Kawhatau River
Gravel Resource Study

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EXECUTIVE SUMMARY

This study examines the gravel resource in the Kawhatau River based on the analysis of a combination of river cross section survey data and gravel extraction records.

The Kawhatau River has been divided into four small individual reaches, which has led to a limitation in the analysis of the gravel resource. This limits the data analysis because an understanding of how the gravel resource is being affected in the wider Kawhatau River is not obtained; only an understanding of what is happening at the four reaches is gained.

The analysis conveyed in this report has shown that overall the gravel volume, mean bed level, and invert elevation has decreased from 1997 to 2015 at reaches one, two, and four, with r each three remaining relatively stable. On average, the gravel resource has displayed a loss of 4,000 cubic metres per annum, which is not considered hugely substantial. This leads to the idea that it is reasonable to assume that current rates of gravel extraction can continue to occur, until a reassessment of the gravel resource is done in the next Kawhatau gravel resource study.

When considering the results of this study it is clear that there are significant amounts of gaps in understanding the Kawhatau Gravel Resource Study. This is due largely to the limitations of the gravel resource data within this river, as there are only four small individual reaches that are surveyed, which don’t give a greater understanding of how the gravel resource is being affected in the wider river. This has led to there being insufficient data to draw meaningful conclusions from this study.

This has led to these recommendations. It is recommended that the Kawhatau River should be re-surveyed in the 2020-2021 season, so further analysis can be done to see if the resource is continuing to degrade. Also, the number of surveyed cross section across the Kawhatau River needs to be increased to gain a better understanding of what is happening in the wider river.

CONTENTS

Kawhatau River Gravel Resource Study

1. Introduction

This study examines the gravel resource in a 14 km reach of the Kawhatau River, based on an analysis of river cross sectional survey data. The cross sectional surveys cover four individual reaches of the Kawhatau, the locations of which are shown on the aerial photograph in Figure 1.1 below, and in more detail in Appendix A.

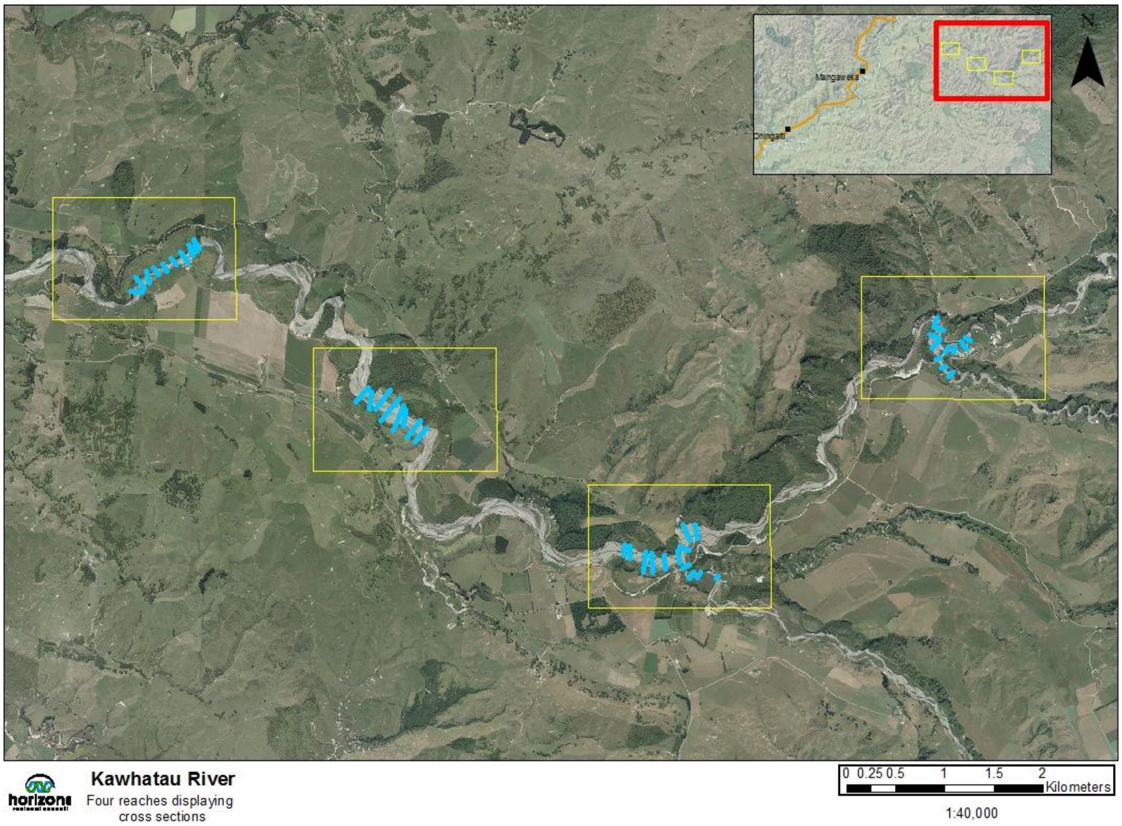


Figure 1.1. Location of the four study reaches along the Kawhatau River (from right to left, reach 1, 2, 3, 4).

This study focuses on the information gathered from surveys that were carried out in 1997, 1999, 2001 and 2015. These surveys provide the most complete record of geomorphological changes in the Kawhatau River, held by Horizons Regional Council.

2. The Kawhatau River

The Kawhatau River originates in the Ruahine Ranges and flows down the western slopes to its confluence with the Rangitikei River. The Kawhatau is a confined river, which is very downcut and gorge-like, and has a significant source of gravels (Alexander, 2012).

3. Cross Section Survey Data

Over the period from 1997 to 2015 a total of 35 cross sections, (the location of which can be seen in Appendix A) have been surveyed at various times. As can be seen in Figure 1.1, the cross sections are located in four distinct reaches of the Kawhatau River.

The reasoning behind the historical survey of these four reaches is not immediately apparent. However, it is likely that they were originally surveyed for reasons associated with the roads and bridges, or for localised river management purposes. Whilst these cross sections enable us to keep a good record of changes in the river at these reaches, they provide us with no record of changes in the wider river reach. As such, it is recommended that the number of surveyed cross sections is increased when the Kawhatau River is next surveyed. The additional cross sections should be spread no more than 1 km apart and ideally should cover the Kawhatau River to its downstream confluence with the Rangitikei River.

3.1. Cross Section Adjustments

When examining a number of the overplotted cross sections it was apparent that not all of the surveys covered the whole cross section between the left and right benchmarks. This is often the case when the river has moved laterally between surveys meaning that the cross section length has been changed to ensure that the river channel is surveyed.

When a survey did not cover the whole channel between the benchmarks the survey was extended by matching the data with that from the survey that most closely matched the one under consideration.

These cross section adjustments are considered reasonable as typically the part of the cross sections that have been adjusted cover vegetated land, the topography of which is unlikely to have significantly changed between surveys.

A summary of the adjustments made to the survey data is shown in Table 3.1 below.

Table 3.1. Adjustments made to the raw survey data.

Reach	Cross Section	Adjustments
1	1 – 9/01/2015	Survey line extended to the left, to match part of the 13/12/2001 survey line.
1	8 – 01/12/1997, 15/11/1999	Survey line extended to the left, both were compared to the 24/11/1998 line, and it was decided to extend them in a straight line.
2	4 – 12/01/2015	Survey line extended to the left, to match part of the 3/04/2014 survey line.
2	5 – 12/01/2015	Survey line extended to the right, to match part of the 29/11/2001 survey line.
2	8 – 12/01/2015	Survey line extended to the left and right, to match with the 3/04/2014 survey line.
2	11 – 12/01/2015	Survey line extended to the right, to match the 7/04/2014 survey line.
2	13 – 12/01/2015	Survey line extended to the left, to match the 7/04/2014 survey line.
3	4 – 26/11/2001	Survey line extended to the left, to match the 27/11/2000 survey line.
4	9 – 01/12/1997	Survey line extended to the left, to match with the 15/12/1998 survey line.

4. Analysis of Cross Section Survey Data

4.1 Gravel Resource

To assess the changes in the volume of gravel in the river, it is assumed that the bed and the berms of the river are predominantly gravel.

To calculate the volume of gravel beneath the active channel of the Kawhatau River, each cross section survey was analysed individually. HILLTOP software was used to calculate the area beneath each cross section using an assumed datum. These cross sectional areas were then integrated over half the distance to the adjacent up and downstream cross section to obtain a volume. These volumes were then compared between surveys to obtain a change in volume over time.

While this volume would include all bed material, it is reasonable to assume that any differences between the surveys will be due to changes in the gravel resource of the river.

4.2 Mean Bed Levels and Invert Elevations

The cross section survey profiles were plotted using the over plot function on Manager. HILLTOP software was used to calculate the mean river bed level and the invert elevation for each cross section survey date.

5. Results

5.1 Gravel Volume Analysis

5.1.1 Reach 1

Figures 5.1, 5.2, 5.3 and 5.4 below, show the change in the volume of gravel in each of the surveyed reaches over the period from 1997 to 2015. In these figures, the variations in the volume of gravel are clearly seen.

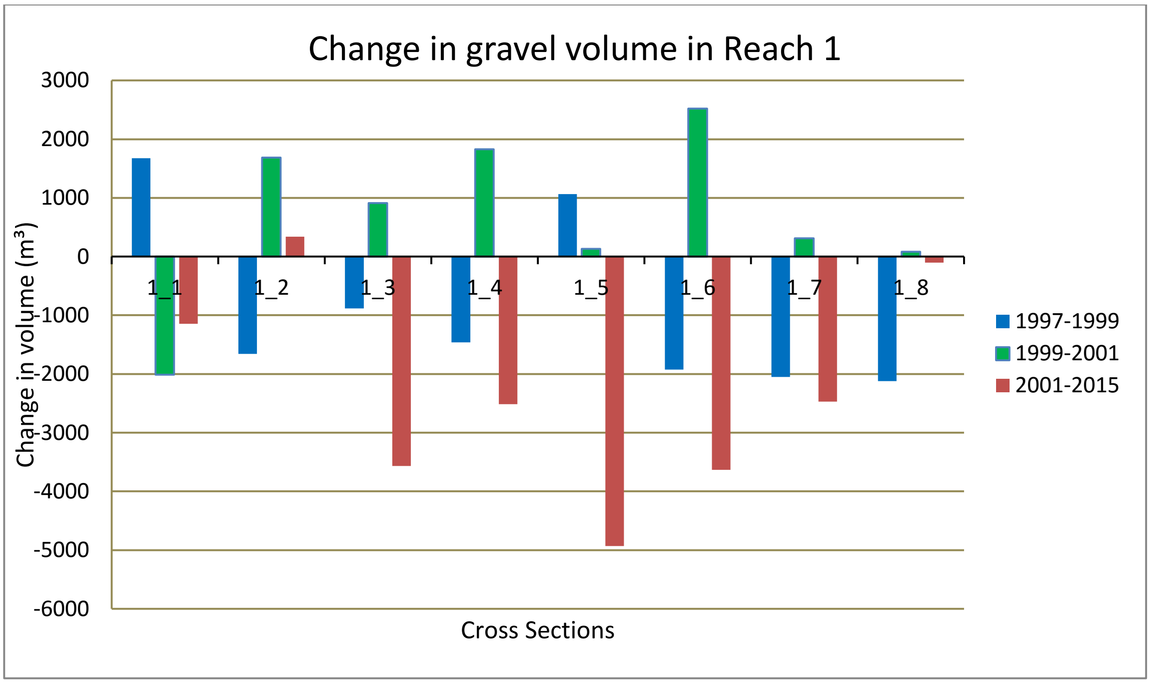
Figure 5.1 below, shows that from 1997 to 1999, there was a clear trend of degradation throughout Reach 1, with only a couple of cross sections seeing an increase in gravel volume. Overall, a net gravel loss of 7,400 m³ occurred in Reach 1.

During the period from 1999 to 2001 aggradation was dominant, with only one cross section showing degradation, a net gain of 5,500 m³ of gravel occurred beneath the active channel of Reach 1.

It is interesting that the aggradation seen between, 1999 to 2001 is of the same order of magnitude as the degradation that occurred over the previous two years. This suggests that over the combined four year time period, the gravel resource in the river was in a dynamic equilibrium.

From 2001 to 2015, a dominant degradation trend is shown across the reach, with only one cross section indicating a period of aggradation. There has been a net loss of 18,000 m³ of gravel from 2001 to 2015. This equates to a loss of approximately 1,300 m³ a year.

Figure 5.1. Change in gravel volume beneath the active channel of reach 1, from upstream to downstream.



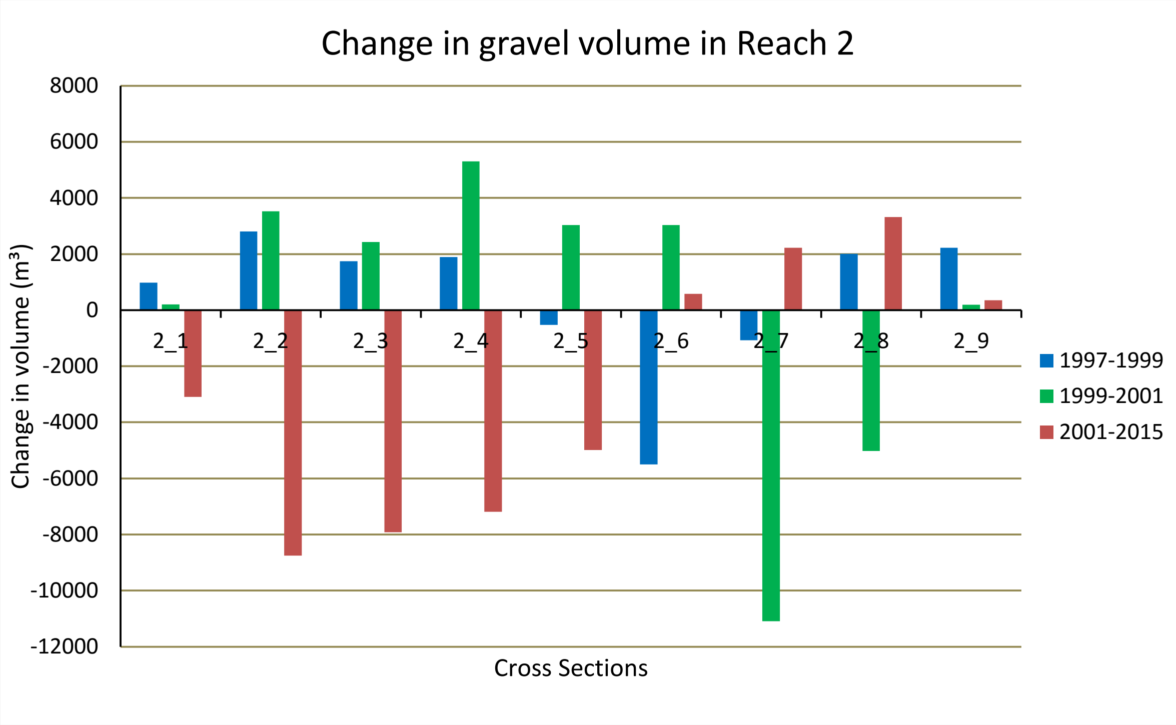
5.1.2 Reach 2

Figure 5.2 below, shows that between 1997 and 1999 a pattern of gravel aggradation was dominant across this reach, especially in the upper and lower parts, whilst in the middle of the reach gravel loss is evident. Overall, a net gain of 4,600 m³ of gravel has taken place.

From 1999 to 2001, there is a clear aggradational trend along the upper part of the reach, which then transitions into significant degradation around cross section 2_7. Looking at the aerial photograph shown in Annex A, it is likely that this degradation of gravel is attributable to the erosion of the left bank of the river at this location. A net gain of 1,600 m³ of gravel has occurred in Reach 2 from 1999 to 2001.

Between 2001 and 2015, degradation is dominant in the upper part of the reach. In the lower half of the reach, the loss of gravel begins to stabilise and an increase in the volume of gravel is apparent. There is a net loss of 25,500 m³ of gravel experienced over this time period, which equates to 1,820 m³ per annum.

Figure 5.2. Change in gravel volume beneath the active channel of Reach 2, from upstream to downstream.



