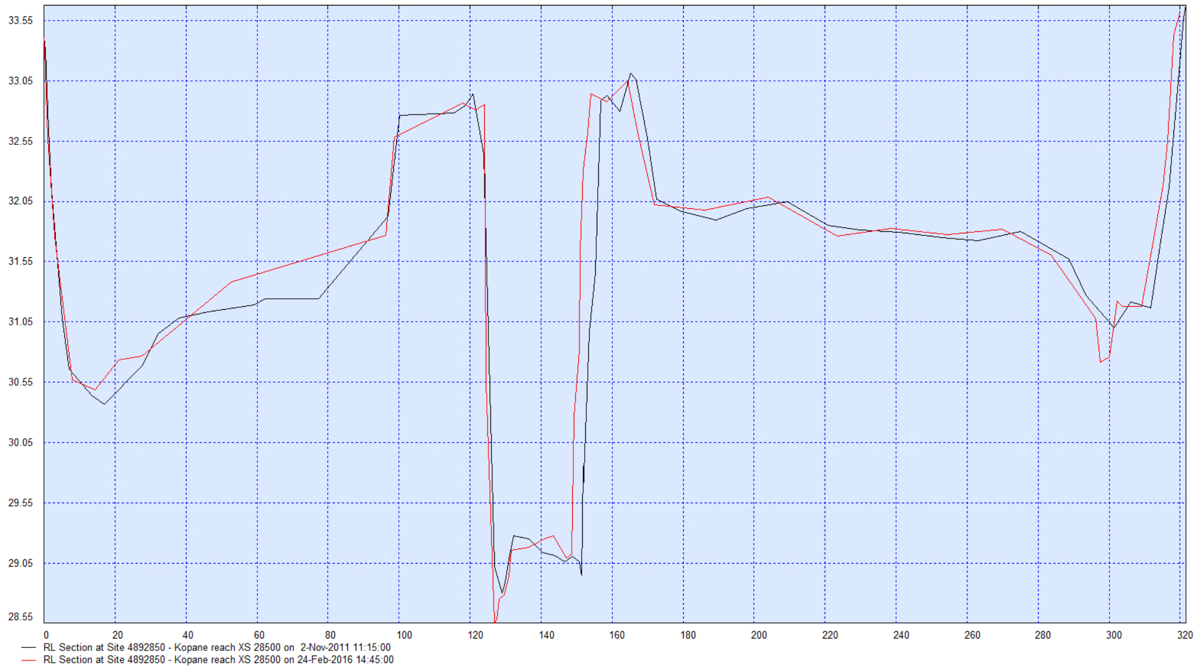
RL Section at Site 4892811 - Kopane reach XS 28115 on 31-Oct-2011 14:30:00
RL Section at Site 4892811 - Kopane reach XS 28115 on 24-Feb-2016 11:30:00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RL Section at Site 4892850 - Kopane reach XS 28500 on 2-Nov-2011 11:15:00
RL Section at Site 4892850 - Kopane reach XS 28500 on 24-Feb-2016 14:45:00


34.64
34.30
33.80
33.30
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28.80
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RL Section at Site 4892875 on 2-Nov-2011 11:30:00
RL Section at Site 4892875 on 24-Feb-2016 14:30:00


35.80
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56
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76
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106
116
126
136
146
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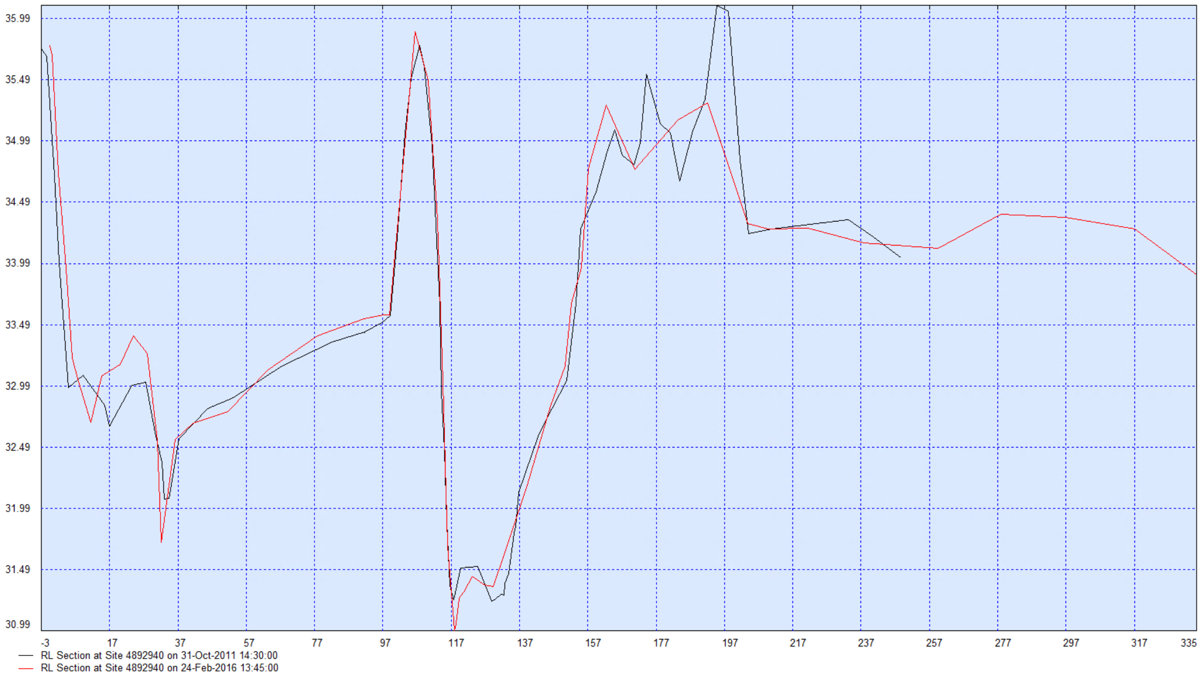
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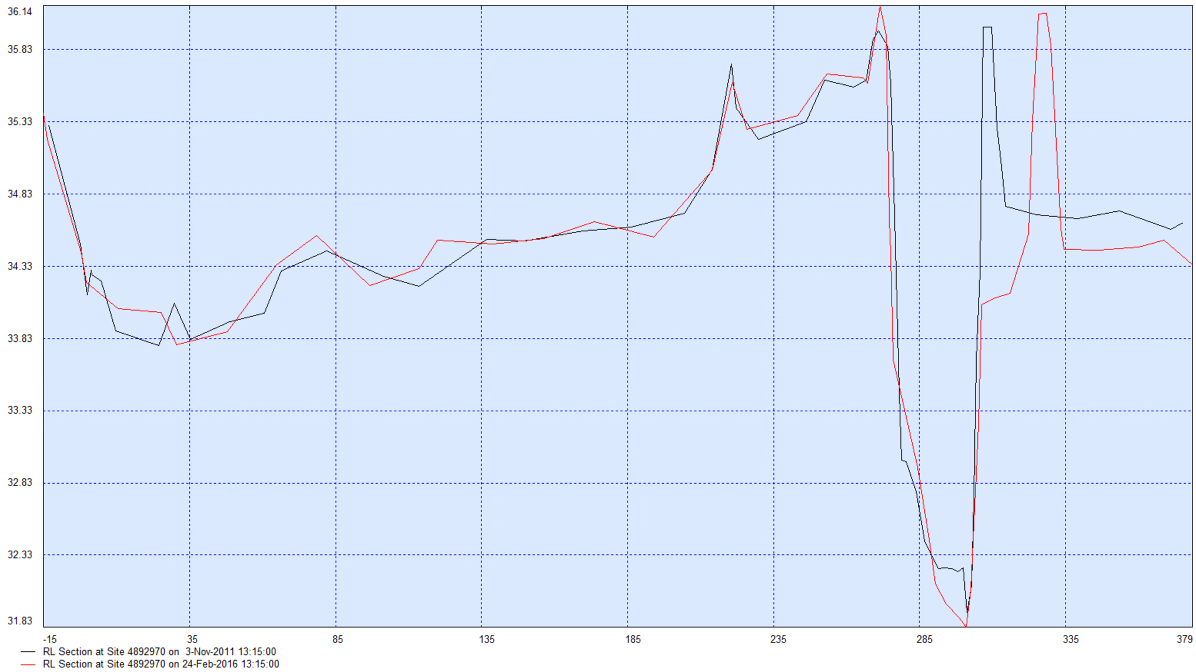
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RL Section at Site 4892970 on 3-Nov-2011 13:15:00
RL Section at Site 4892970 on 24-Feb-2016 13:15:00