5.1.3 Reach 3

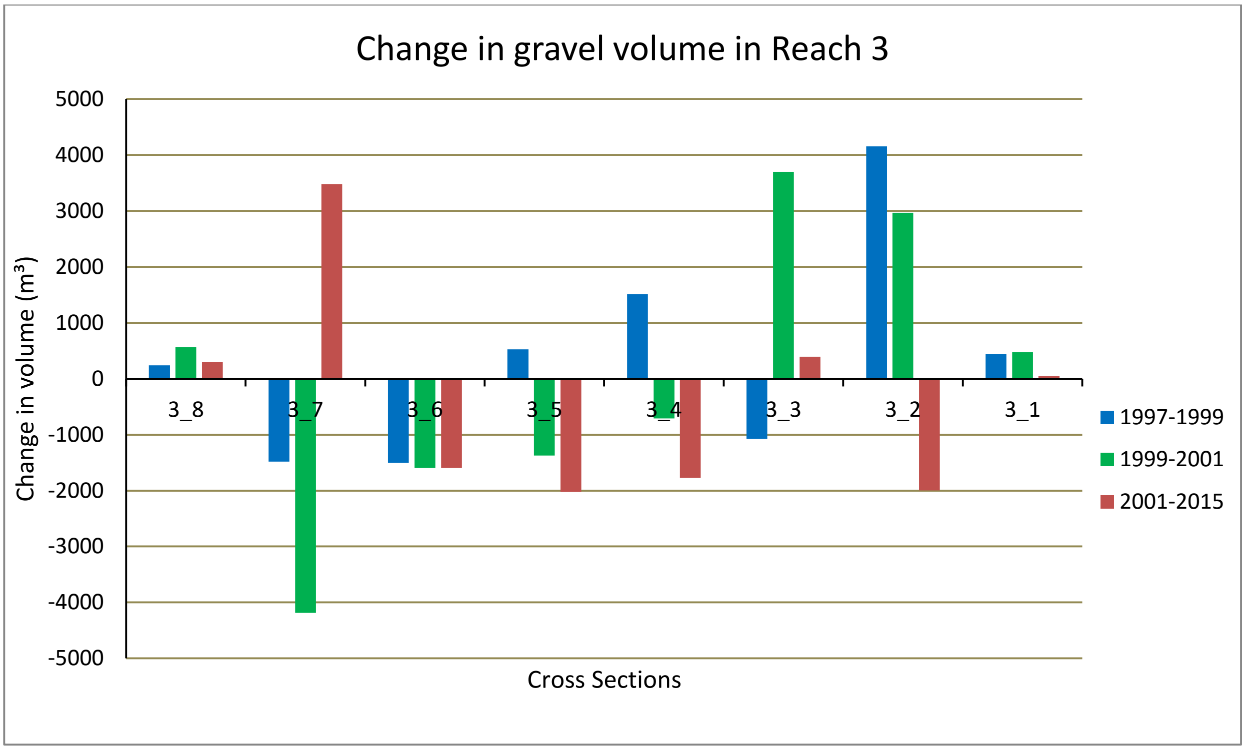
Figure 5.3 below, shows how the gravel volume in Reach 3 of the Kawhatau River has changed over time.

Between 1997 and 1999, the gravel volume remained relatively stable, with mainly small peaks of aggradation and degradation occurring across the reach. These small changes of gravel volume are of an order of magnitude that one would expect to naturally see in a gravel bed river. There is one noticeable peak in aggradation in the lower reach, around cross section 3_2. Overall, there was a net gain of 2,800 m³ of gravel.

The period from 1999 to 2001, shows fluctuations in the gravel volume. There was an increase in gravel volume in the lower part of the reach, and a dominant trend of gravel loss in the upper to middle part of the reach. A net loss of 170 m³ of gravel occurred in this reach of the river. Overall, the total volume of gravel in this reach of the river remained relatively stable and the observed changes through the reach could be attributable to a slug of gravel moving through the reach.

Between, 2001 and 2015 a pattern of degradation is observed across a majority of the reach, with only a couple instances where there has been an increase in gravel volume. This reach experienced a net loss of 3,200 m³ of gravel beneath the active channel, which equates to approximately 230 m³ per year.

Figure 5.3. Change in gravel volume beneath the active channel of Reach 3, from upstream to downstream.



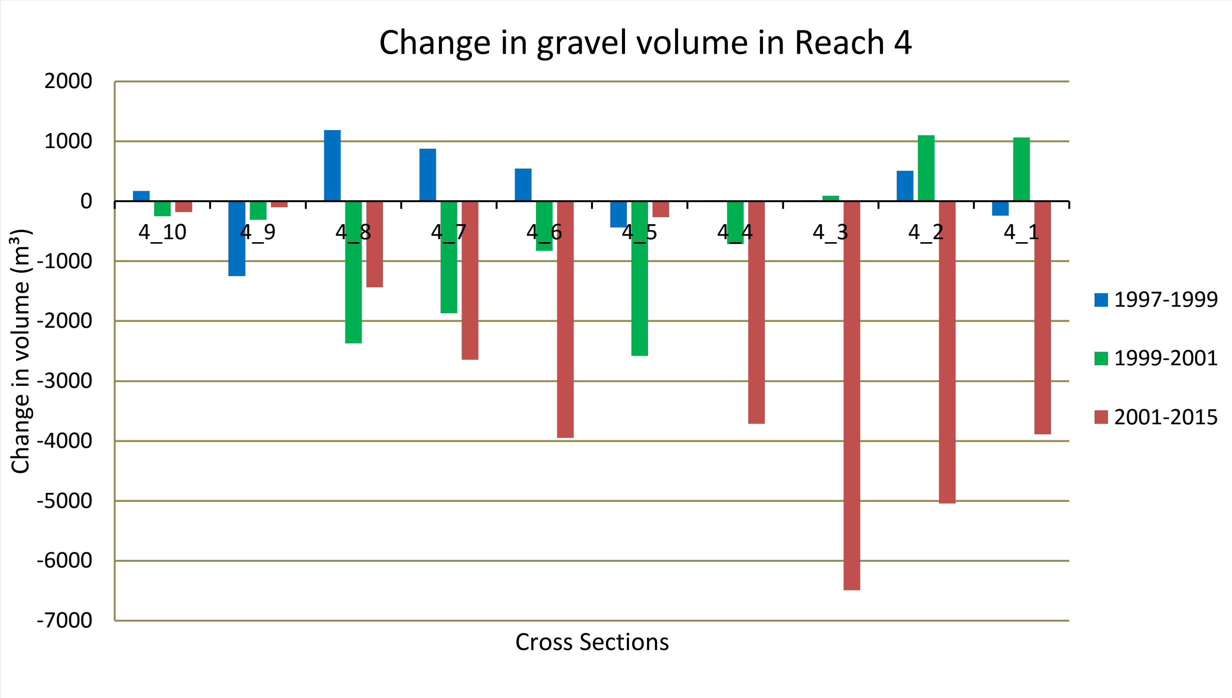
5.1.4 Reach 4

Figure 5.4 below, shows that from 1997 to 1999 the volume of gravel in this reach has remained relatively stable, with only small volumes of aggradation and degradation occurring. A net gain of 1,400 m^3 of gravel occurred beneath the active channel.

The time period ranging from 1999 to 2001, saw a pattern of degradation developing in the upper to middle part of this reach, whilst in the lower part of the reach there was an increase in gravel volume. A net loss of 6,600 m^3 of gravel occurred between, 1999 and 2001 in this reach of the Kawhatau River.

The dominant trend observed from 2001 to 2015 is one of degradation across the entire reach. A net loss of 27,700 m^3 of gravel has occurred, which equates to approximately 2,000 m^3 per annum.

Figure 5.4. Change in gravel volume beneath the active channel of Reach 4, from upstream to downstream.



6. Cumulative Change in the Gravel Resource of the Kawhatau River

The overall change of the gravel resource in the surveyed reaches of the Kawhatau River are summarised in Table 5.1, below:

Table 5.1. Summary of the cumulative change that has occurred across the four reaches.

Period	Cumulative change in gravel volume (m^3)	Cumulative change per year (m^3)
1997-1999	1,400	700
1999-2001	260	130
2001-2015	-74,400	-5,300
Total	-72,700	-4,000

As Table 5.1 shows, there was a relatively small aggradation of the gravel resource in the surveyed reaches of the Kawhatau River between 1997 and 2001. However, there has been a significant degradation of the gravel resource between, 2001 and 2015, which has been occurring at a rate of approximately 5,300 m^3 per year.

6.1 Mean Bed Level Analysis

6.1.1 Reach 1

Figure 5.5 below, shows how the mean bed level has changed across reach one between the various surveys.

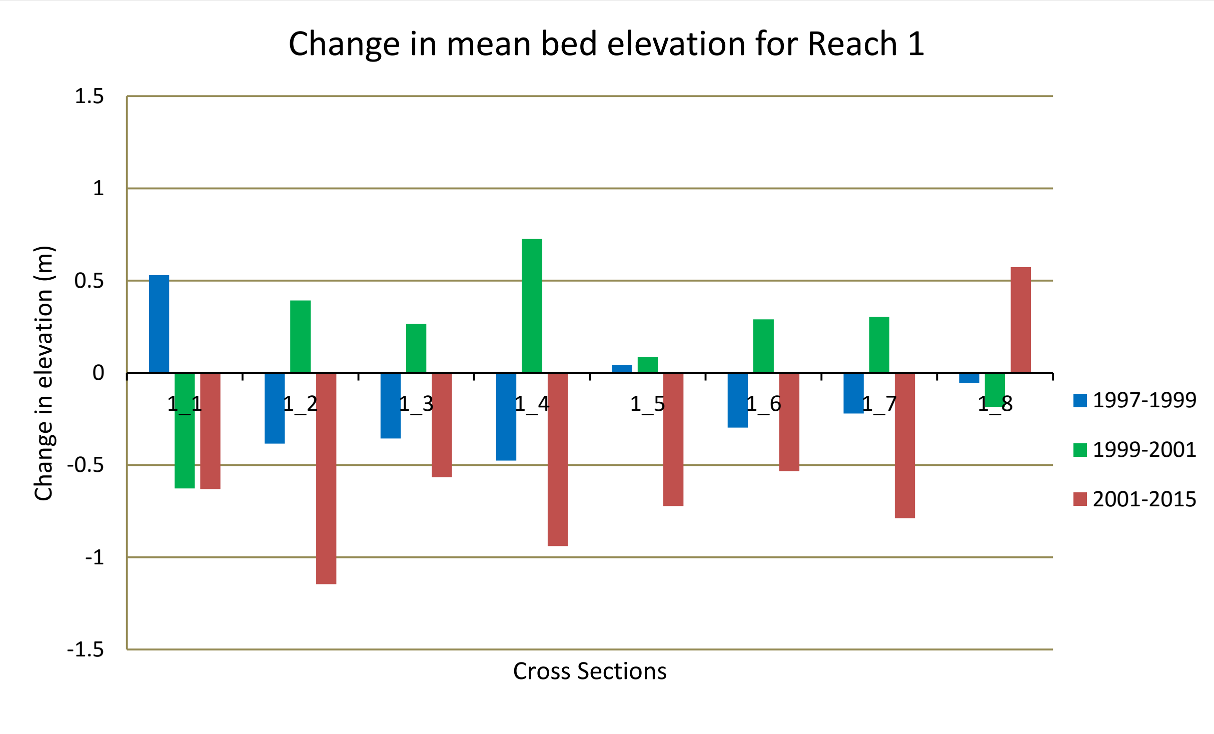
It can be seen that from 1997 to 1999 there was a clear decreasing trend, with only cross sections 1_1 and 1_5 showing a slight increase in mean bed level. The changes in the mean bed level are generally of an order of magnitude of less than 0.4 m which one would expect to naturally see within a gravel bed river.

The time period ranging from 1999 to 2001 shows a clear increasing trend across much of the reach, with the exceptions of cross sections 1_1 and 1_8, which display a loss of the mean bed level. This change in bed level is also within the natural range that one would expect to see.

Between, 1999 and 2001 the gravel trend was one of rising bed levels. It is observed that these bed level rises roughly balance out the drops that occur between 1997 and 1999. This suggests the overall bed level remained relatively stable from 1997 to 2001.

The dominant trend observed from 2001 to 2015 is a decline in the mean bed level across a majority of the reach, with only one peak displaying bed level gain. The bed level decrease between this period is much more substantial than the changes previously observed.

Figure 5.5. Shows the change in mean bed level across Reach 1, from upstream to downstream.



6.1.2 Reach 2

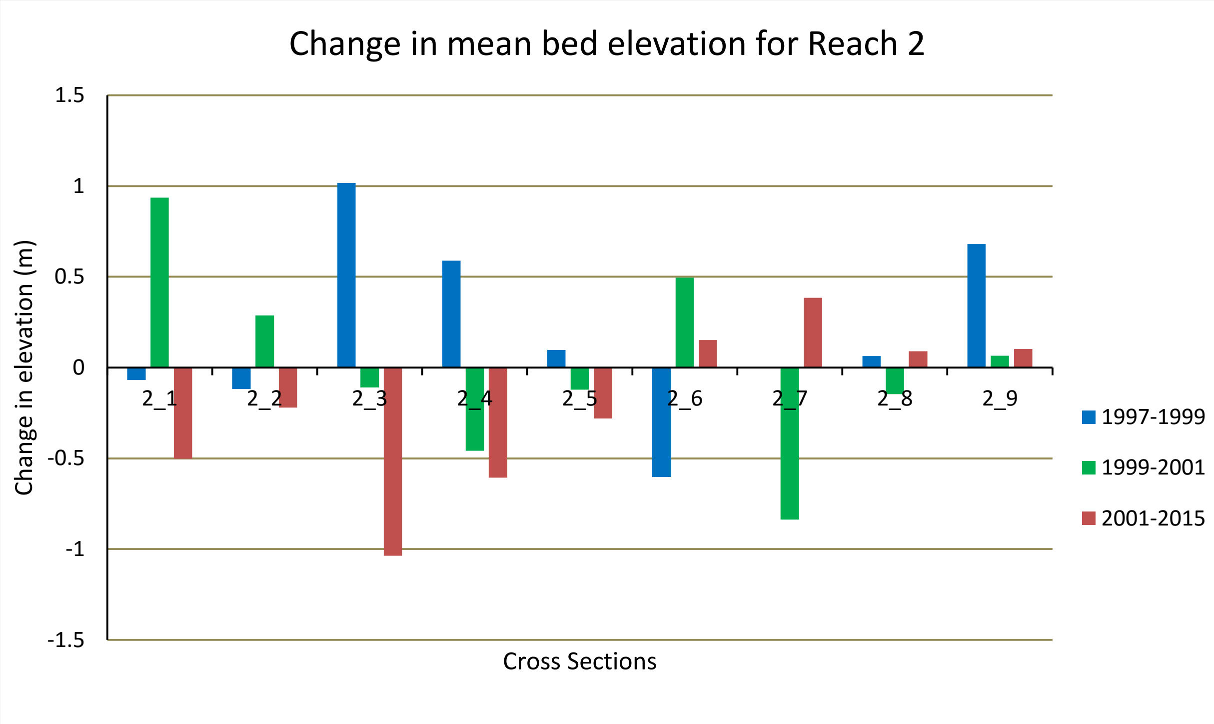
Figure 5.6 below, shows from 1997 to 1999 the change in mean bed level was variable with five cross sections increasing, three of which show significant growth greater than 0.5 m. The other four cross sections were subjected to a loss, which was not of a significant quantum.

From 1999 to 2001, the bed level fluctuated where both gains and losses occurred across this reach. Overall, there was a dominant decreasing pattern observed as five of the cross sections were subjected to a reduction of bed level, whereas four of the cross sections displayed a gain in bed level.

However, the overall increases and decreases of the bed level from 1997 to 2001 are usually less than 0.5 m, which is well within the range of natural movement in a gravel bed river, suggesting the bed level remained relatively stable.

Between, 2001 and 2015 there are distinct fluctuations in the mean bed level. In the upper part of the reach, a dominant declining trend is observed from cross sections 2_1 to 2_5. This then transitions into a dominant increasing trend in the downstream part of the reach from cross section 2_6 through to cross section 2_9.

Figure 5.6. Shows the change in mean bed level across Reach 2, from upstream to downstream.



6.1.3 Reach 3

Figure 5.7 below, shows how the mean bed level of reach three has changed over time.

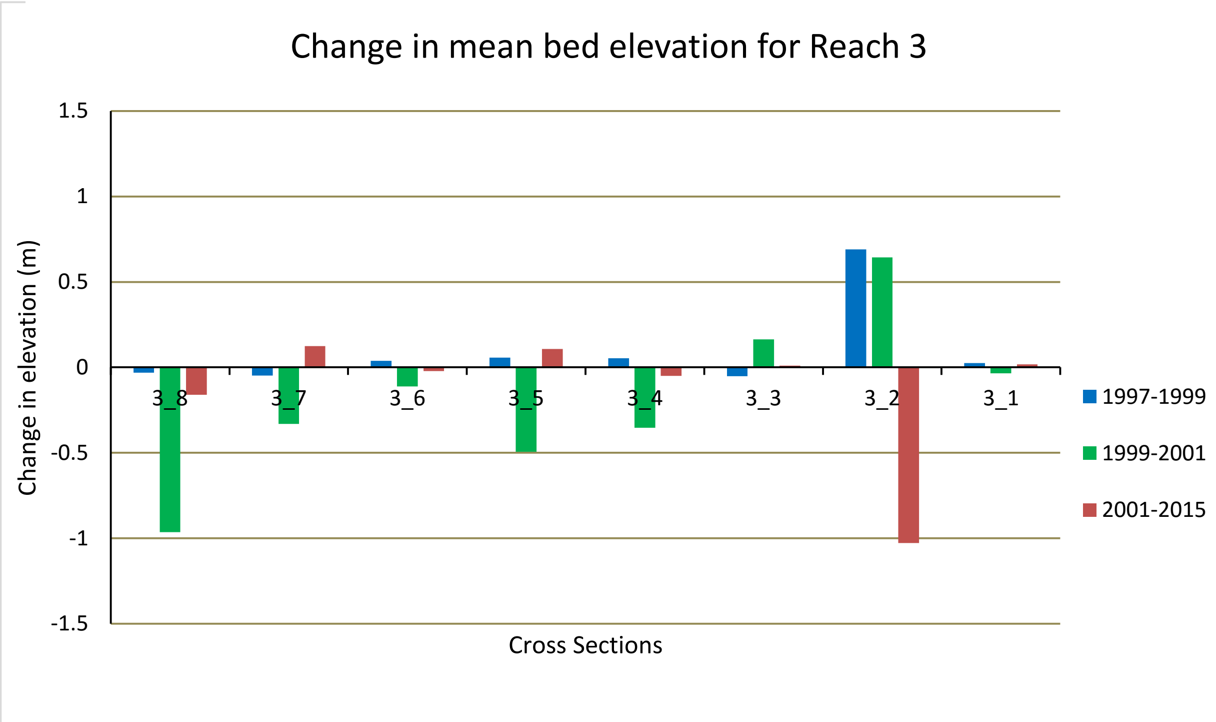
From 1997 to 1999, it is noticed the mean bed level remained very stable throughout a majority of the reach, with only cross section 3_2 showing significant increase.

Between, 1999 and 2001 there is a prominent decreasing trend with all cross sections apart from 3_3 and 3_2 displaying a loss of bed level. However, the changes in mean bed level that have occurred are not of a significant magnitude as most cross sections show a bed level change of less than 0.5 m.

The period from 2001 to 2015 indicates there has been minor increases and decreases in the bed level across the reach, indicating an overall stability of the reach. There was only one peak of significant loss at cross section 3_2.

Overall, this reach remains considerably stable with the bed level increases and decreases roughly balancing each other out from 1997 to 2015. This suggests that this reach has mostly been in a dynamic equilibrium for the 18 year period. This could be attributed to the fact this reach is wider than the other three reaches meaning there could be a more adequate supply of gravel being delivered to this reach, due to the formation of a gravel slug. These changes in the gravel resource could have a lesser impact on the mean bed level.

Figure 5.7. Shows the change in mean bed level across Reach 3, from upstream to downstream.



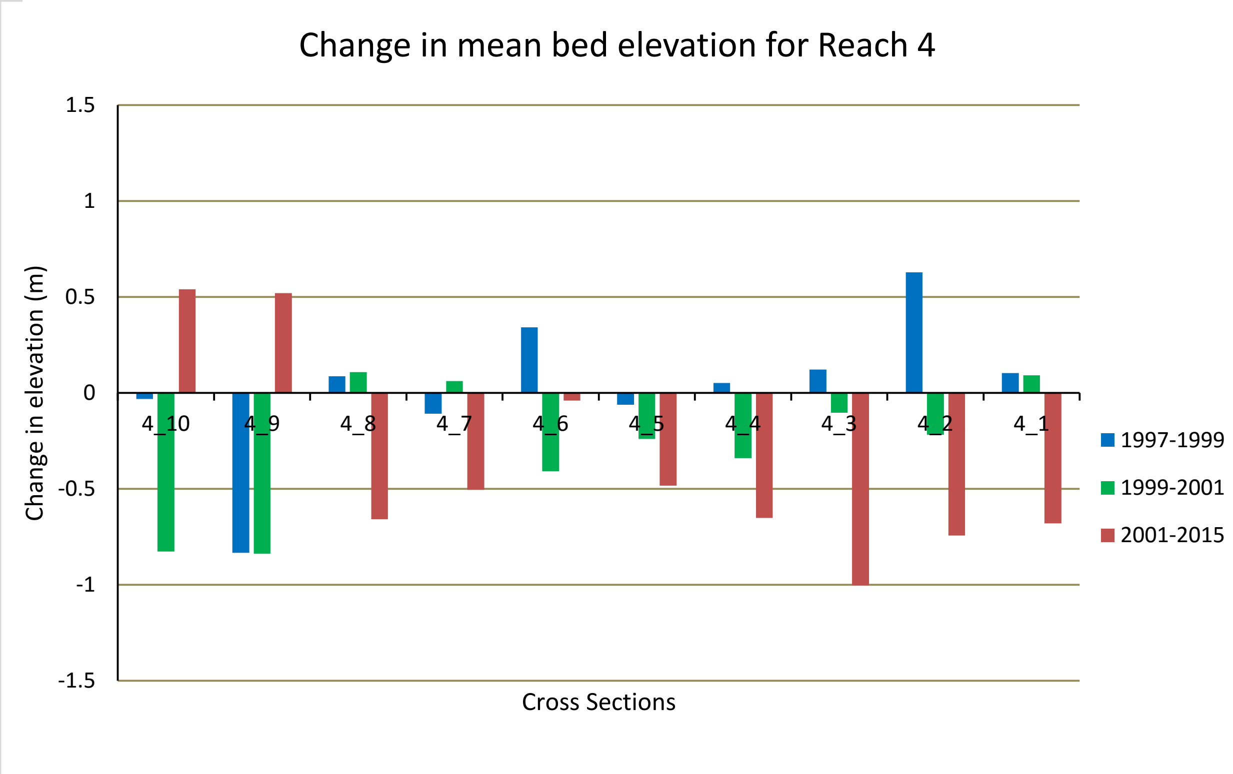
6.1.4 Reach 4

Figure 5.8 below, shows that from 1997 to 1999 the reach remained relatively stable with mainly minor increases and decreases in the bed level, which is expected in a gravel bed river. Cross section 4_9 shows significant loss of almost 1 m, and cross section 4_2 displays a significant gain of 0.63m.

The time period ranging from 1999 to 2001 shows the overall pattern is a loss of bed level across the reach, with only cross sections 4_8, 4_7, and 4_1 showing very slight gains. Cross sections 4_9 and 4_10 show that the loss of bed level was the most significant in the upper part of the reach.

Between, 2001 and 2015 it is observed that the dominant trend is one of increasing bed level across a majority of the reach. From cross section 4_8 through to 4_1 the loss is significant with most peaks showing a bed level drop of more than 0.5 m. There are two peaks in the very upper part of the reach that indicate a gain in mean bed level has occurred.

Figure 5.8. Shows the change in mean bed level across Reach 4, from upstream to downstream.



6.2 Invert Elevation Analysis

6.2.1 Reach 1

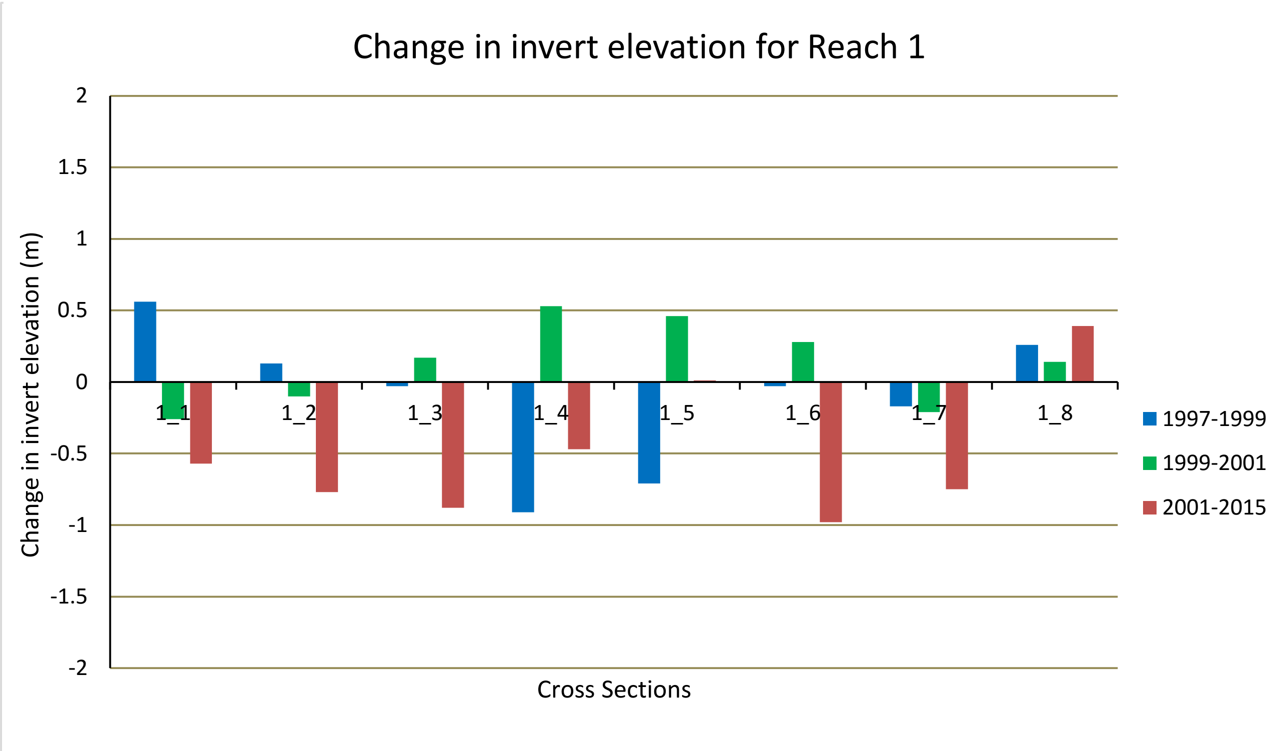
Figure 5.9 below, shows how the invert elevation has changed from 1997 to 2015. From 1997 to 1999, the invert level has fluctuated, where the middle of the reach from cross section 1_3 to 1_7 shows a decreasing trend, whilst at either end of the reach a slight increase occurs.

Between, 1999 and 2001 the trend has changed where the middle of the reach is now showing an increase in the invert elevation, and the upper and lowest part of the reach is decreasing with the exception of cross section 1_8.

The period of time from 2001 to 2015 suggests that the dominant trend is a decreasing invert elevation, where at every cross section along the reach there has been a loss of elevation, except at cross section 1_8 which had a minor increase in the invert elevation.

Overall, from 1997 to 2001 the invert elevation remained relatively stable where the increasing and decreasing invert levels roughly balance out, but from 2001 to 2015 the stability of the reach appears to decrease as the loss of invert elevation is much greater and becomes the dominant pattern.

Figure 5.9. Shows the change in invert elevation across Reach 1, from upstream to downstream.



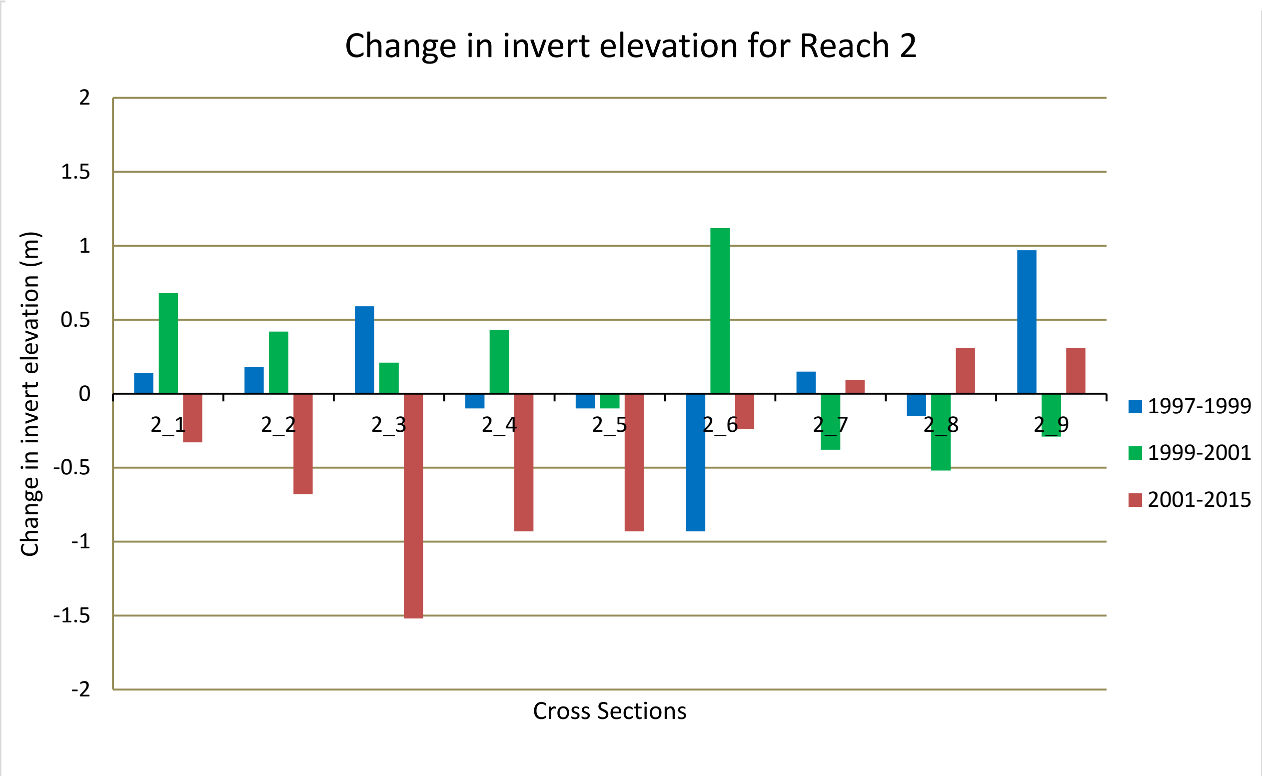
6.2.2 Reach 2

Figure 5.10 below, shows from 1997 to 1999 the invert elevation has fluctuated, where increases and decreases in the elevation have occurred, most of which are minor changes. The upper part of the reach and cross section 2_9, display an increasing trend. Whereas the middle reach shows the invert elevation is dropping.

From 1999 to 2001, the trend is dominantly an increasing invert elevation particularly in the upper reach. This trend then changes around cross section 2_7, where the invert elevation drops, which continues into the rest of the lower reach.

The period of time that occurs between 2001 and 2015 shows that in the upper reach the invert elevation is largely decreasing until a transition occurs at cross section 2_ 7, where the invert elevation starts to increase.

Figure 5.10. Shows the change in invert elevation across Reach 2, from upstream to downstream.



6.2.3 Reach 3

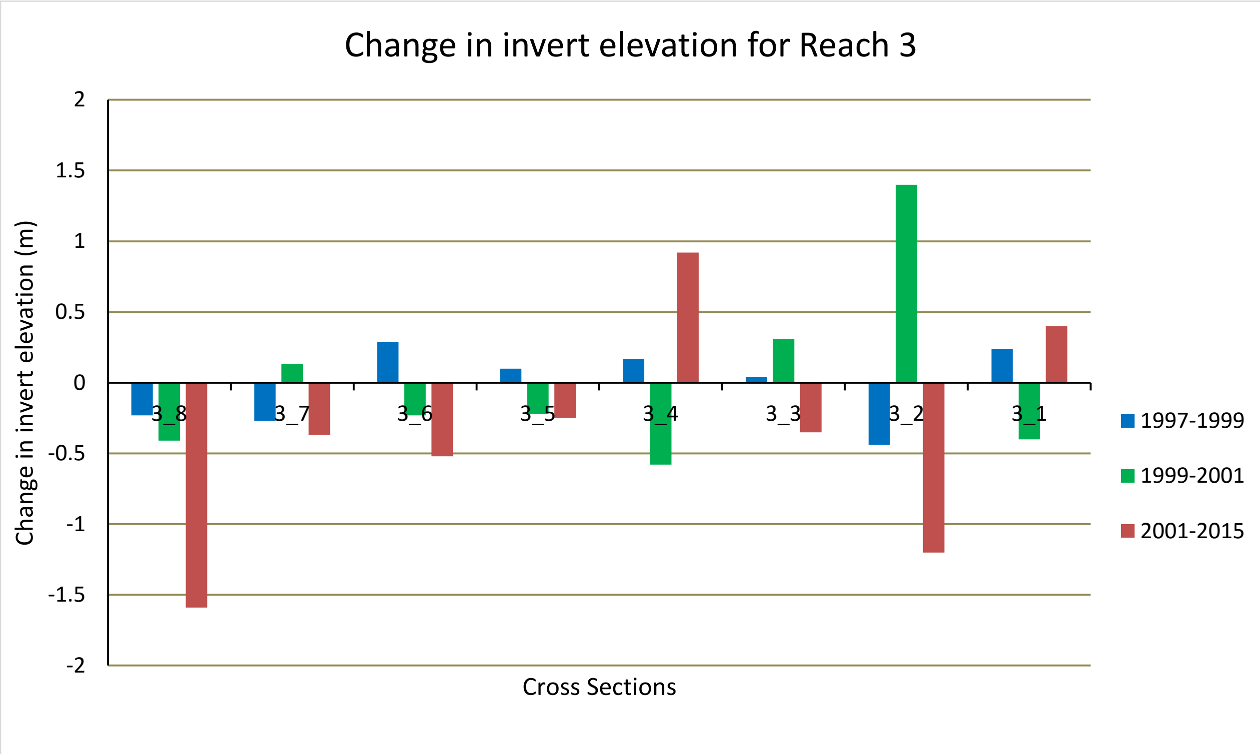
Figure 5.11 below, indicates that from 1997 to 1999 the invert elevation was relatively stable where only small increases and decreases occurred.

From 1999 to 2001, the trend continued to remain primarily stable across the reach except for cross section 3_2, which displays a significant peak of a 1.4 m invert elevation gain.

The period ranging from 2001 to 2015 indicates a pattern of an overall decreased invert elevation, where cross sections 3_8 and 3_2 show the greatest decrease in elevation. Only cross sections 3_4 and 3_1 show an increase in the invert elevation.

Overall, this reach is the most stable out of the four reaches, but it still displays an overall decreasing trend. The stability of this reach could be due to the wider channel and the sediment slug that is observed from the aerial photography (Annex A).

Figure 5.11. Shows the change in invert elevation across Reach 3, from upstream to downstream.