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110
120
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160
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180
190
200
210
RL Section at Site 4893000 on 3-Nov-2011 13:30:00
RL Section at Site 4893000 on 24-Feb-2016 13:00:00


38.74
38.24
37.74
37.24
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99
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249
299
349
399
449
499
549
568
RL Section at Site 4893060 on 16-Nov-2011 13:30:00
RL Section at Site 4893060 on 25-Feb-2016 11:45:00


41.11
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RL Section at Site 4893105 on 17-Nov-2011 12:30:00
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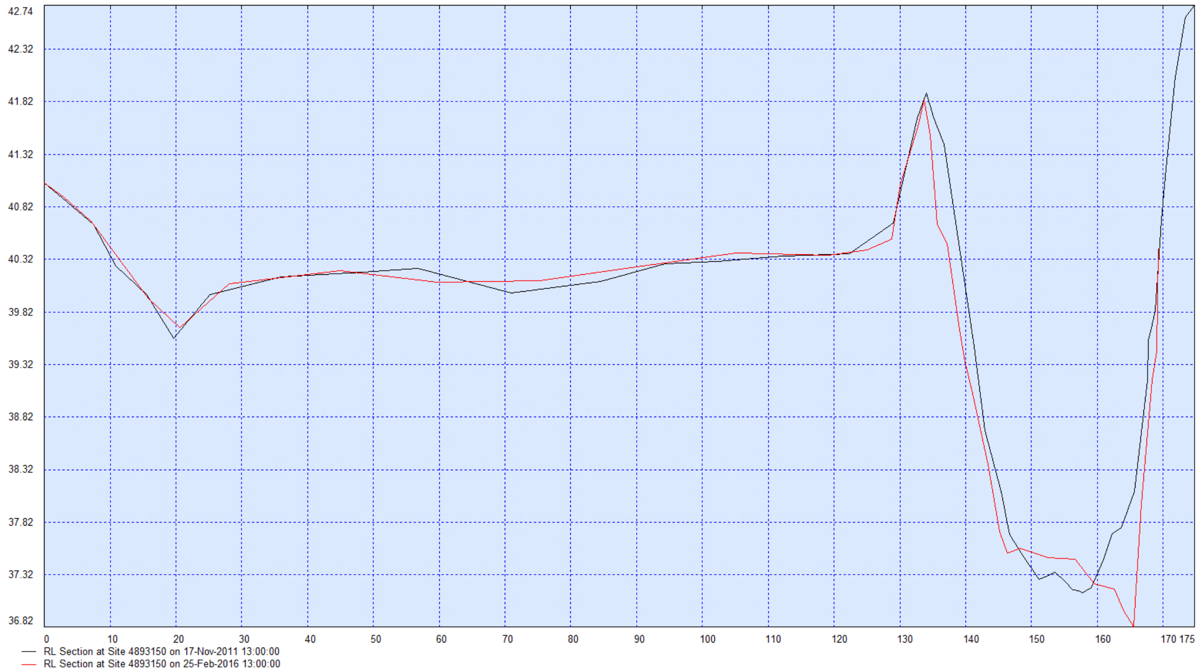

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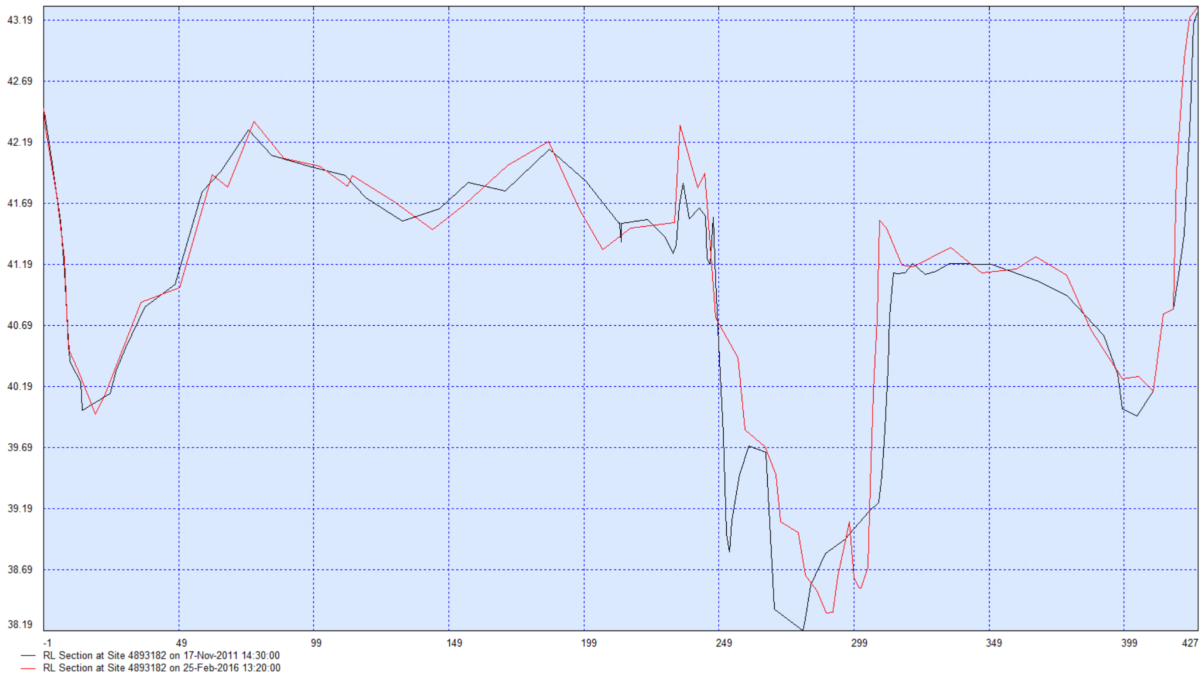

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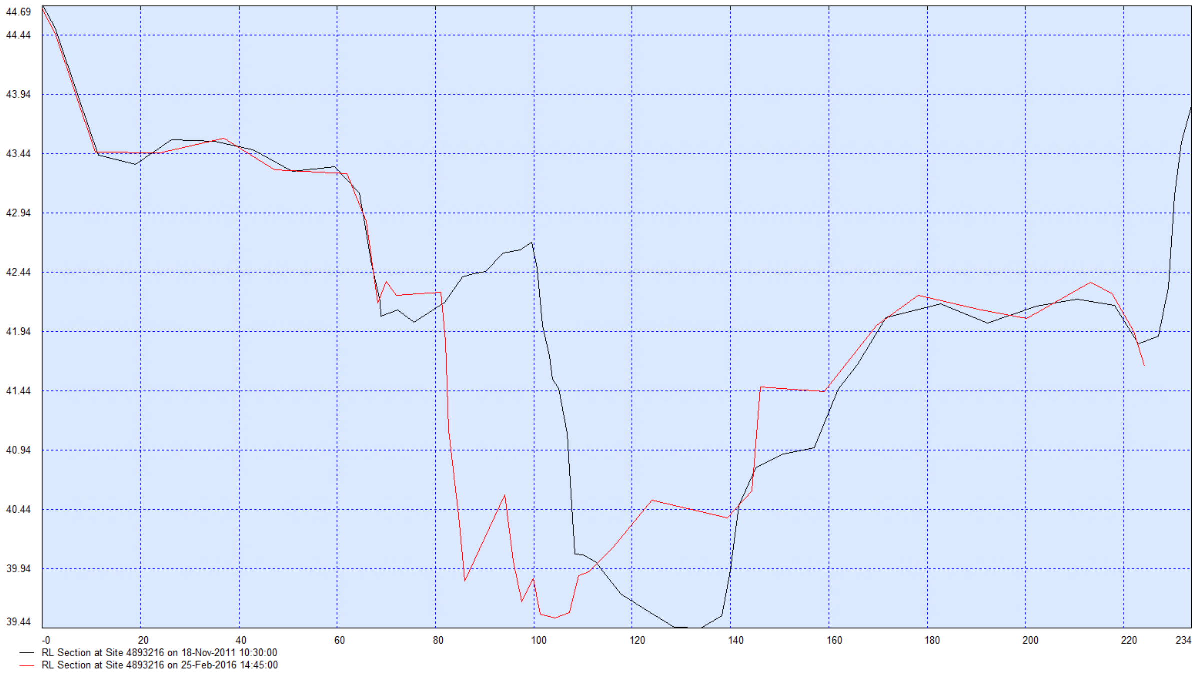
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100
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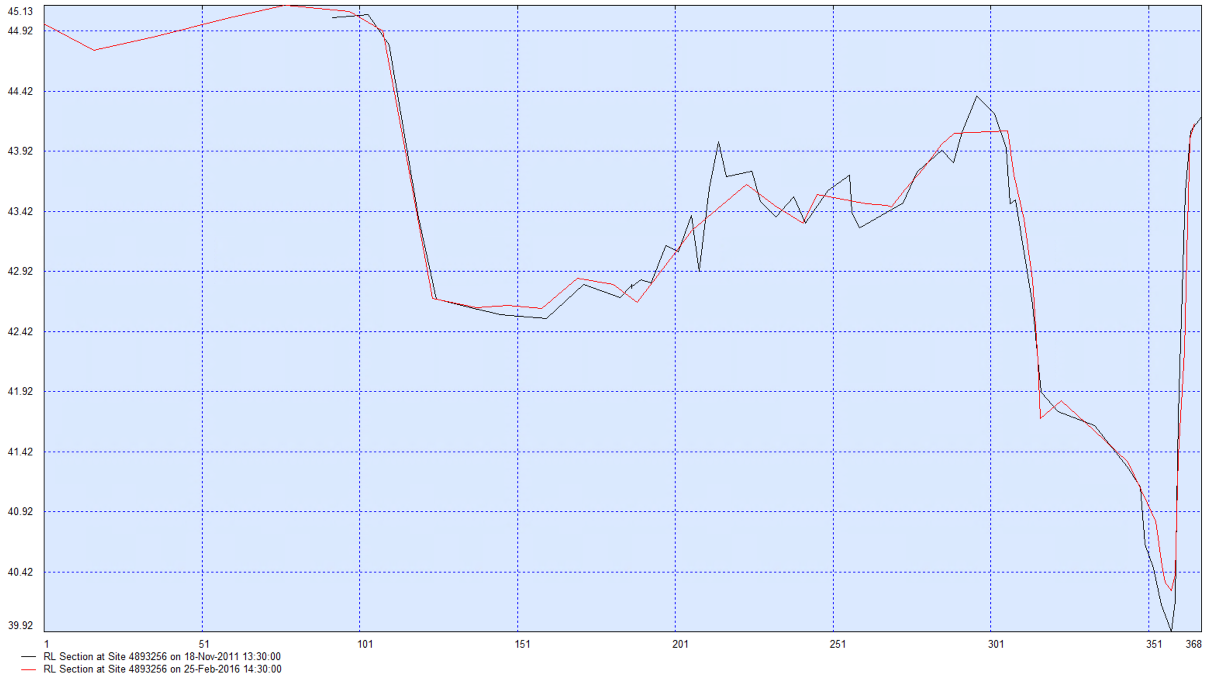
RL Section at Site 4893216 on 25-Feb-2016 14:45:00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RL Section at Site 4893256 on 18-Nov-2011 13:30:00
RL Section at Site 4893256 on 25-Feb-2016 14:30:00