6.2.4 Reach 4

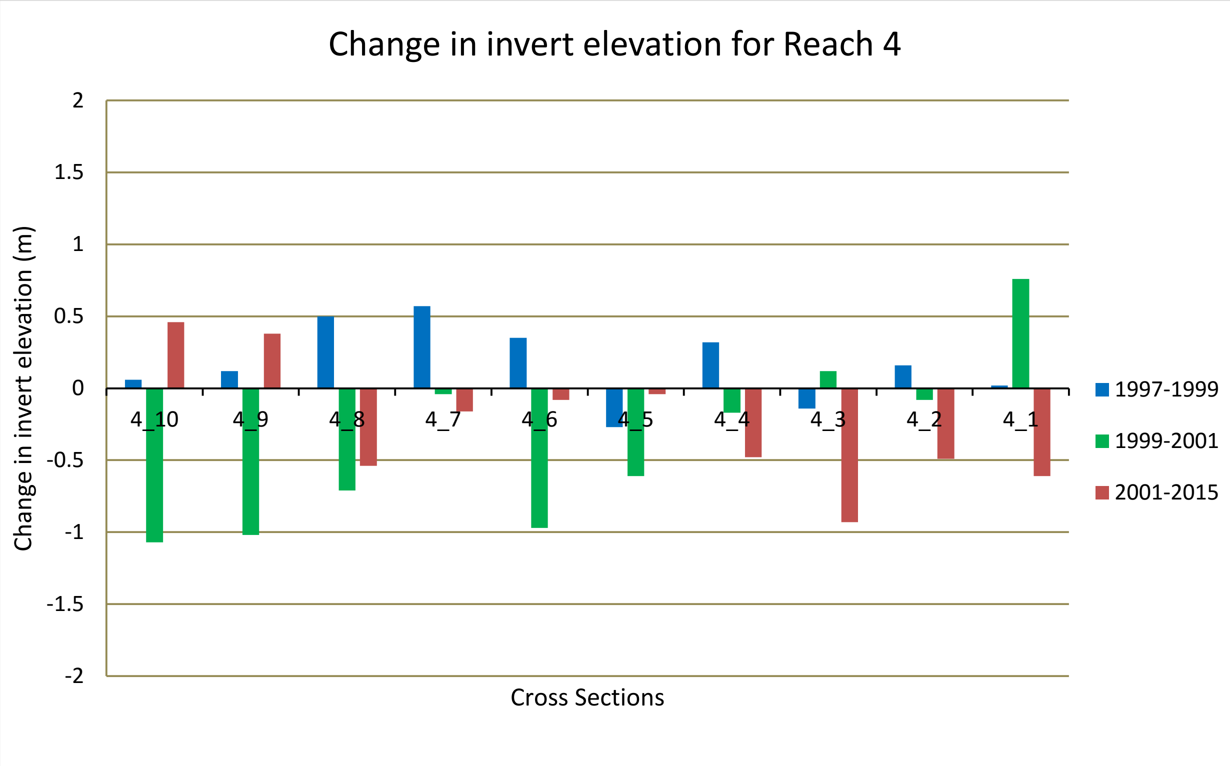
Figure 5.12 below, shows how the invert elevation has changed across reach four of the Kawhatau River from 1997 to 2015.

From 1997 to 1999, the invert elevation varies across the reach, where peaks of an increasing and decreasing invert elevation are identified. A decreasing invert elevation is more prominent in the upper part of the reach from cross section 4_10 to 4_6, the reach then becomes more stable further downstream.

Between, 1999 and 2001 the main trend is a loss of invert elevation particularly in the upper part of the reach, a transition then occurs around cross section 4_4, where the reach becomes more stable before considerably increasing at cross section 4_1.

From the period of 2001 to 2015, the overall trend is a loss of invert elevation. The most significant amount of invert loss occurs from cross section 4_4 to 4_1. The middle of the reach remains relatively stable. The only invert elevation increase occurs at cross sections 4_10 and 4_9, the very upper part of the reach.

Figure 5.12. Shows the change in invert elevation across Reach 4, from upstream to downstream.



7. Gravel Extraction

Horizons Regional Council holds records of volumes of gravel that have been extracted under consents from the Kawhatau River since 1993. For the purpose of this study, the extraction record from 1997 to 2015 will be used (See Annex C), to complete the survey record.

In Chapter 17 of the One Plan, Table 17.1 – Long term average annual allocable volumes of gravel, states that no more than 20,000 m^3 of gravel can be extracted from the Kawhatau River per annum.

The gravel extraction occurs in four areas along the Kawhatau which include; the Pourangaki site in Reach 2, Gorringes and McKinnon which are just below Reach 4, and McGregor Roache, which is near the Rangitikei River confluence. The gravel extraction sites and survey reach sites do not entirely correlate as the majority of the gravel extraction sites are located downstream of the four survey reaches.

The McGregor Roache site is located the furthest downstream from the survey reaches near the Kawhatau-Rangitikei River confluence. The Gorringes and McKinnon sites are located a bit closer to the survey reaches in particular Reach 4, as the two sites are just downstream of this survey reach. The Pourangaki site is the only site located within one of the survey reaches. This site is located within Reach 2 and is the extraction site located furthest upstream. The locations of the survey reaches and gravel sites can be seen in Figure 6.1 below.

The majority of the gravel has been extracted from the Gorringes and McGregor Roache sites, where the Gorringes site has seen around 160,500 m^3 of gravel extracted, and the McGregor Roache site has seen an amount of 85,000 m^3 extracted, from 1997 to 2015.The least amount of gravel has been extracted from the Pourangaki site up in Reach 2, with around 1,500 m^3 being extracted from 1997 to 2015.

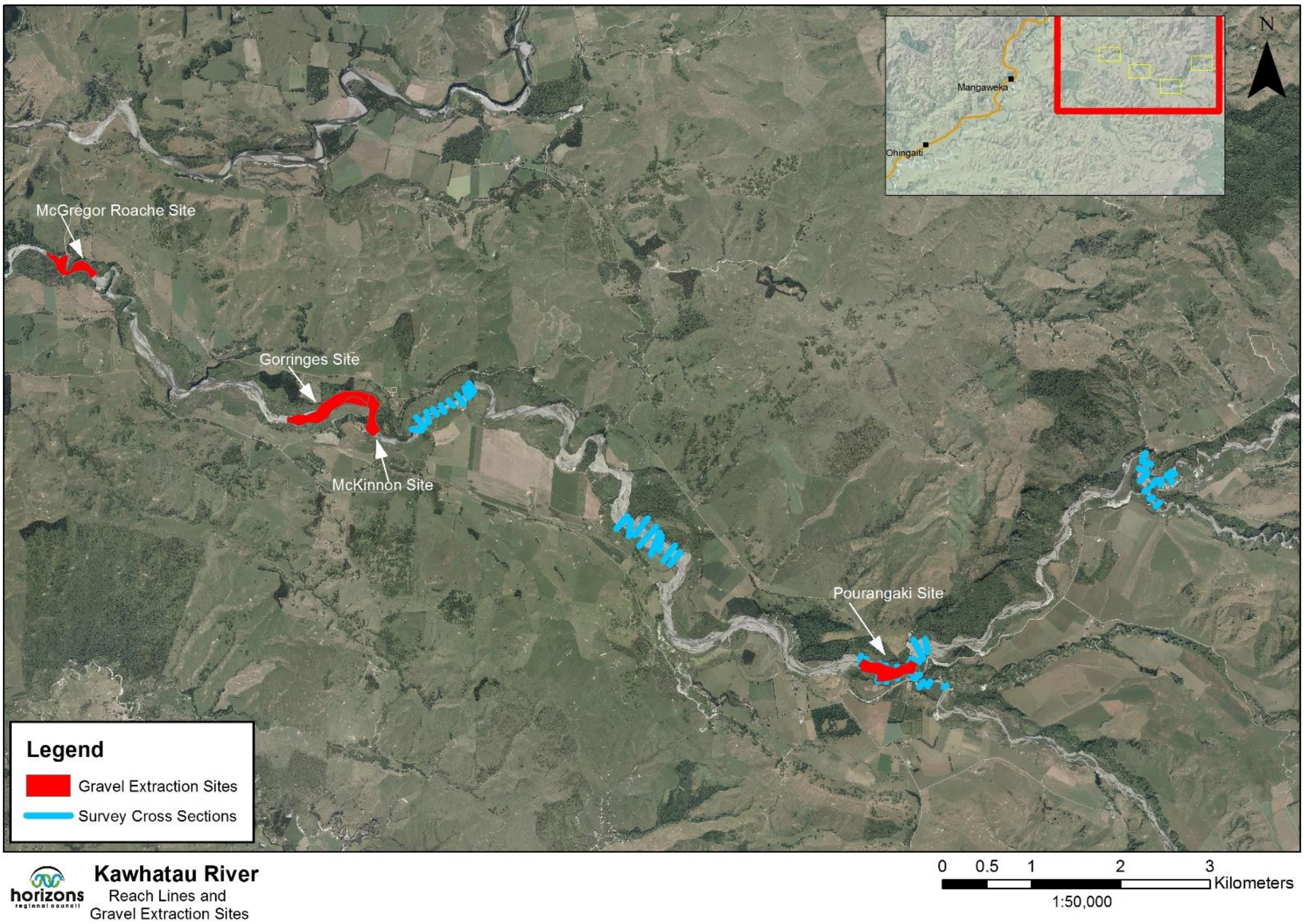
From 1997 to 2015, a total of 247,700 m^3 of gravel has been extracted from the Kawhatau River, which equates to about 13,800 m^3 per annum.

Observations from the site visit in December 2017, suggested that visually there was a substantial amount of gravel in Reaches 1, 2, and 3, whereas at Reach 4 it was identified that the amount of visible gravel appeared to be reduced compared to the other three reaches. At the McGregor Roache gravel extraction site it was observed that the visual amount of gravels are relatively low as the basement rock could be seen exposed in multiple locations at the site.

Table 6.1. Gravel extraction amounts per year

Year	Gravel Extraction Amounts (m^3)
1997	21209
1998	18332
1999	12377
2000	19193
2001	7606
2002	23610
2003	22750
2004	9554
2005	17080
2006	14927
2007	14083
2008	11737
2009	12280
2010	5570
2011	6712
2012	5920
2013	4900
2014	9100
2015	10700
2016	2955
2017	10000
Total	**260595**

Figure 6.1. Location map showing the reaches (from right to left 1, 2, 3, 4), and the gravel extraction sites (red polygons).



8. Discussion

Overall Reaches 1, 2 and 4 show a significant loss of gravel volume, mean bed level, and invert elevation, particularly from 2001 to 2015. The gravel resource analysed at reach three indicates this reach has remained relatively stable from 1997 to 2015.

When all four reaches are considered, the gravel volume is the most greatly affected variable. This is because significant degradation of the gravel volume has dominantly occurred from 1997 to 2015, where an estimated net loss of 72,700 m^3 has occurred during this period. The results show that overall the mean bed level and invert elevation have remained relatively stable with a majority of the cross sections displaying peaks of less than 0.5 m from 1997 to 2015, which is within the range of natural movement of a gravel bedded river.

When considering these results a number of factors have to be taken into consideration to determine the usefulness of the data. With this data set, it was recognised that there are gaps in the analysis, which has led to a limit of what conclusions can be drawn for this study. During the analysis, it was noticed that the surveyed data has been split into four individual reaches along the Kawhatau River. These reaches are small and spread a considerable distance apart, which does not allow for a greater understanding of the gravel resource within the wider reach of the Kawhatau River. Only an understanding of what is happening at the four reaches is obtained.

These four individual reaches are also problematic when it comes to analysing the gravel resource in correlation with gravel extraction, as the survey reaches do not currently align with the gravel extraction sites. To obtain a more accurate understanding of how the gravel resource is being affected in the wider reach, the number of cross sectional surveys needs to be increased to cover a wider area of the river. Another factor to consider when interpreting the results is the time that has occurred between the surveys. This is because there is a significant 14 year gap between the 2001 to 2015 surveys, where previously there was only a two year gap between surveys. When considering the significance of this time gap it can be assumed that the results give an overall picture of how the gravel resource is being affected, but it will not be the most accurate representation of what has occurred.

The results that have risen out of this gravel resource study, however, can still be interpreted to provide an understanding on what factors or events may have affected the gravel resource of the Kawhatau River.

The gravel volume has largely been affected from 2001 to 2015 where significant degradation has occurred. These gravel losses could potentially be due to the gravel source becoming affected or slowing down in production. This is because the initiation of the gravel source will start up in the headwaters of the river, where multiple factors will contribute to the initiation of erosion. These erosional processes up in the headwaters and throughout the Kawhatau River may not have had a significant triggering event for an extended period of time. This is a natural process of how the volume of gravel may be affected, as human influenced processes such as gravel extraction will also have an effect on the gravel volume.

The mean bed level has also seen an overall loss of elevation across the reaches. The mean bed level and gravel volume in Reaches 1 and 2 could also be affected by the steeper terrain. This is because according to the NZ Topographic Map, Reaches 1 and 2 are located in terrain that is steeper than the other two reaches. This increased steepness of terrain could make it more difficult for aggradation to occur at Reaches 1 and 2, which could contribute to a decreased gravel volume and mean bed level. This is because the steeper terrain could lead to a steeper gradient, which could cause the gravel to move downslope at a faster rate, reducing the amount of gravel in the upper two reaches.

The invert elevation has undergone a loss of elevation across the reaches. In Reaches 1 and 2 it was visually observed in December 2017, that there was a considerable increase in the vegetation growth within the channel. This vegetation growth could be constricting the channel, which could cause the river channel to become narrower and therefore decreasing the lateral movement, which could cause a decreased invert elevation. However, due to the nature of the valley in which the Kawhatau River is situated, where it is largely confined, lateral movement would be expected to be limited to a certain extent. The confined valley nature of the Kawhatau River also means that downcutting would occur, where the river will naturally cut down into the gorge environment, leading the invert elevation to naturally decrease over time.

When considering the results and potential explanations as to why these results have been produced the natural movement of the river also has to be taken into consideration. This is because to an extent aggradation and degradation are natural processes within a dynamic river system. This needs to be considered because some of the gains and losses observed in the gravel volume, mean bed level, and invert elevation are not of a huge amount compared to the size of the catchment and the amount of natural movement that occurs within a gravel bedded river.

Gravel extraction in correlation with the gravel resource needs to be assessed to see if the gravel extraction that occurs within the Kawhatau River is having a detrimental effect on the gravel resource. However, it has been observed in this study that a majority of the gravel extraction does not take place in the surveyed reaches, it takes place further downstream below

Reach 4. This makes it difficult to assess whether the gravel extraction is having a significant effect on the gravel resource as it is not known how the gravel resource is being affected at the extraction sites. The gravel extraction records indicate the rates of extraction have remained fairly consistent from 1997 to 2015 (Annex C). Since the rate of gravel extraction has remained fairly consistent from 1997 to 2015 the gravel extraction does not explain the loss of the gravel resource that has occurred.

The sustainability of the current rate of gravel extraction needs to be considered, which is difficult due to the extraction sites not corresponding with the survey reaches. However, since the gravel volume has only estimated to have decreased by 4,000 m^3 per year from 1997 to 2015, the current rates of gravel extraction could continue to occur as the loss each year is not substantial. However, even though the current rates of gravel extraction are considered sustainable, if the volume of gravel continues to decrease the sustainability of the gravel extraction rates will have to be reassessed in the next Kawhatau Gravel Resource Study.

9. Conclusions

This study of the Kawhatau Gravel Resource has found:

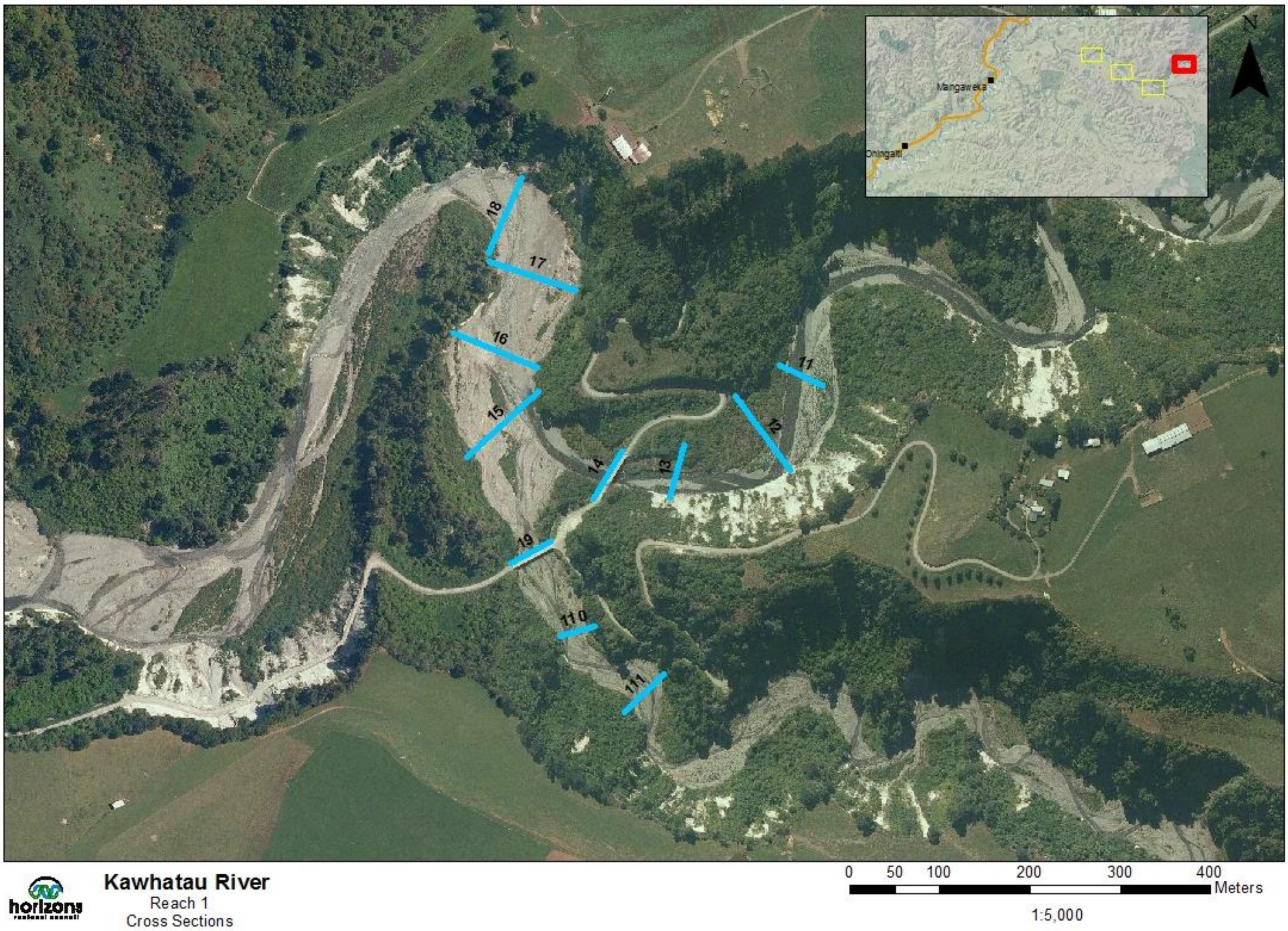
- When considering the results of this study it is clear that there are a significant amount of gaps in understanding the Kawhatau Gravel Resource Study. This is due largely to the limitations of the gravel resource data within this river, as there are only four small individual reaches that are surveyed, which do not give a greater understanding of how the gravel resource is being affected in the wider river. This has led to there being insufficient data to draw meaningful conclusions from this study.