46.63
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RL Section at Site 4893300 on 18-Nov-2011 14:30:00
RL Section at Site 4893300 on 25-Feb-2016 14:15:00


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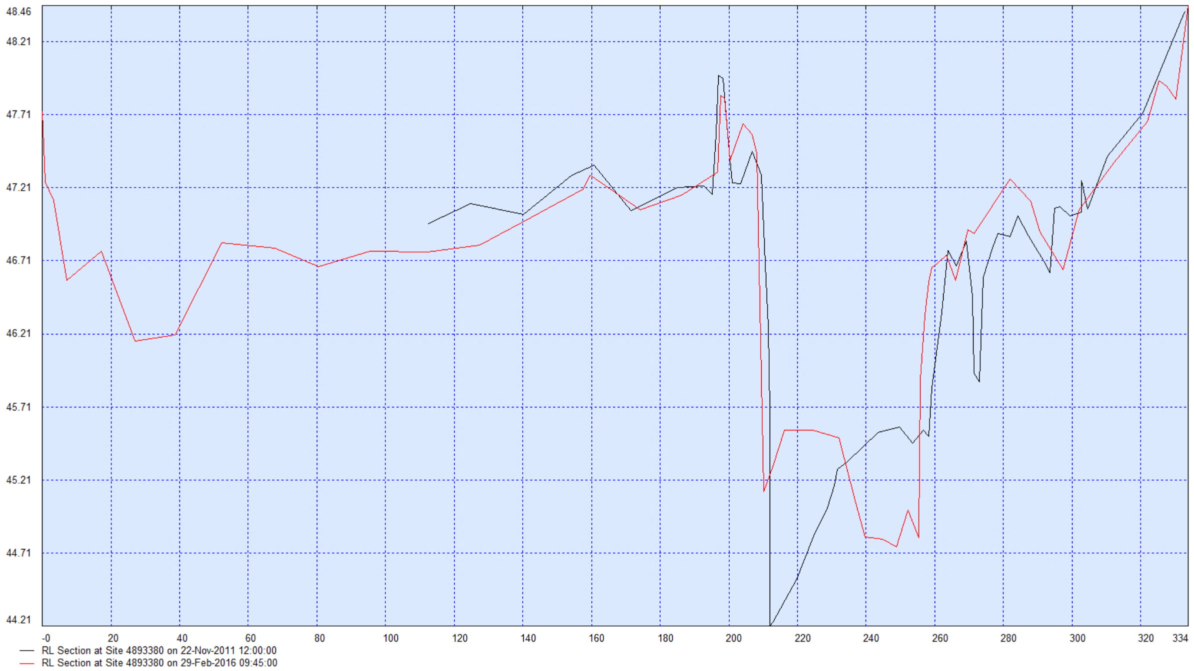
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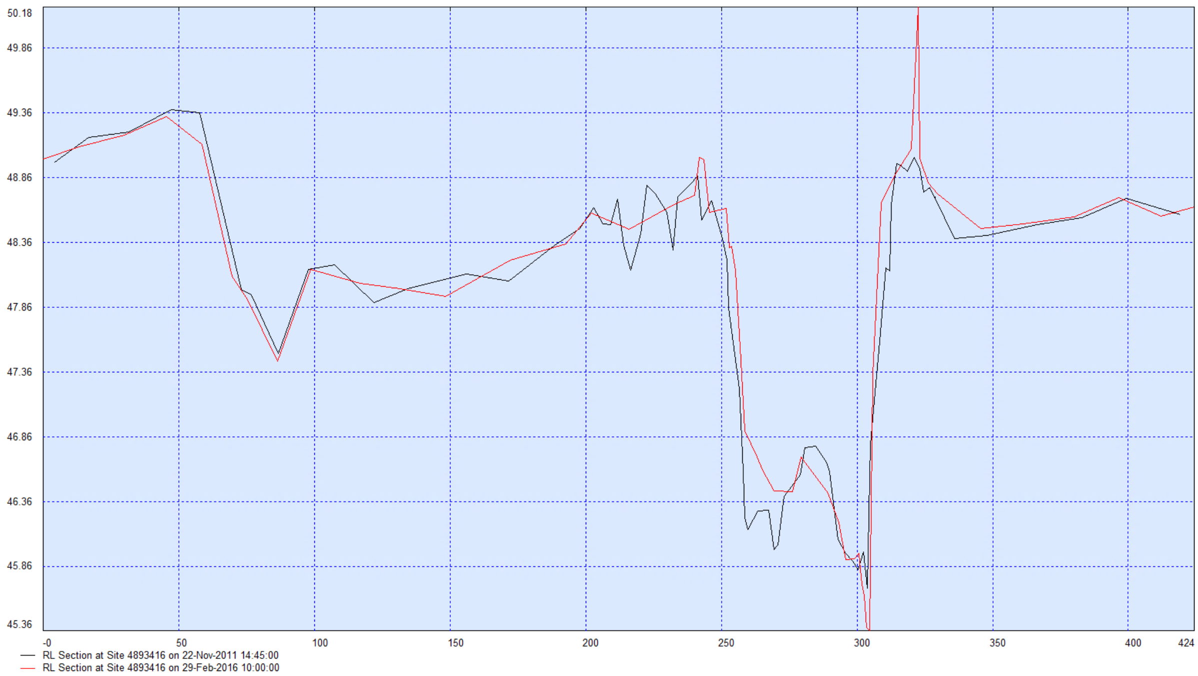
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118
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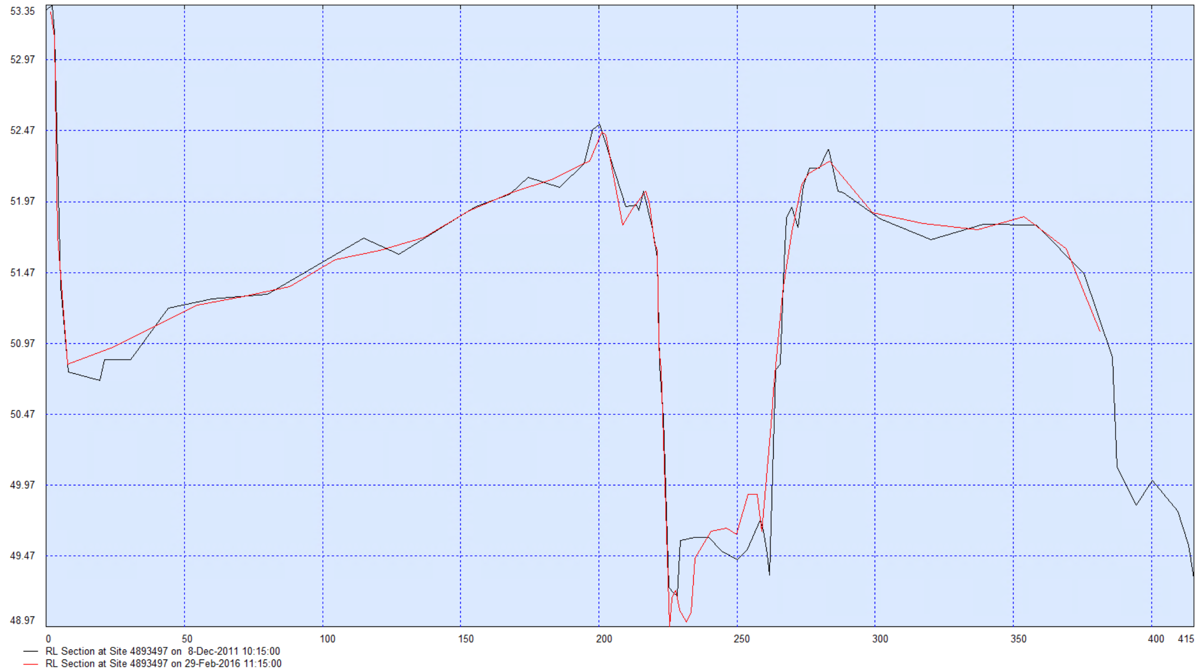

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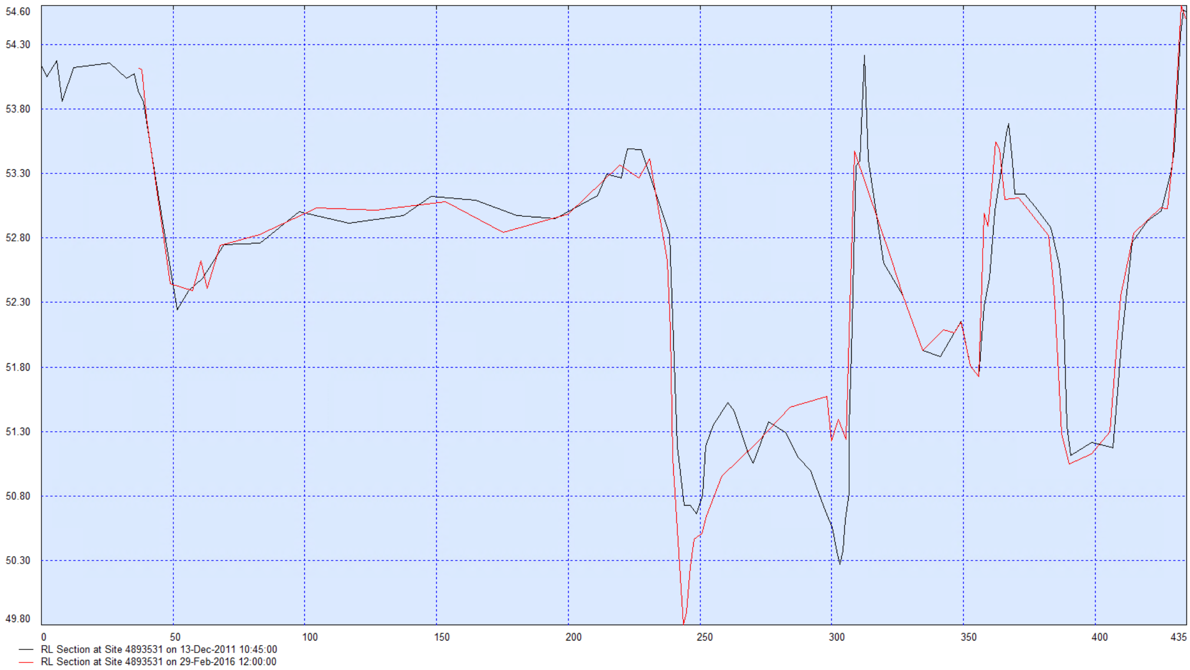
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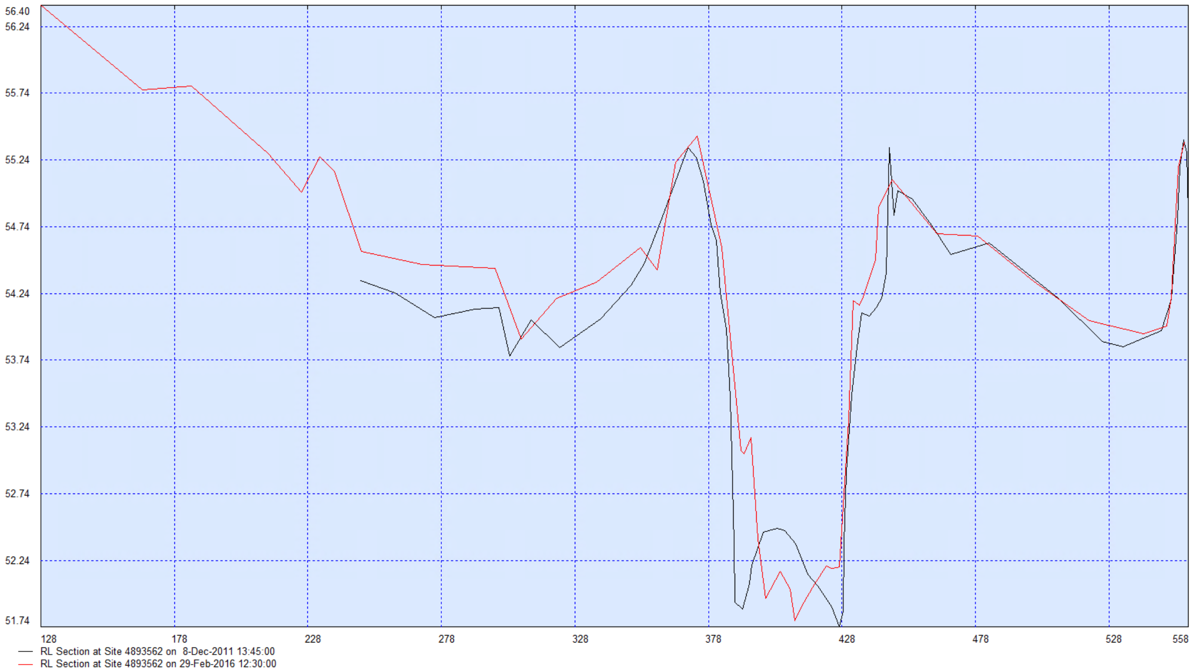
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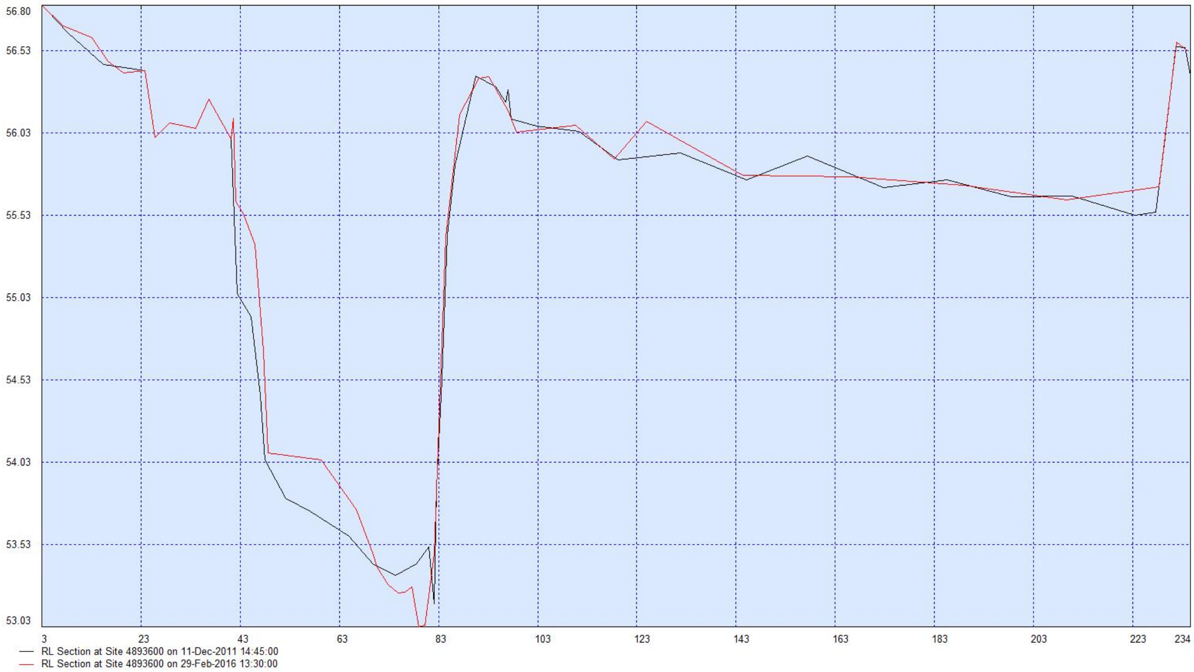
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103
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163
183
203
223
234
RL Section at Site 4893600 on 11-Dec-2011 14:45:00
RL Section at Site 4893600 on 29-Feb-2016 13:30:00