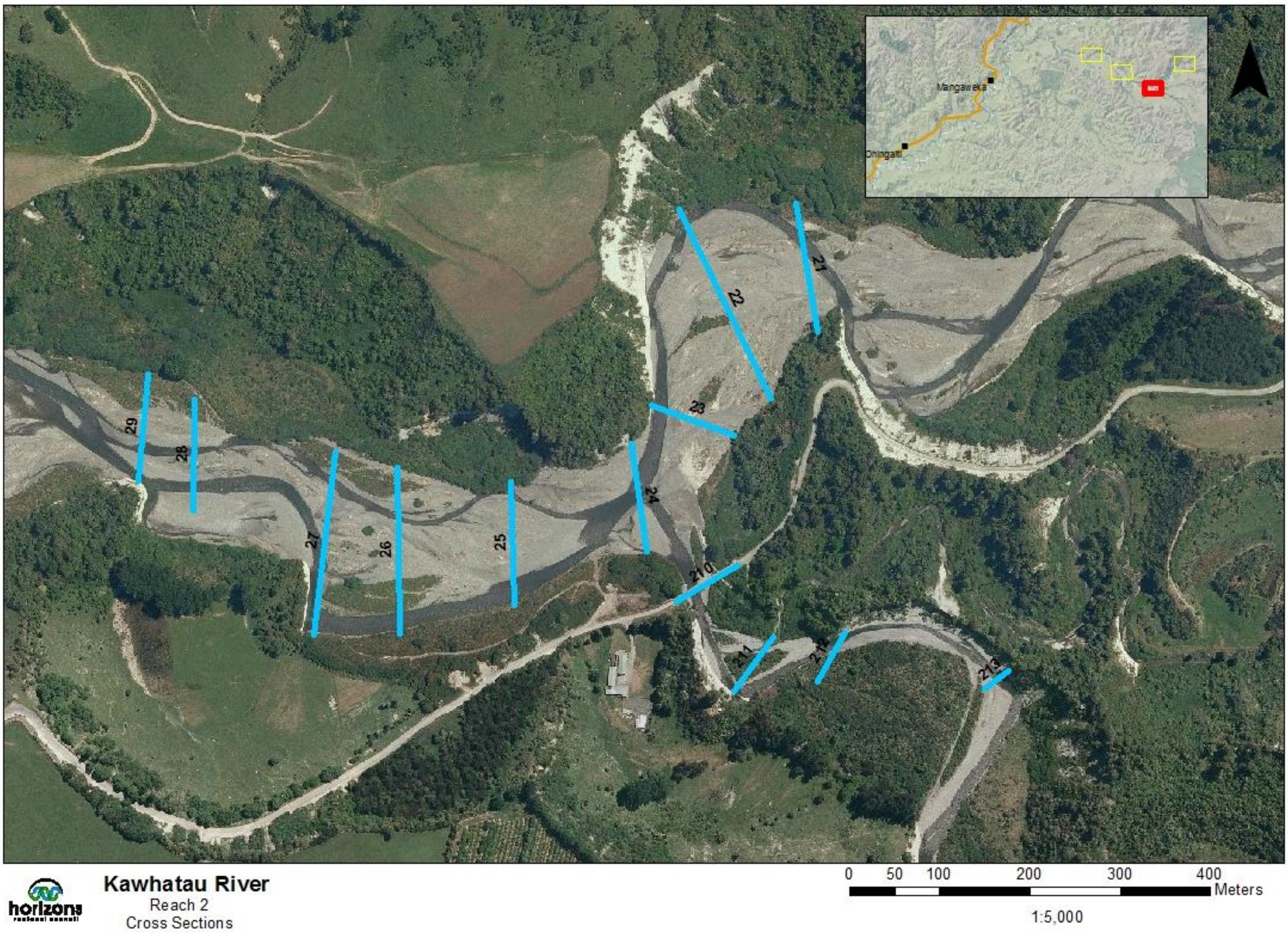
- However, from the analysis it has been observed that overall Reaches 1, 2 and 4 show a loss of gravel volume, mean bed level, and invert elevation, whereas the resource at Reach 3 has remained relatively stable. However, even though this has been observed when the loss of gravel is considered over the time frame an estimated decrease of 4,000 m^3 of gravel has occurred per annum from 1997 to 2015 which is not hugely substantial. This leads to the idea that it is reasonable to assume that current rates of gravel extraction can continue to occur, until a reassessment of the gravel resource is done in the next Kawhatau Gravel Resource Study.

10. Recommendations

- Re-survey in 2020-2021.
- Increase the number of surveyed cross sections across the Kawhatau River.

11. Appendix A

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Reach 2
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Meters
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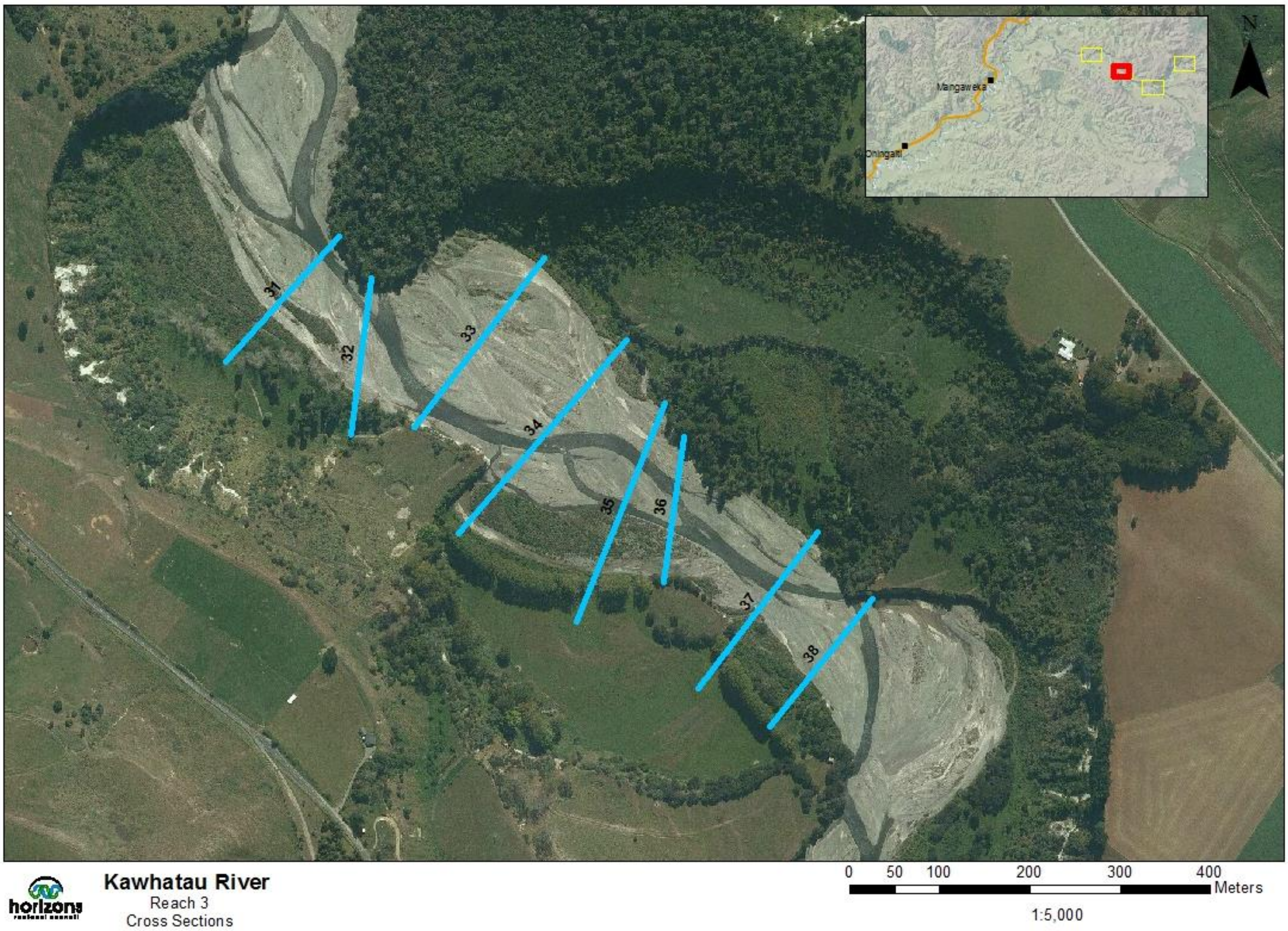
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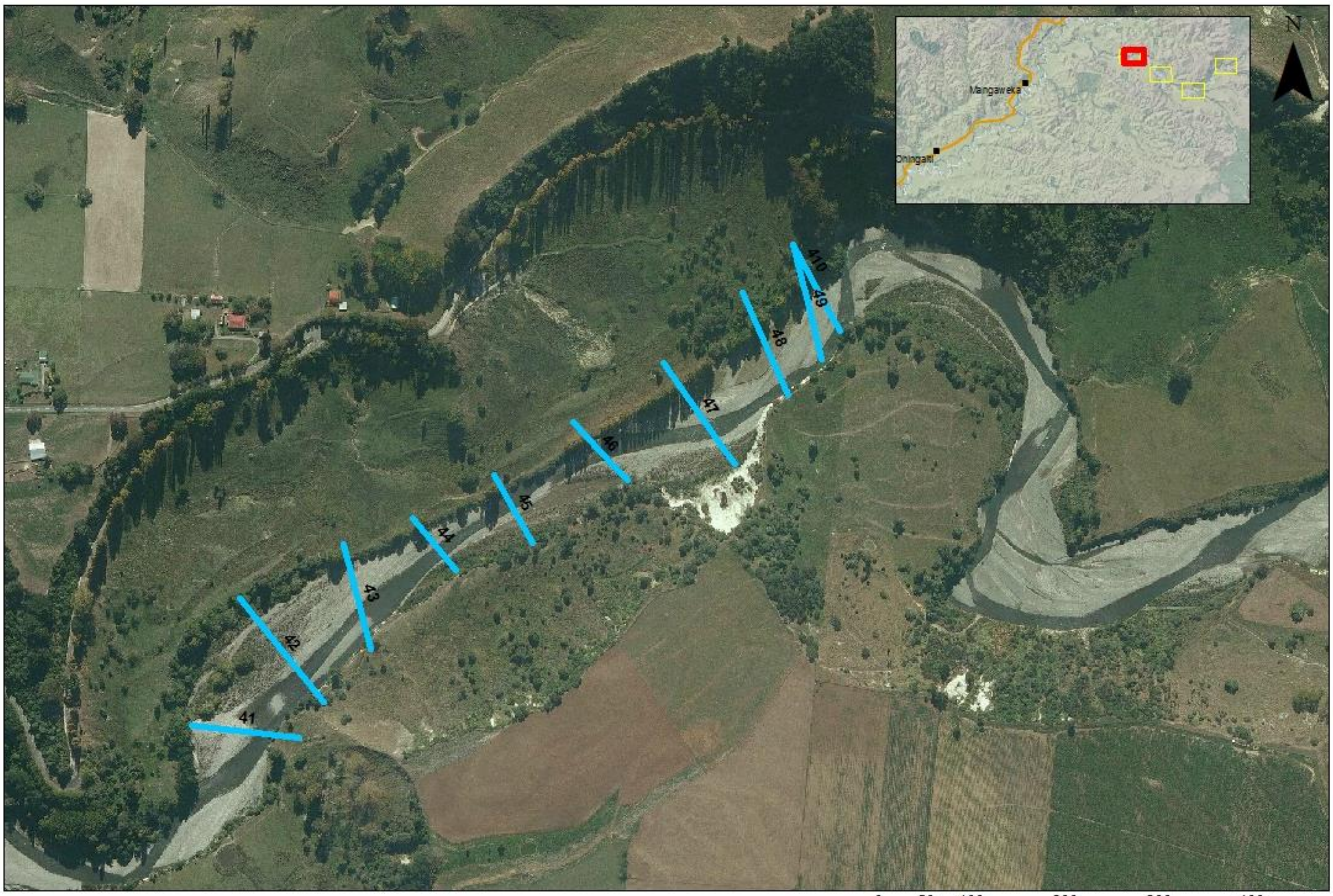