58.96
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633
RL Section at Site 4893629 on 9-Dec-2011 09:45:00
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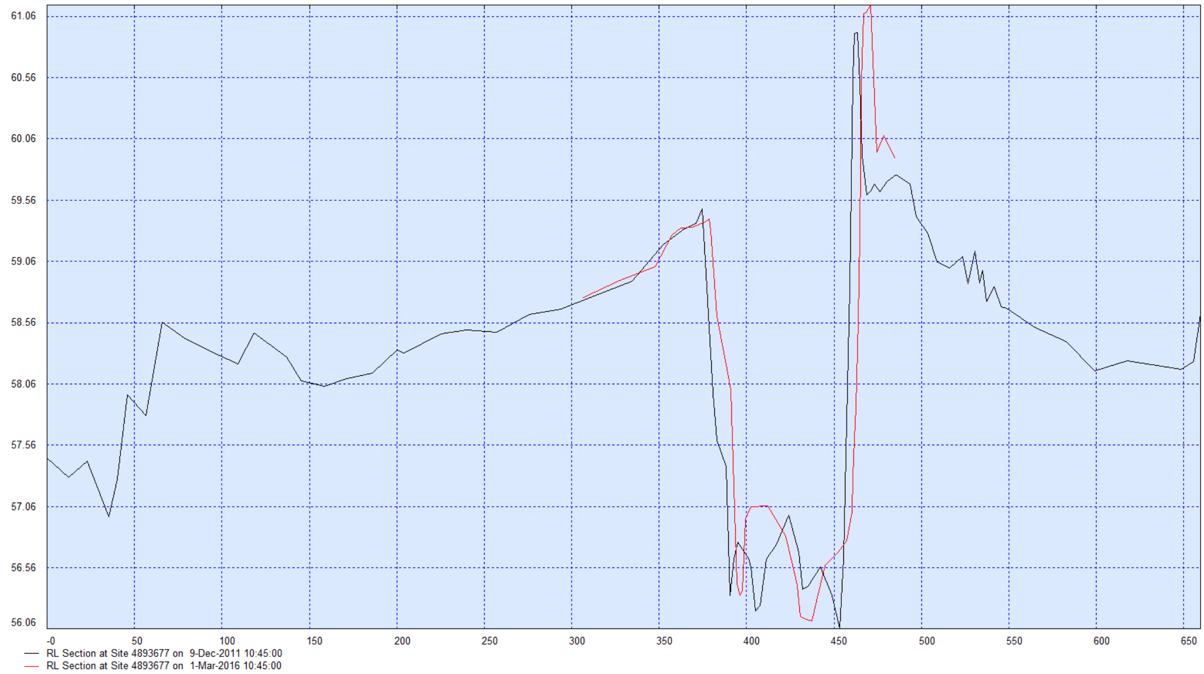
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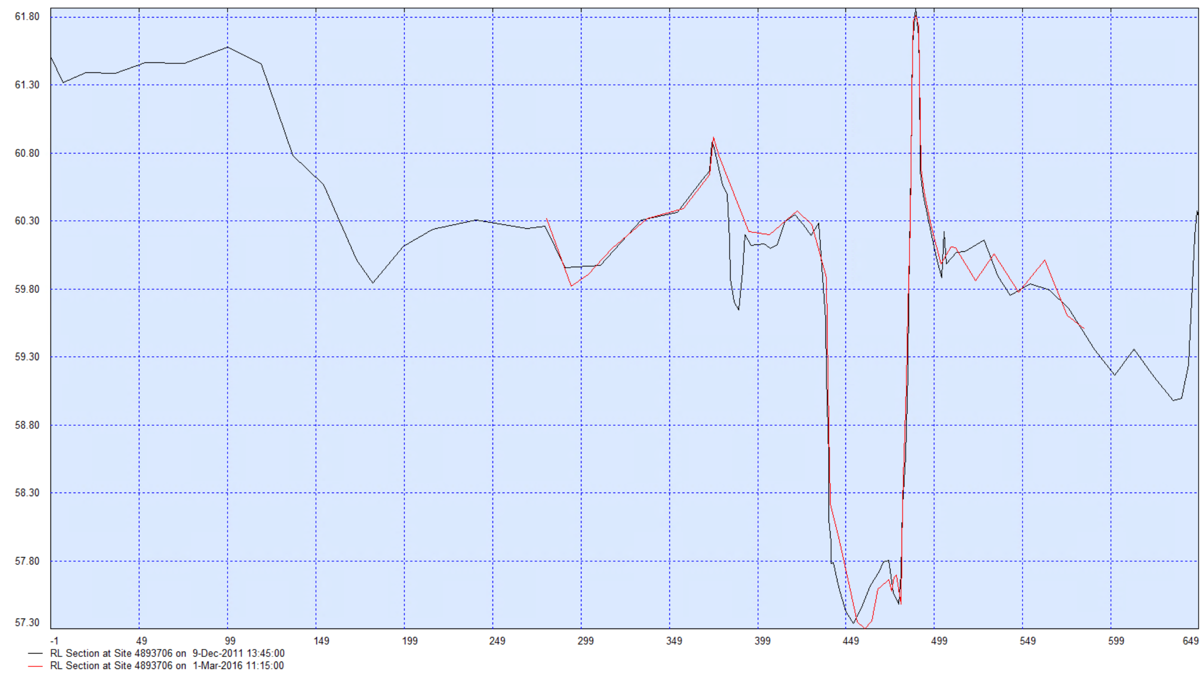
650
RL Section at Site 4893677 on 9-Dec-2011 10:45:00
RL Section at Site 4893677 on 1-Mar-2016 10:45:00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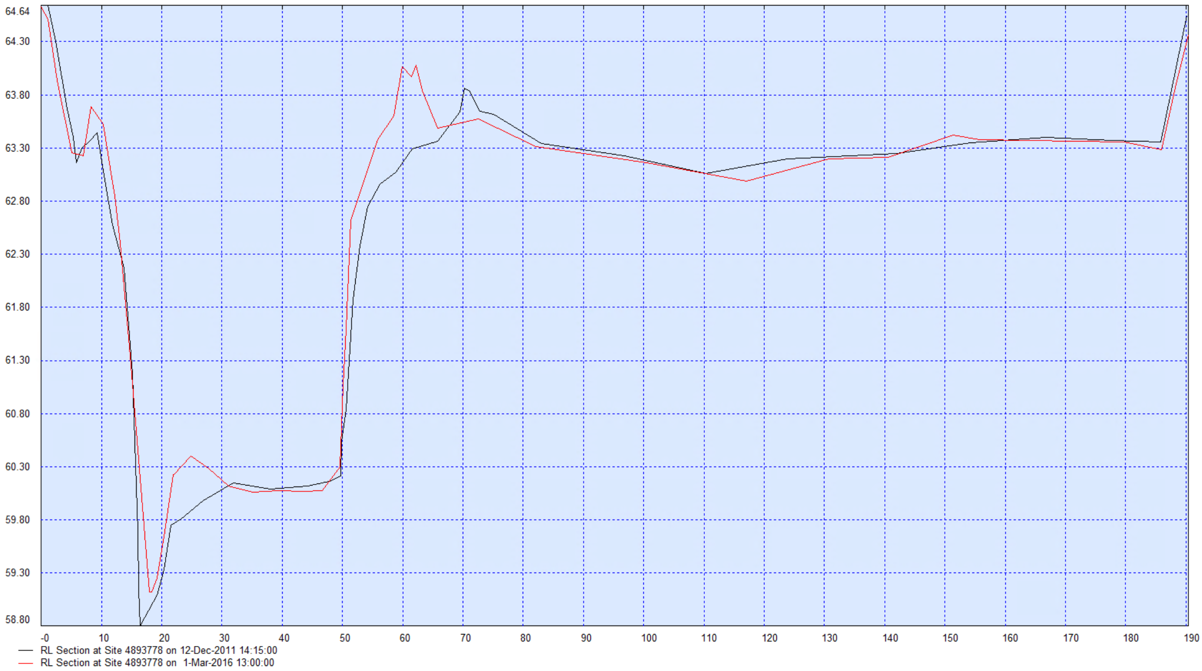
599
649
RL Section at Site 4893706 on 9-Dec-2011 13:45:00
RL Section at Site 4893706 on 1-Mar-2016 11:15:00


RL Section at Site 4893750 on 12-Dec-2011 13:15:00
RL Section at Site 4893750 on 1-Mar-2016 11:45:00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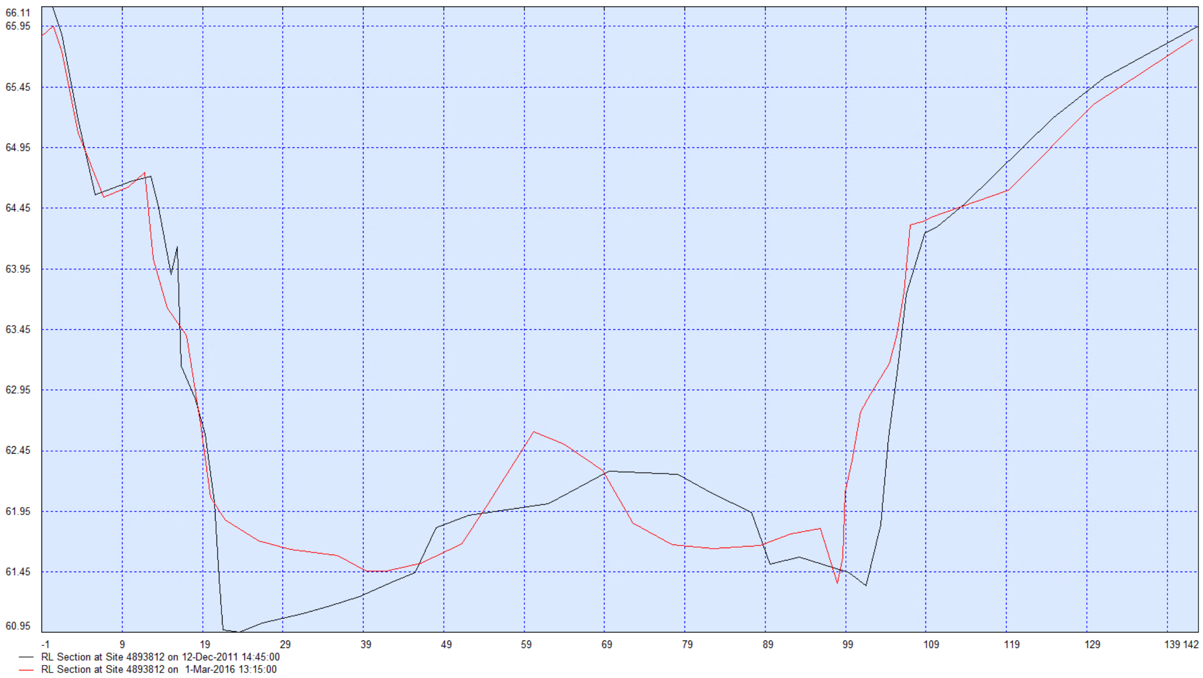
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39
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69
79
89
99
109
119
129
139 142
RL Section at Site 4893812 on 12-Dec-2011 14:45:00
RL Section at Site 4893812 on 1-Mar-2016 13:15:00