Kawhatau River
Reach 4
Cross Sections

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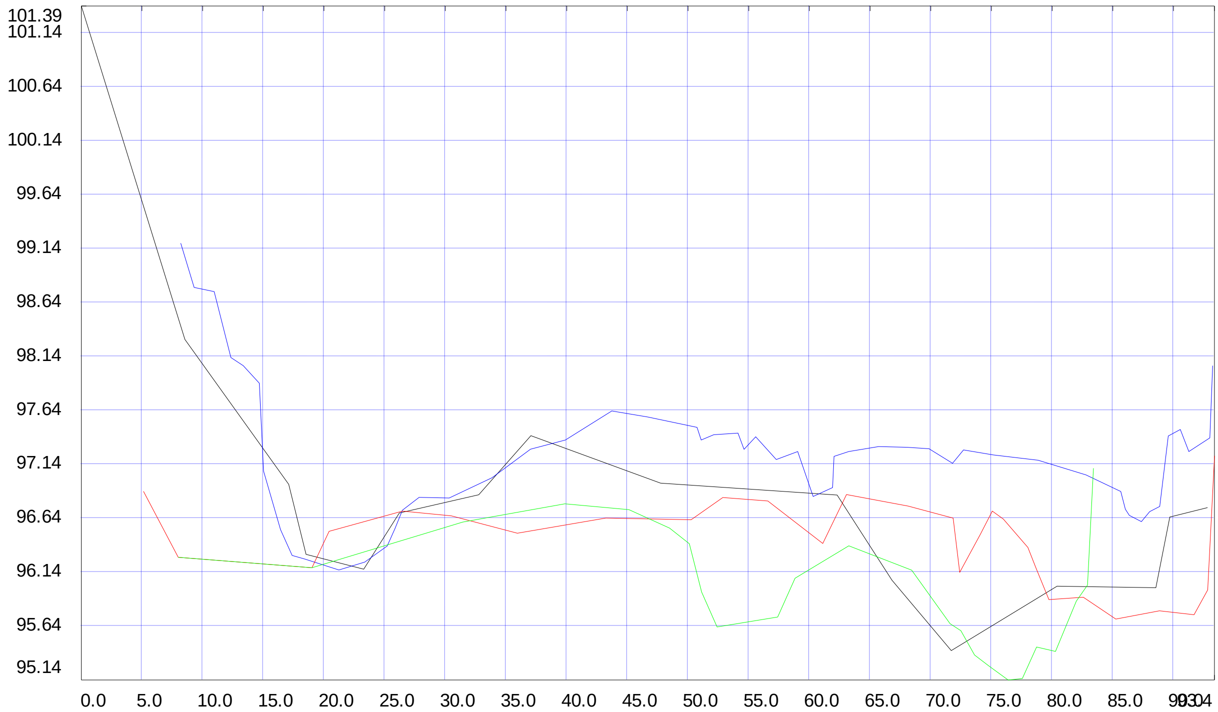
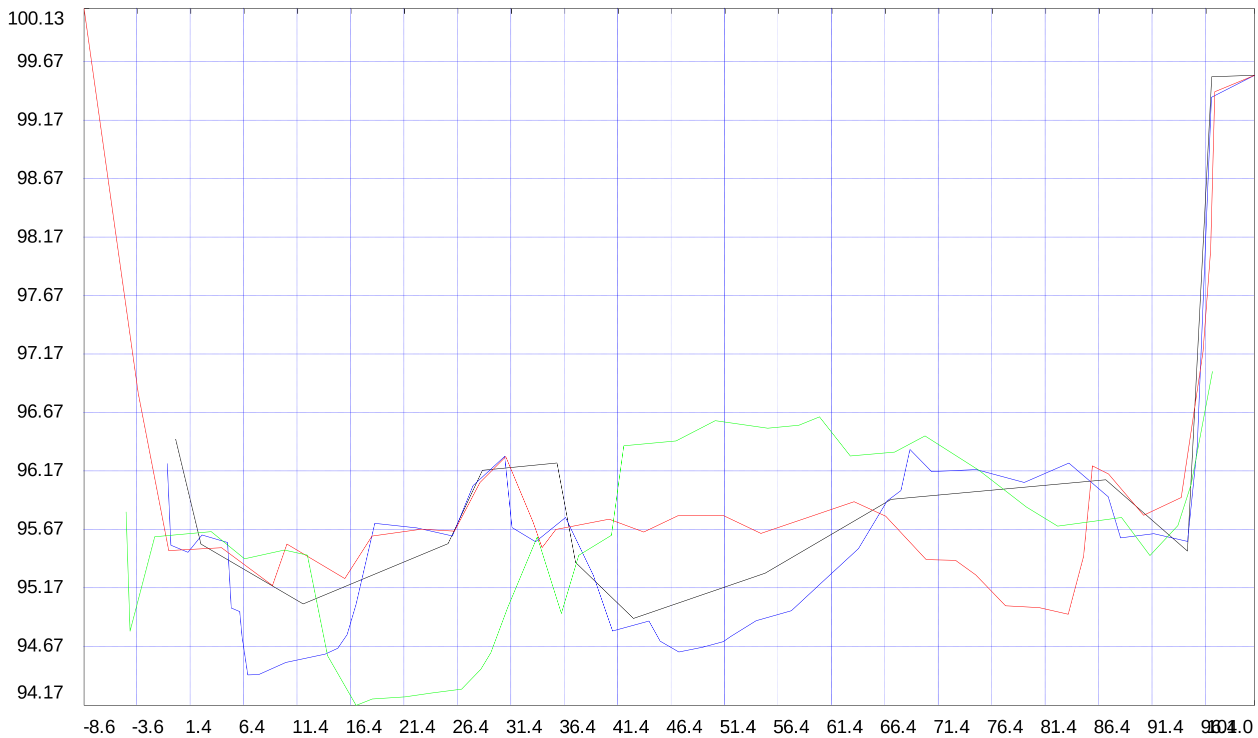
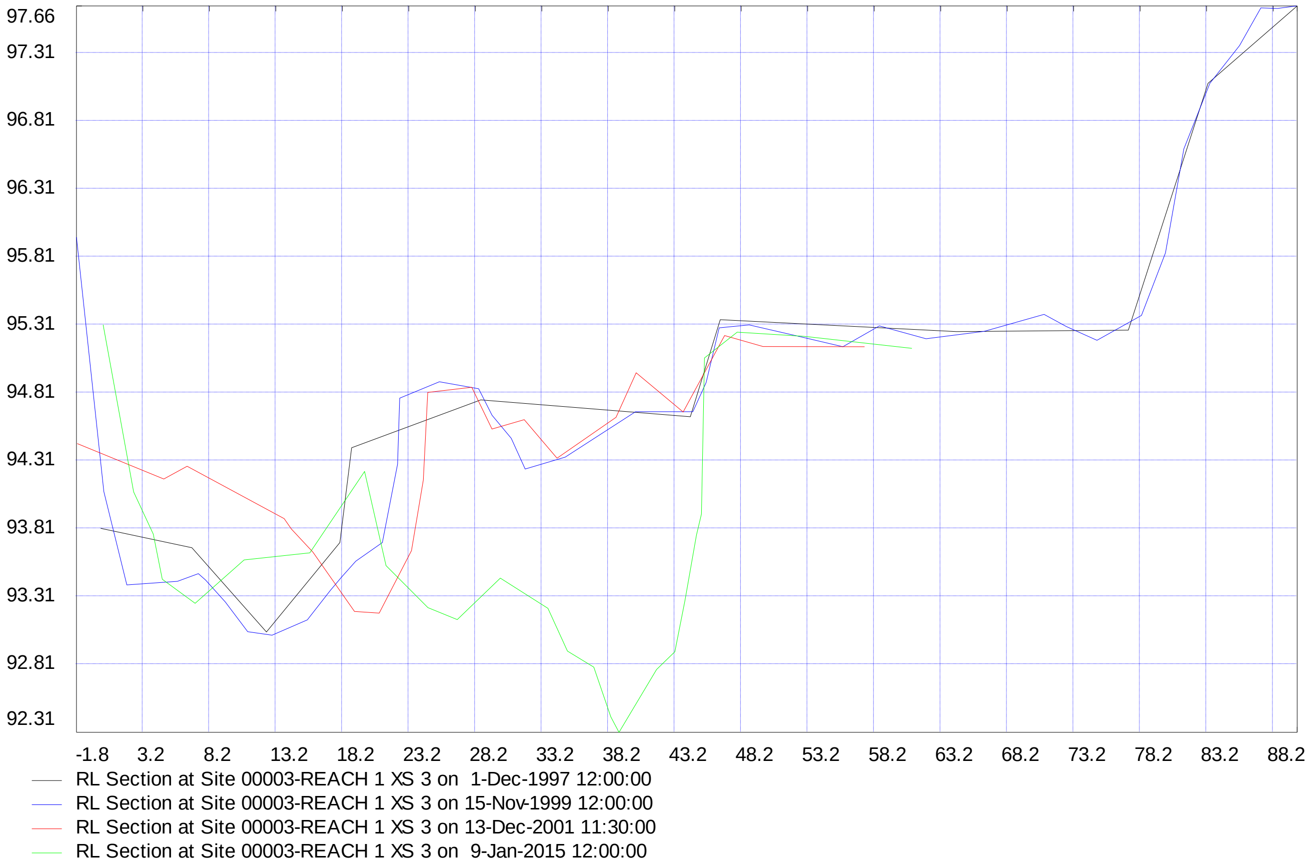
12. Appendix B



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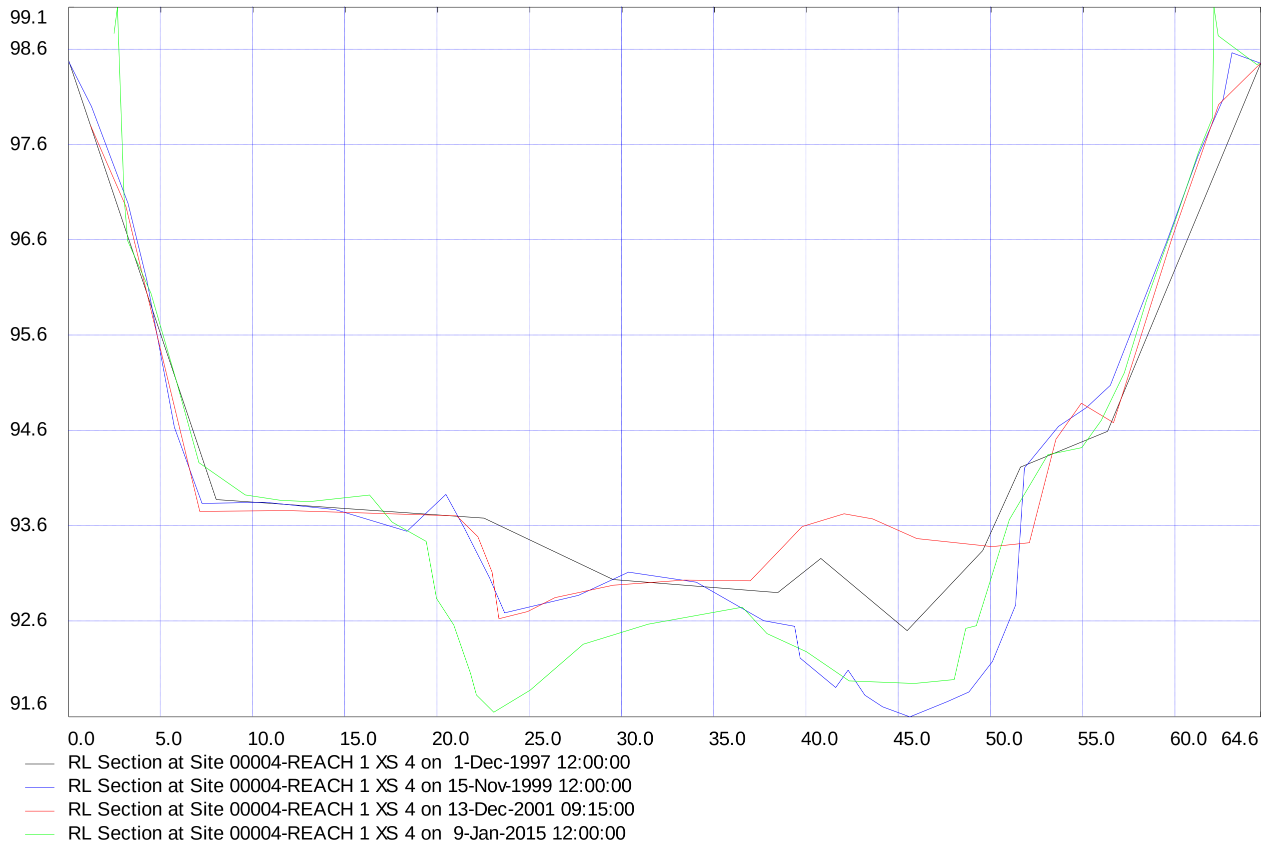
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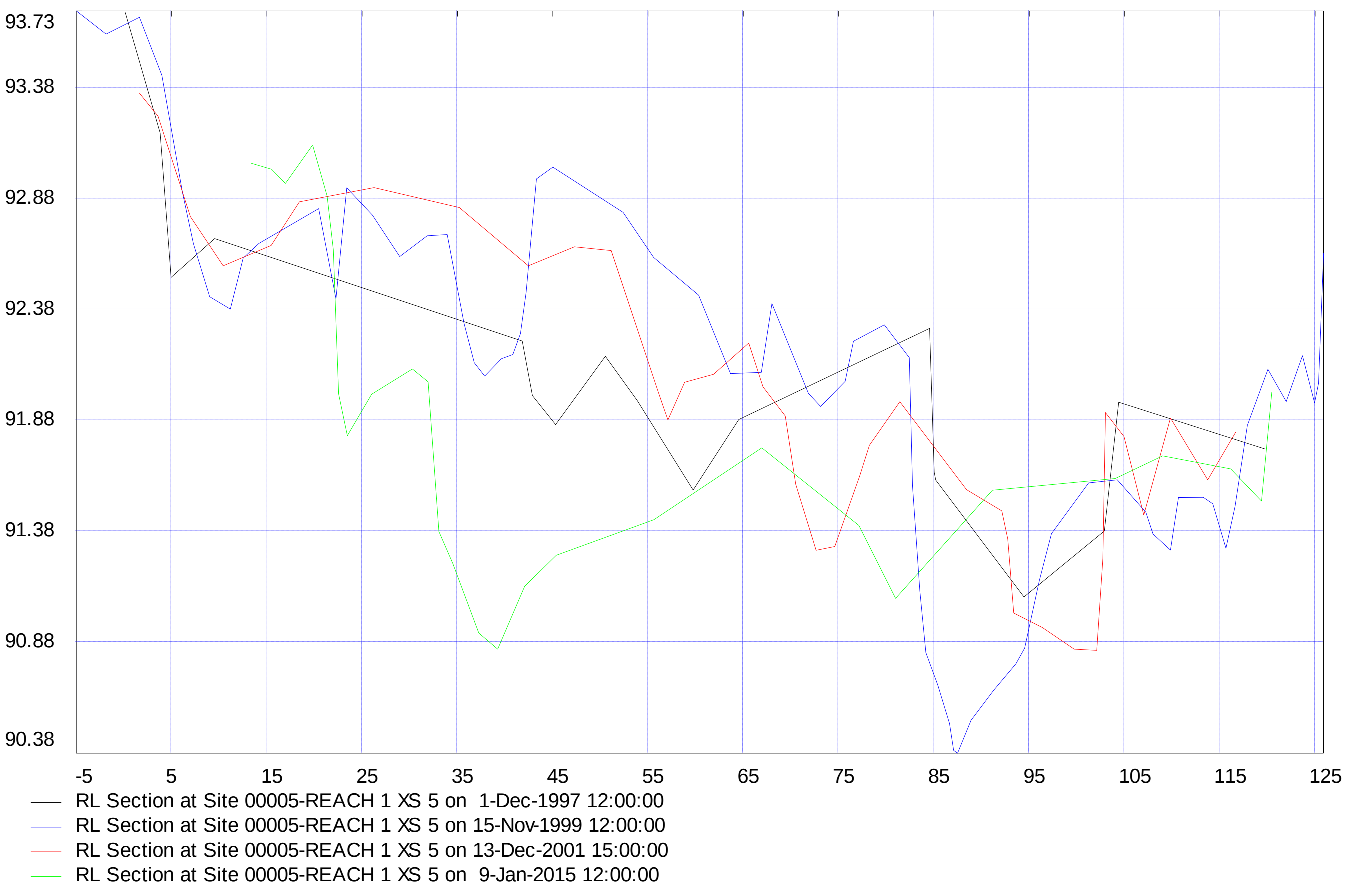
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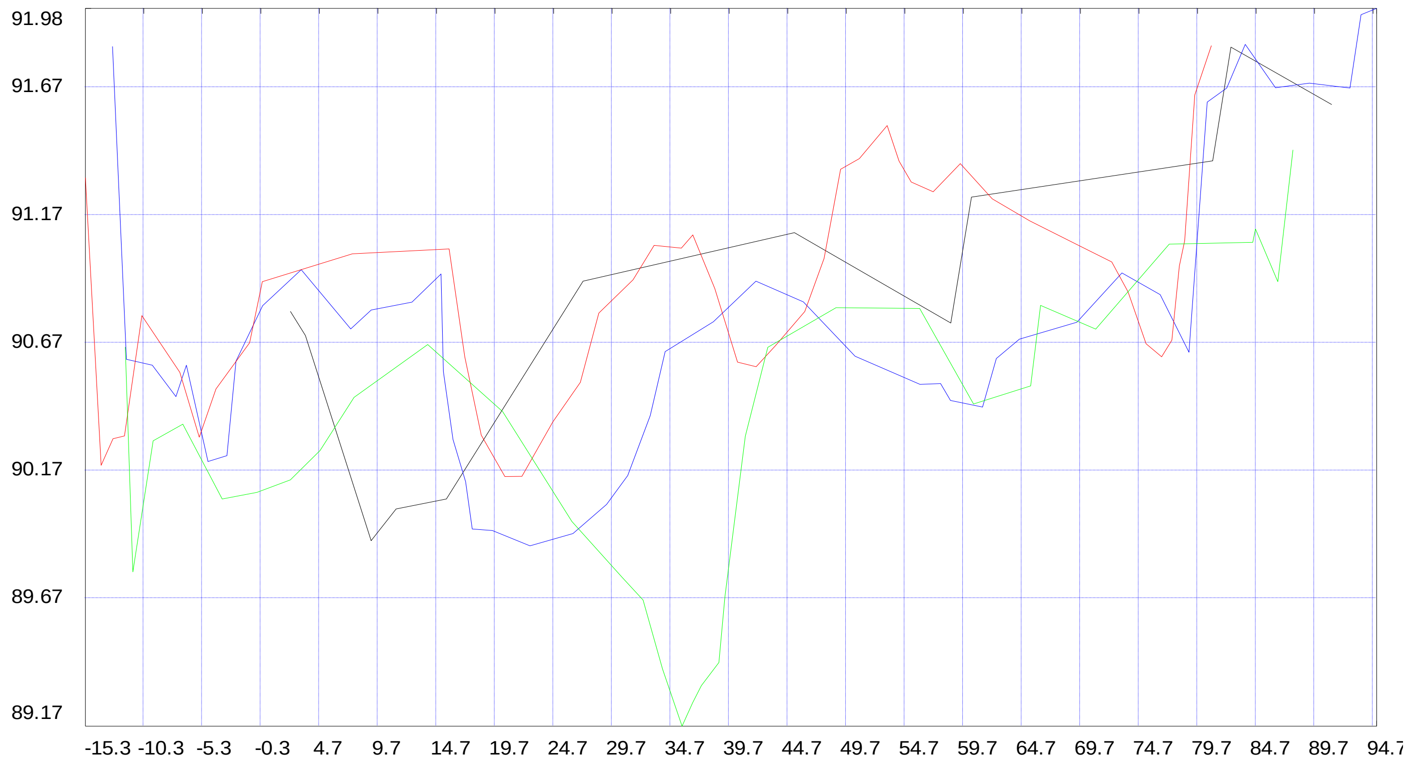

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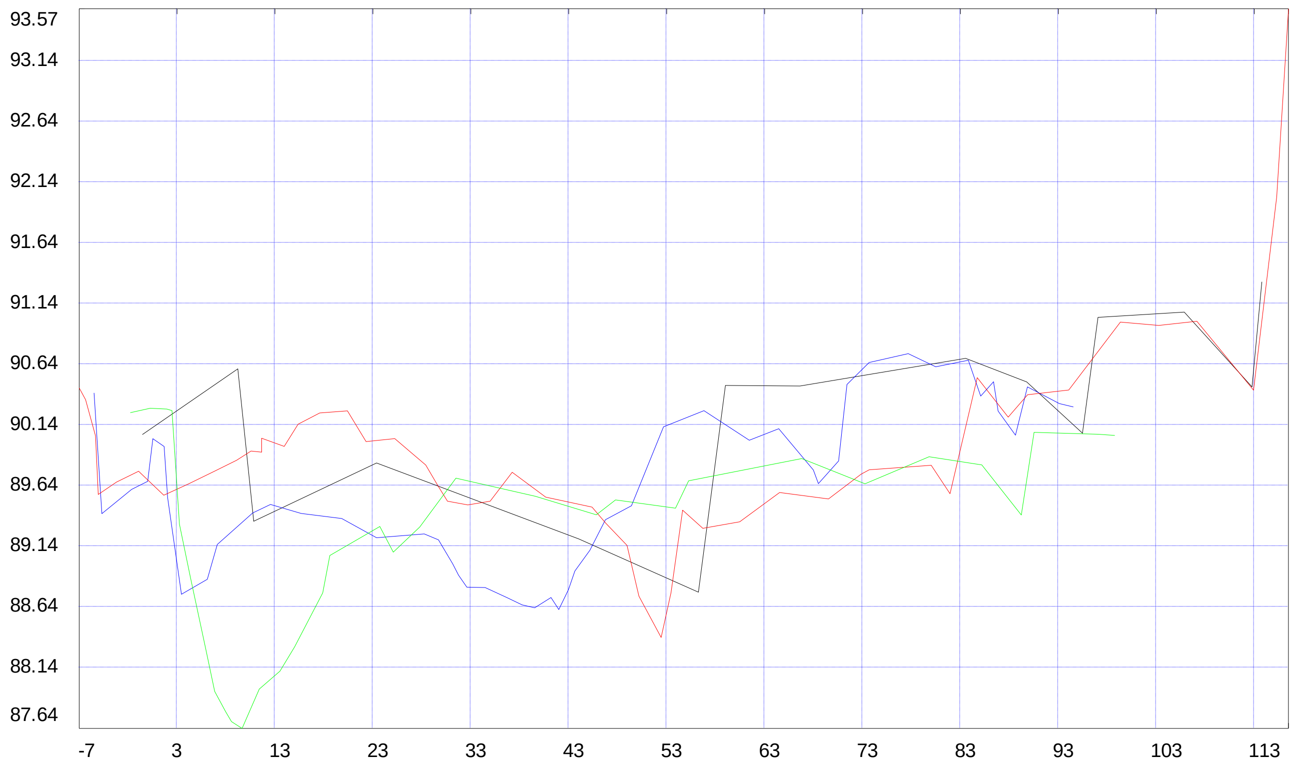