70.3
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63.3
62.3
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49
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89
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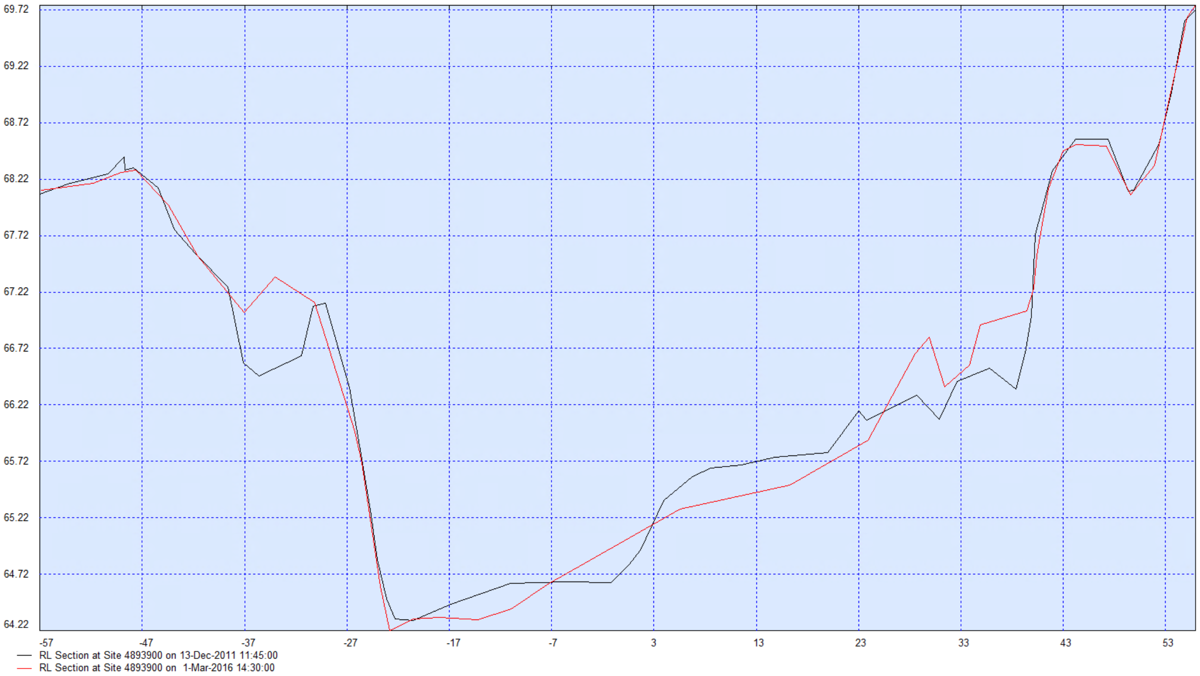
149
159
RL Section at Site 4893857 on 13-Dec-2011 10:15:00
RL Section at Site 4893857 on 1-Mar-2016 13:45:00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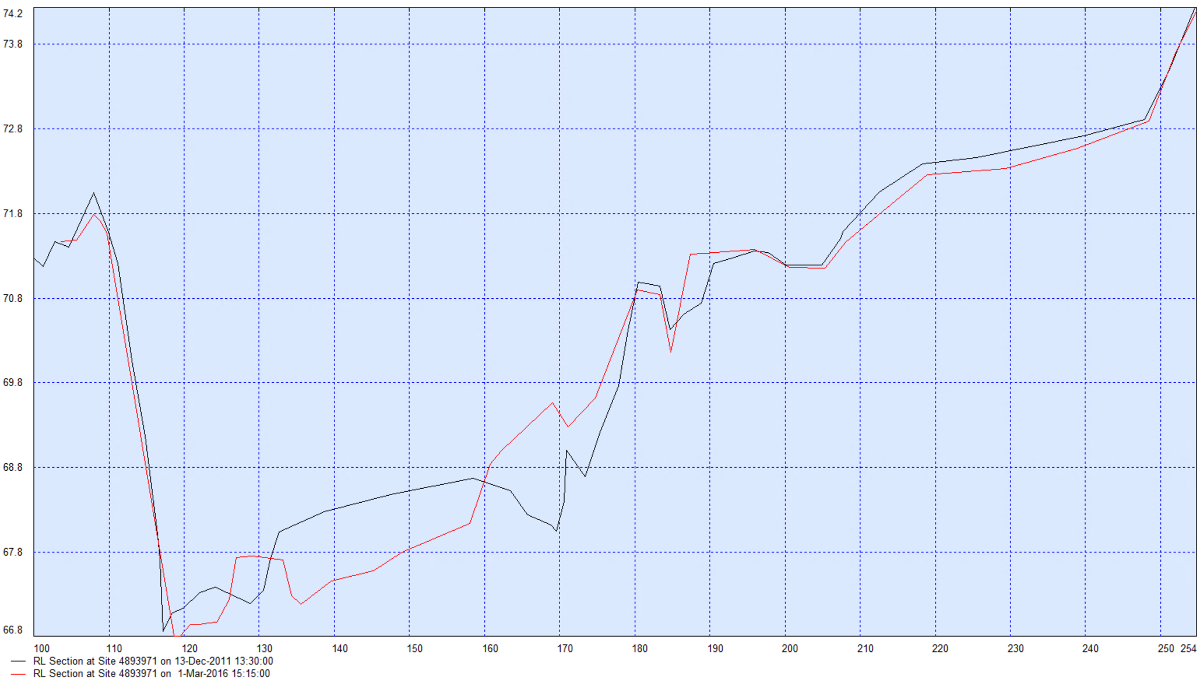
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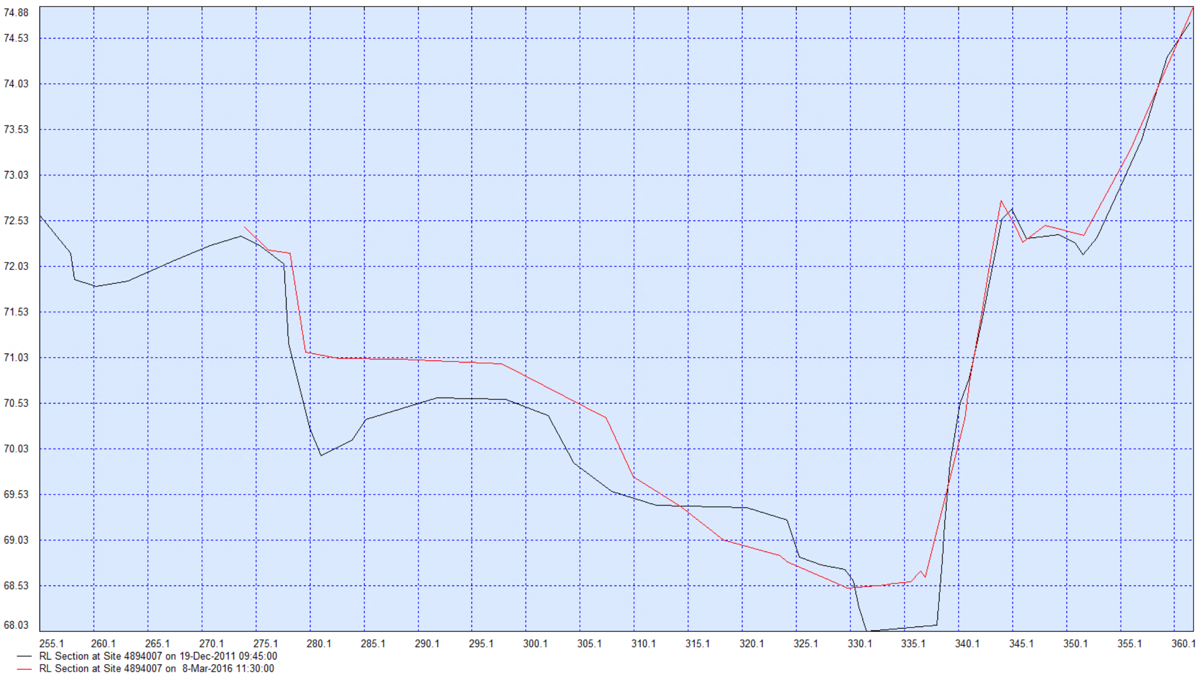
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72.16
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144
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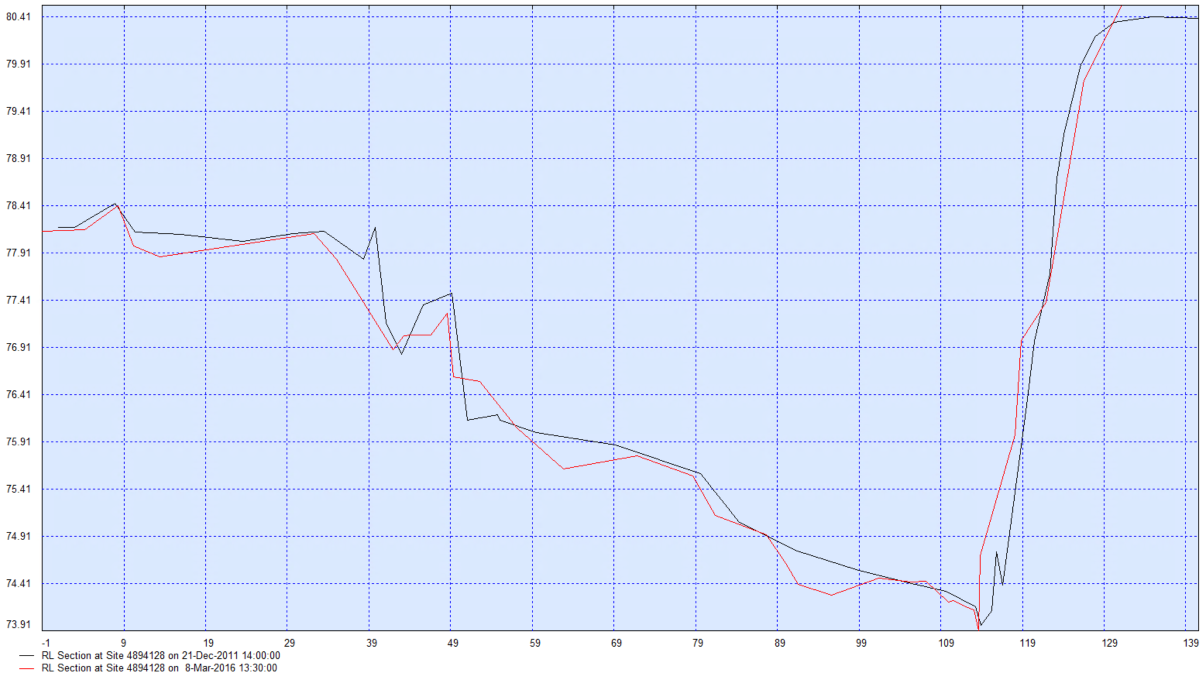
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RL Section at Site 4894128 on 8-Mar-2016 13:30:00


80.4
79.7
78.7
77.7
76.7
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74.7
73.7
72.7
71.7
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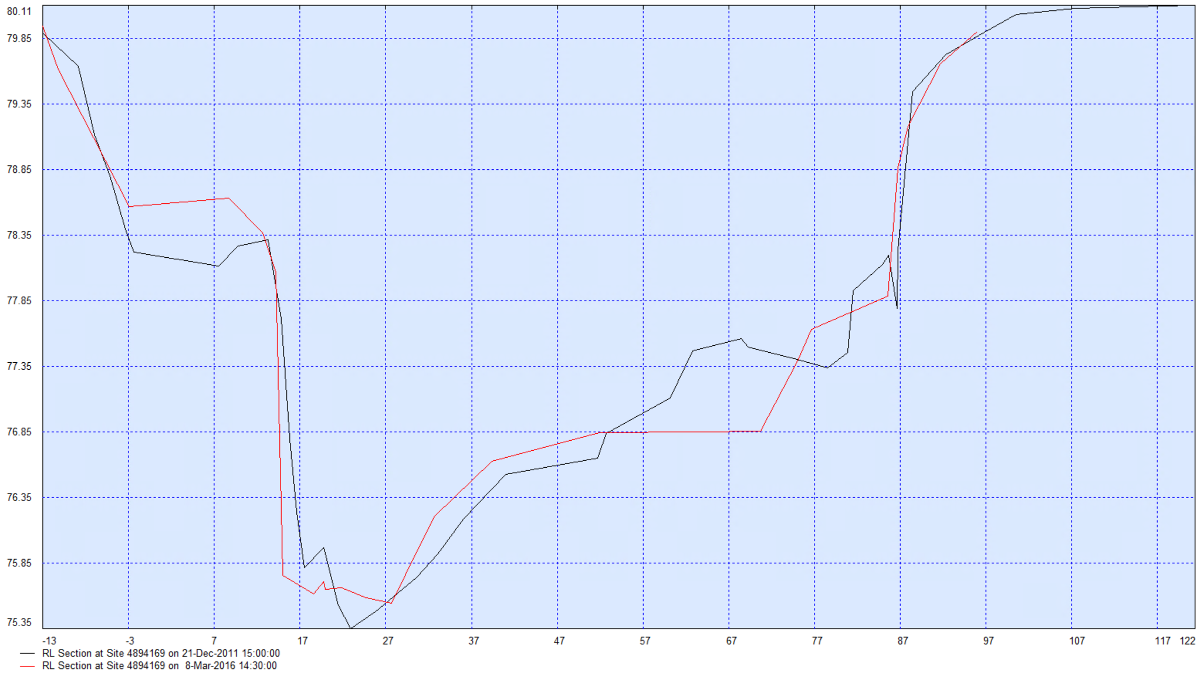
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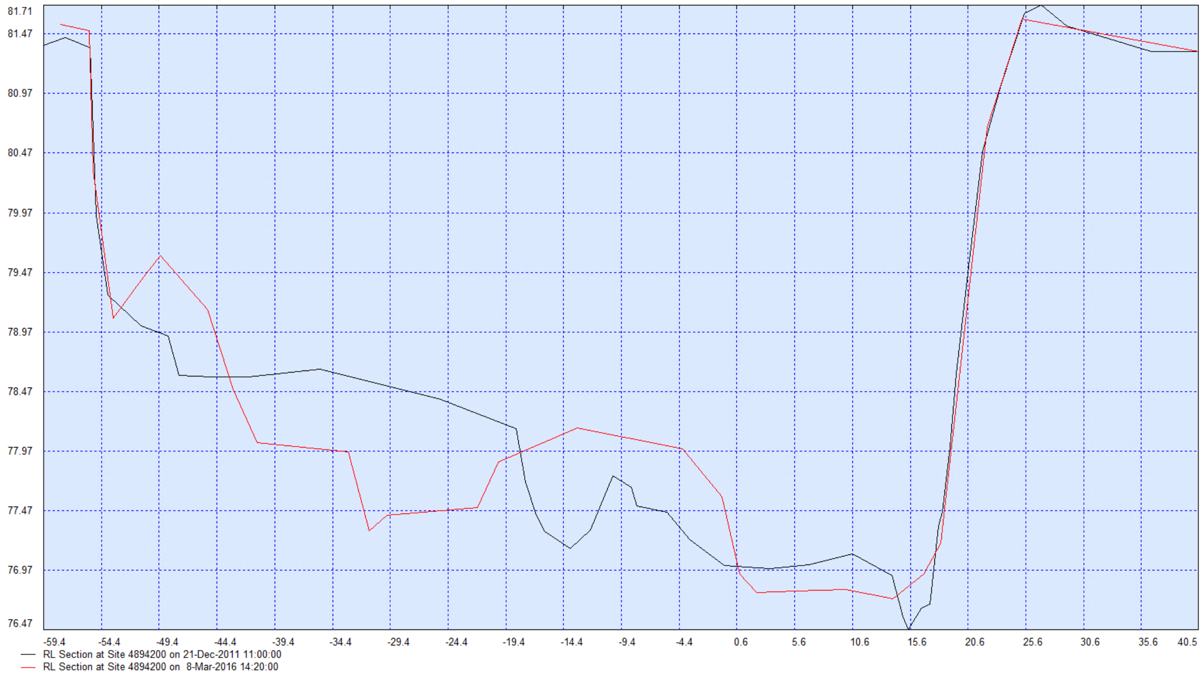
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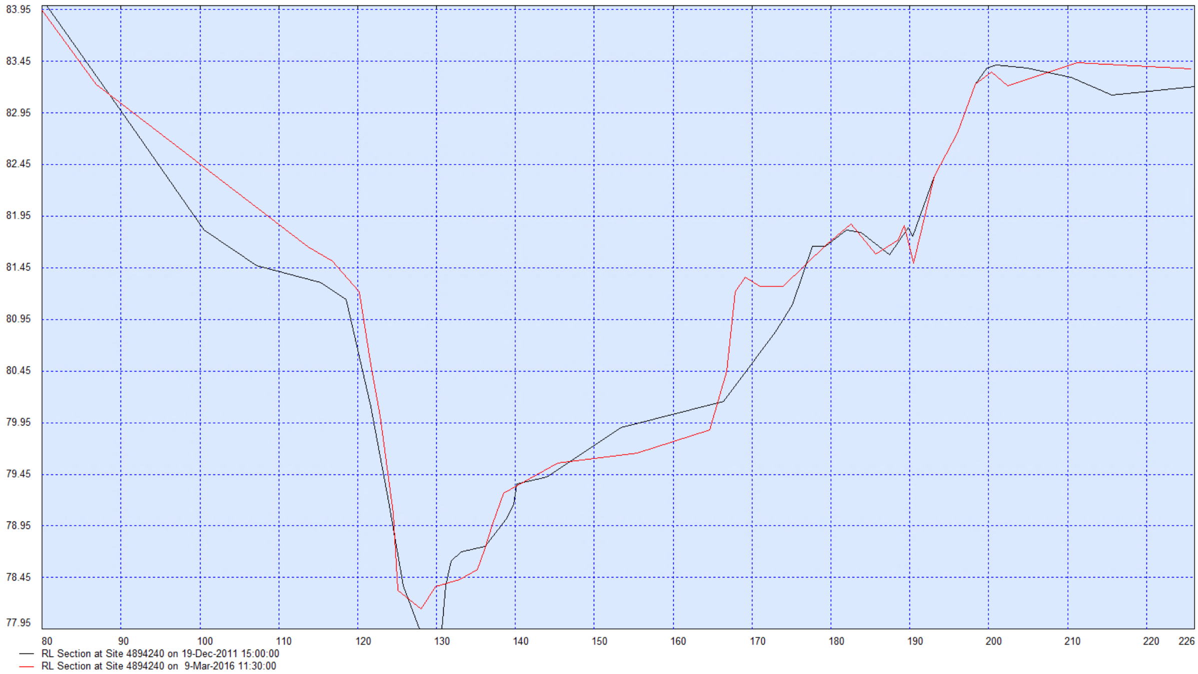
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226
RL Section at Site 4894240 on 19-Dec-2011 15:00:00
RL Section at Site 4894240 on 9-Mar-2016 11:30:00


91.0
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85.6
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81.6
80.6
79.6
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638
688
RL Section at Site 4894275 on 19-Dec-2011 13:30:00
RL Section at Site 4894275 on 9-Mar-2016 10:00:00


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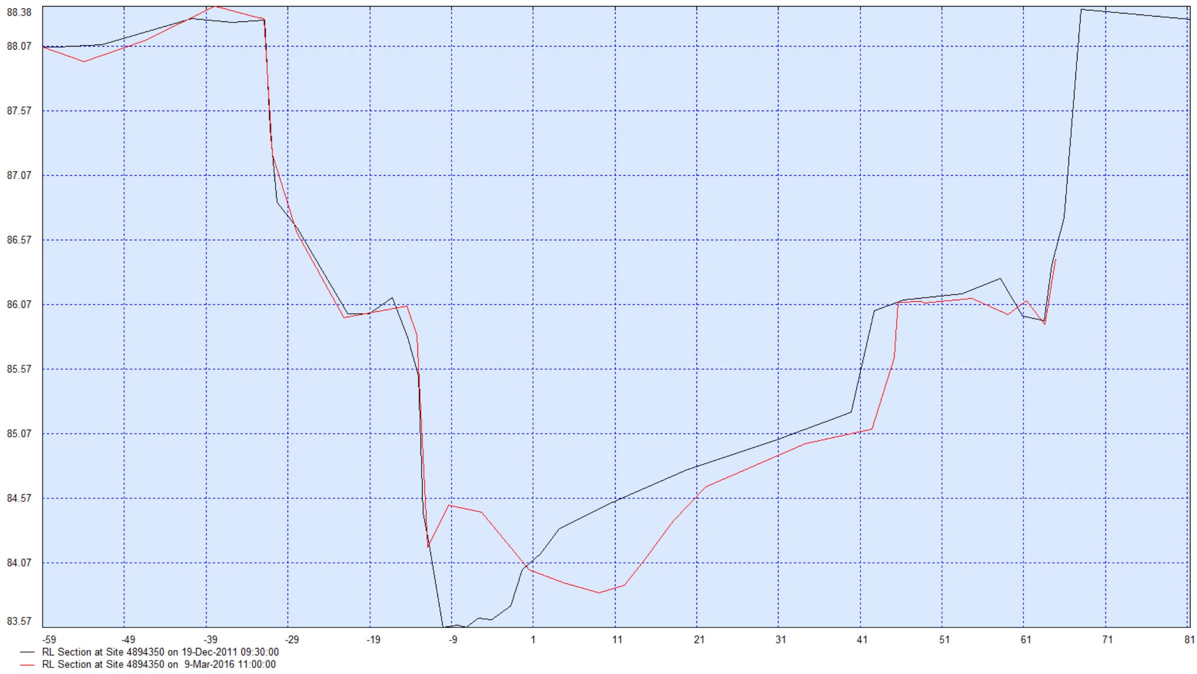
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RL Section at Site 4894350 on 19-Dec-2011 09:30:00
RL Section at Site 4894350 on 9-Mar-2016 11:00:00