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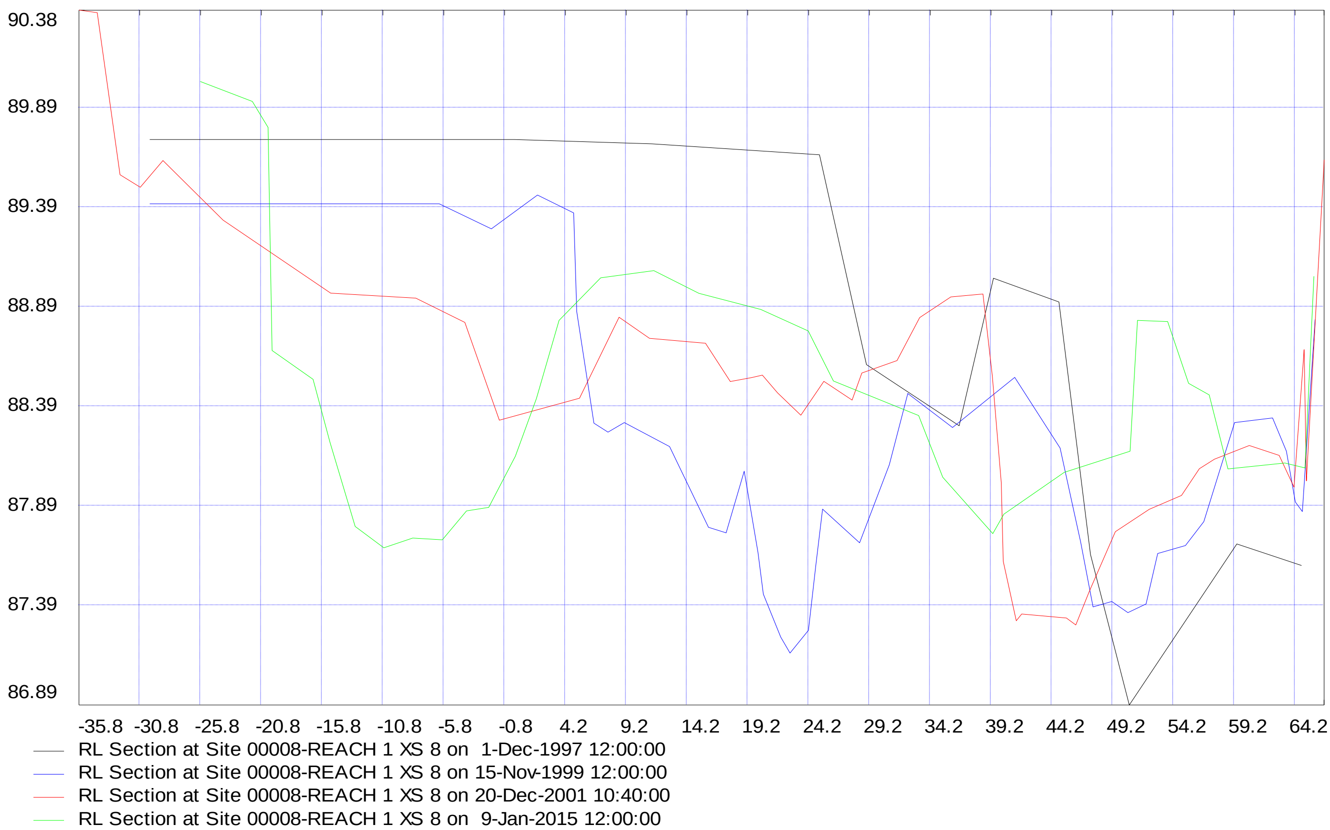
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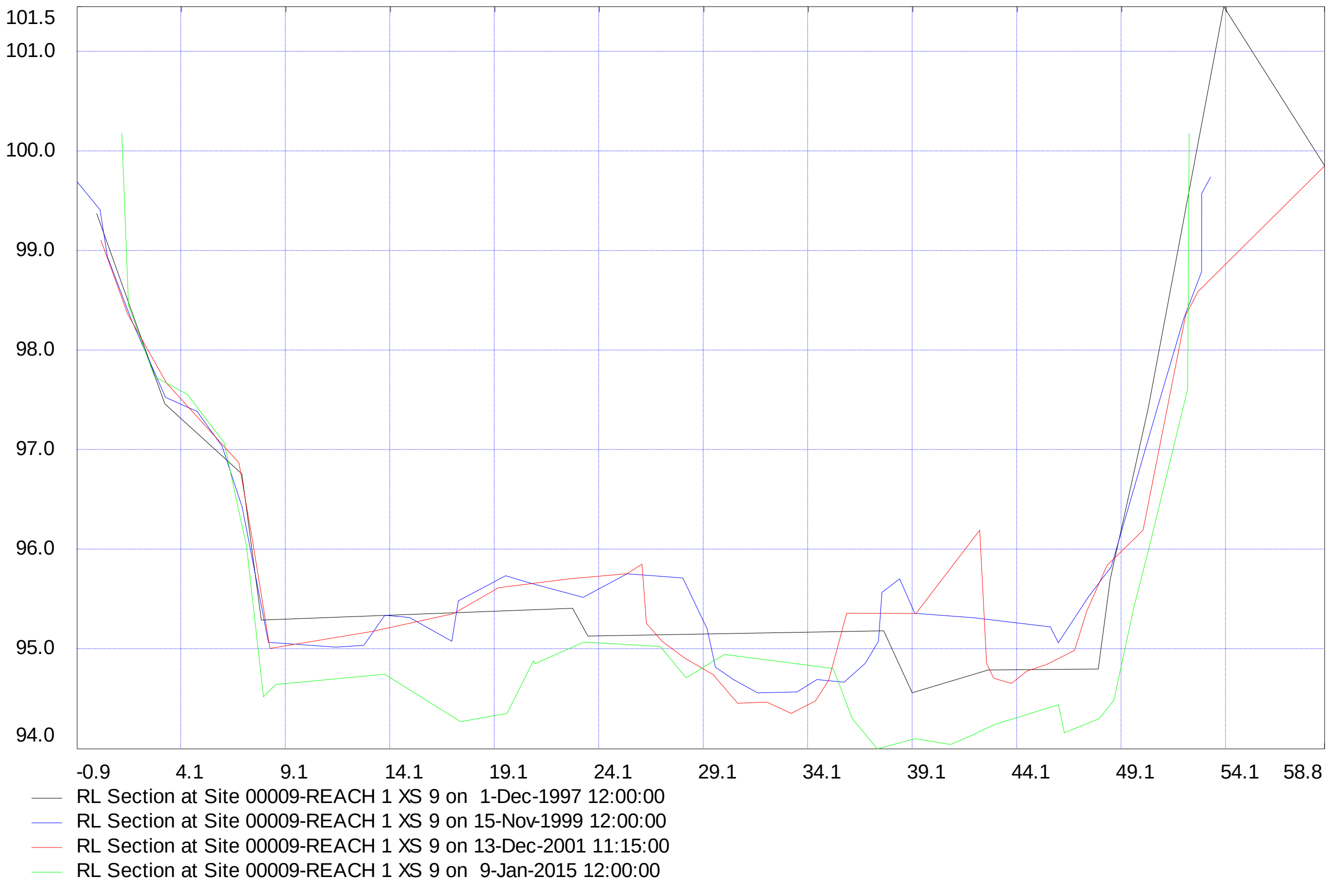
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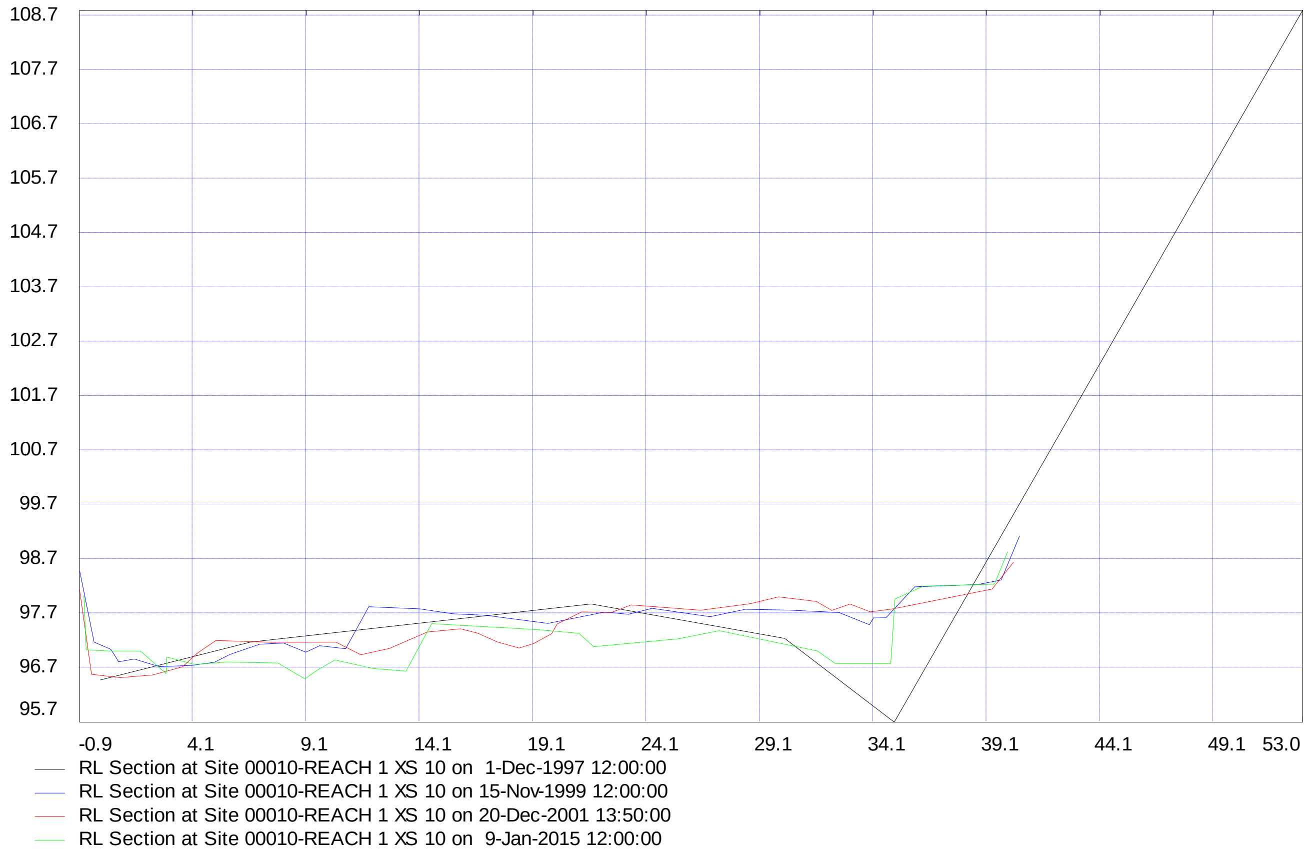
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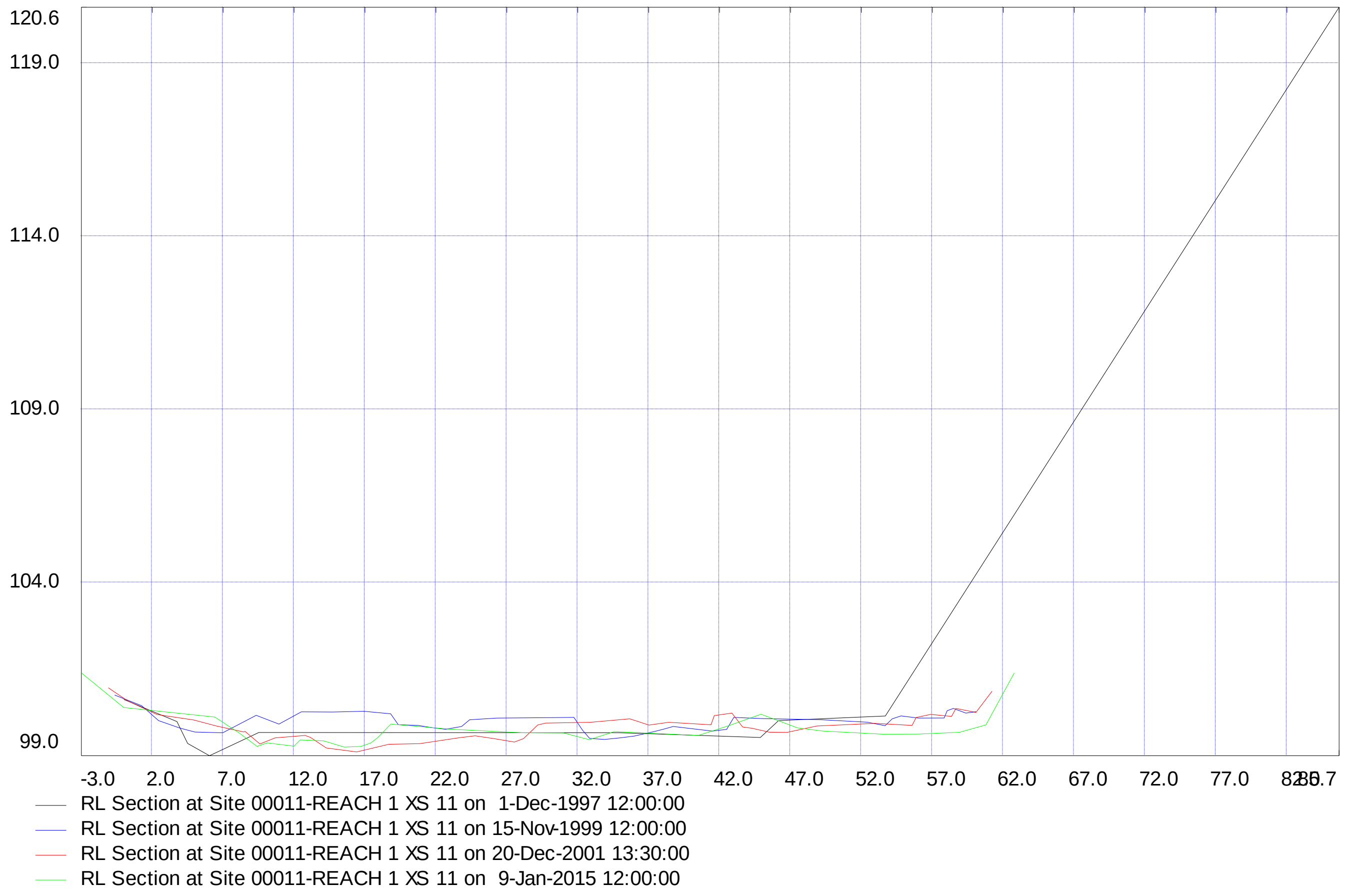
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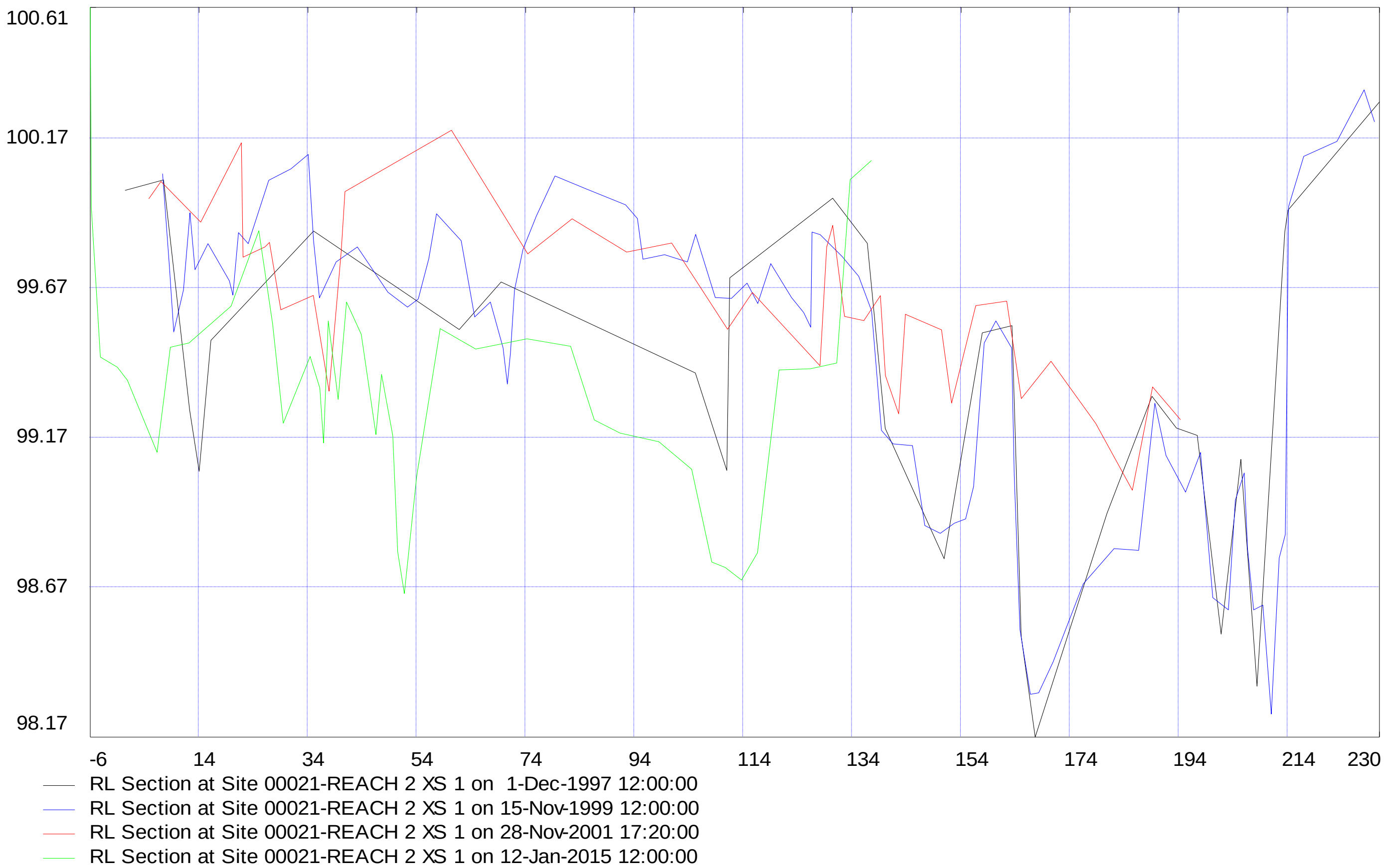
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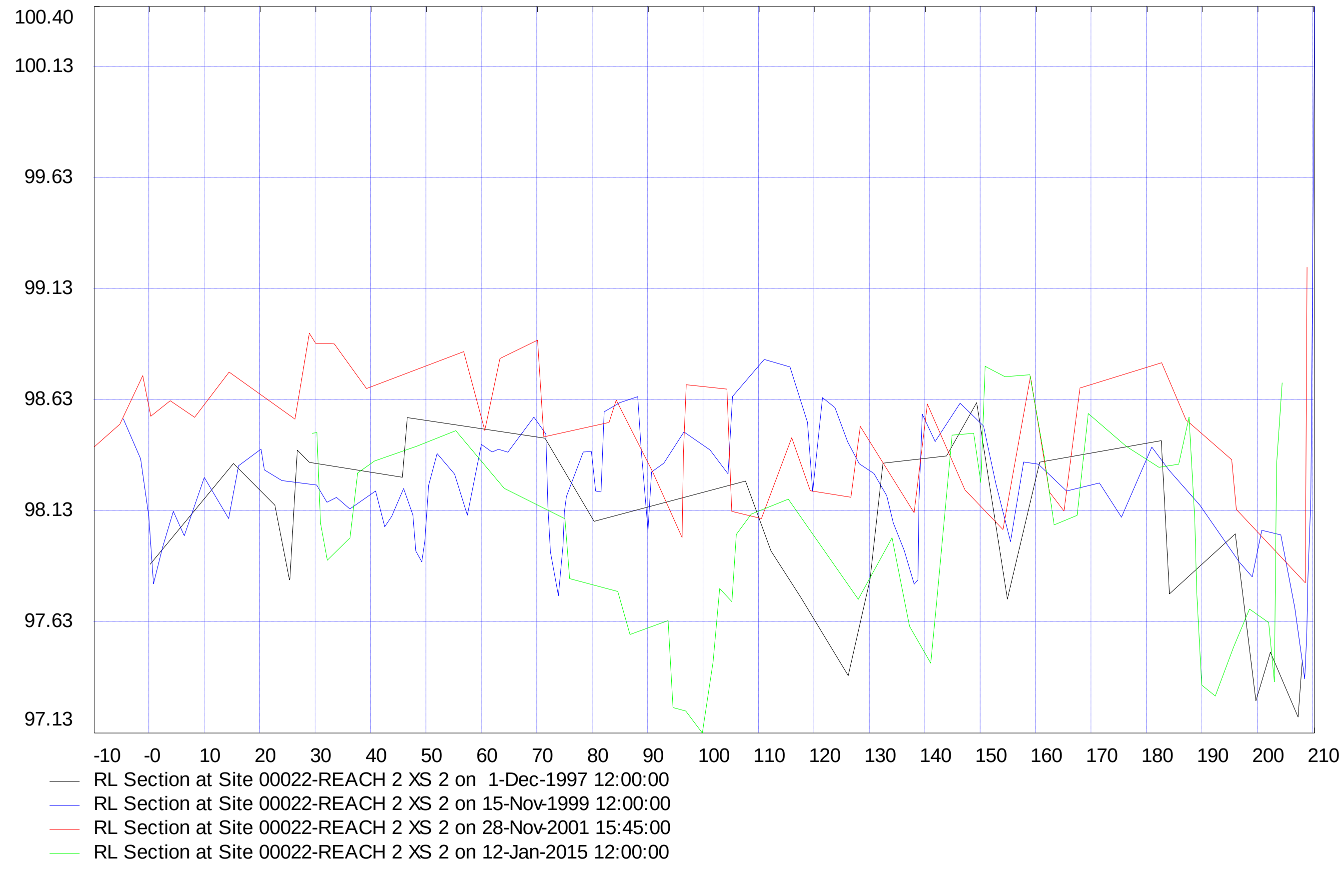
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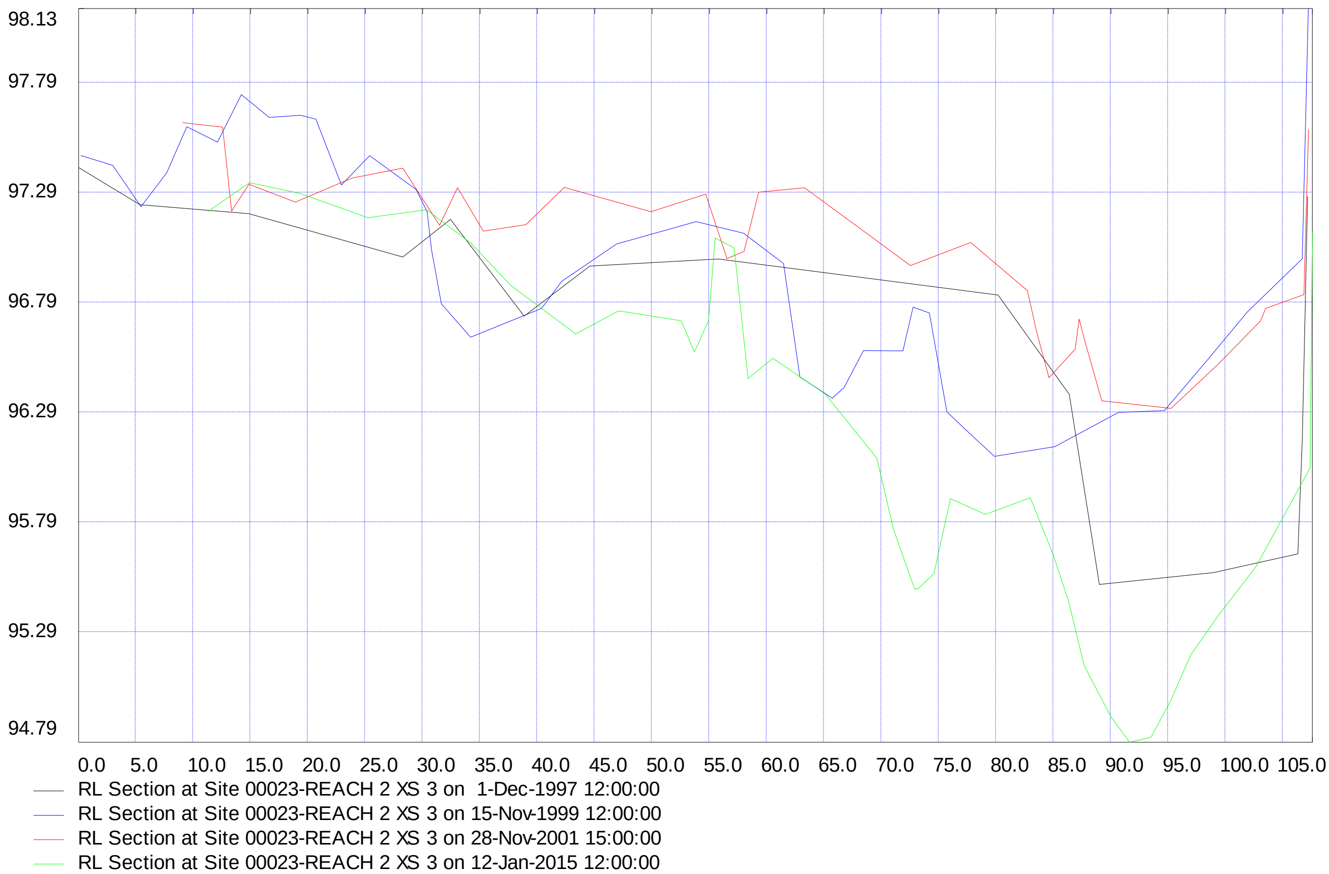
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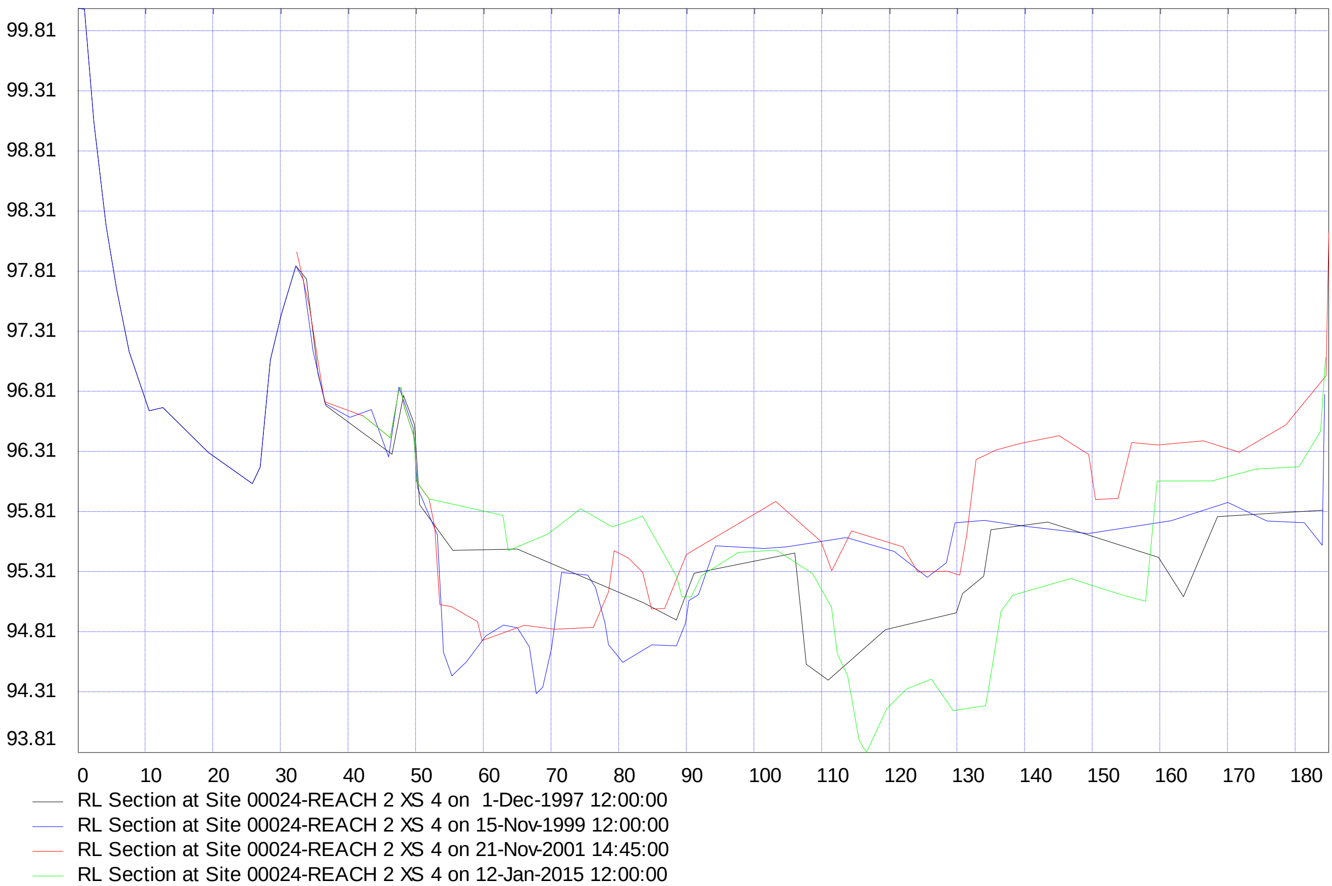
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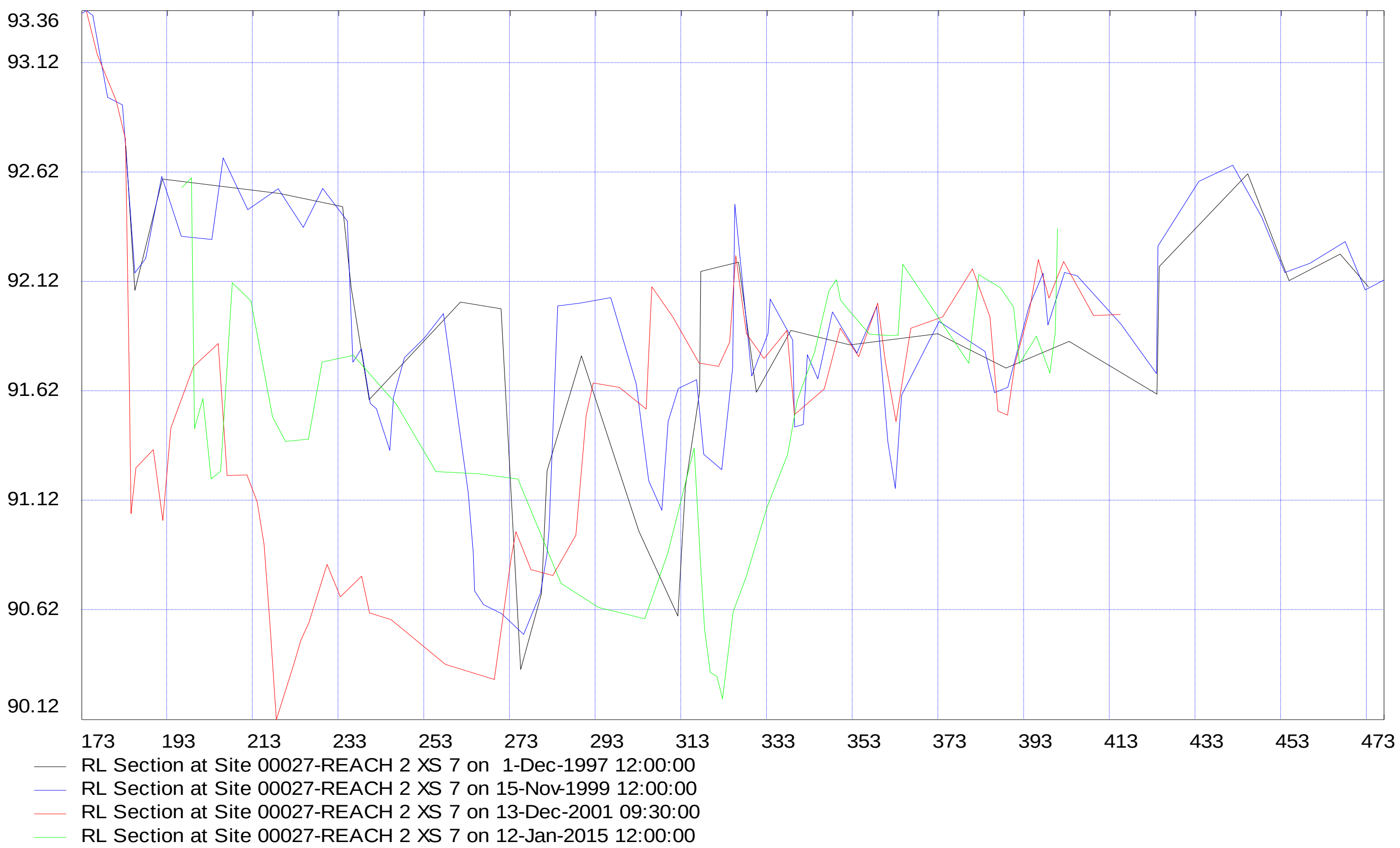
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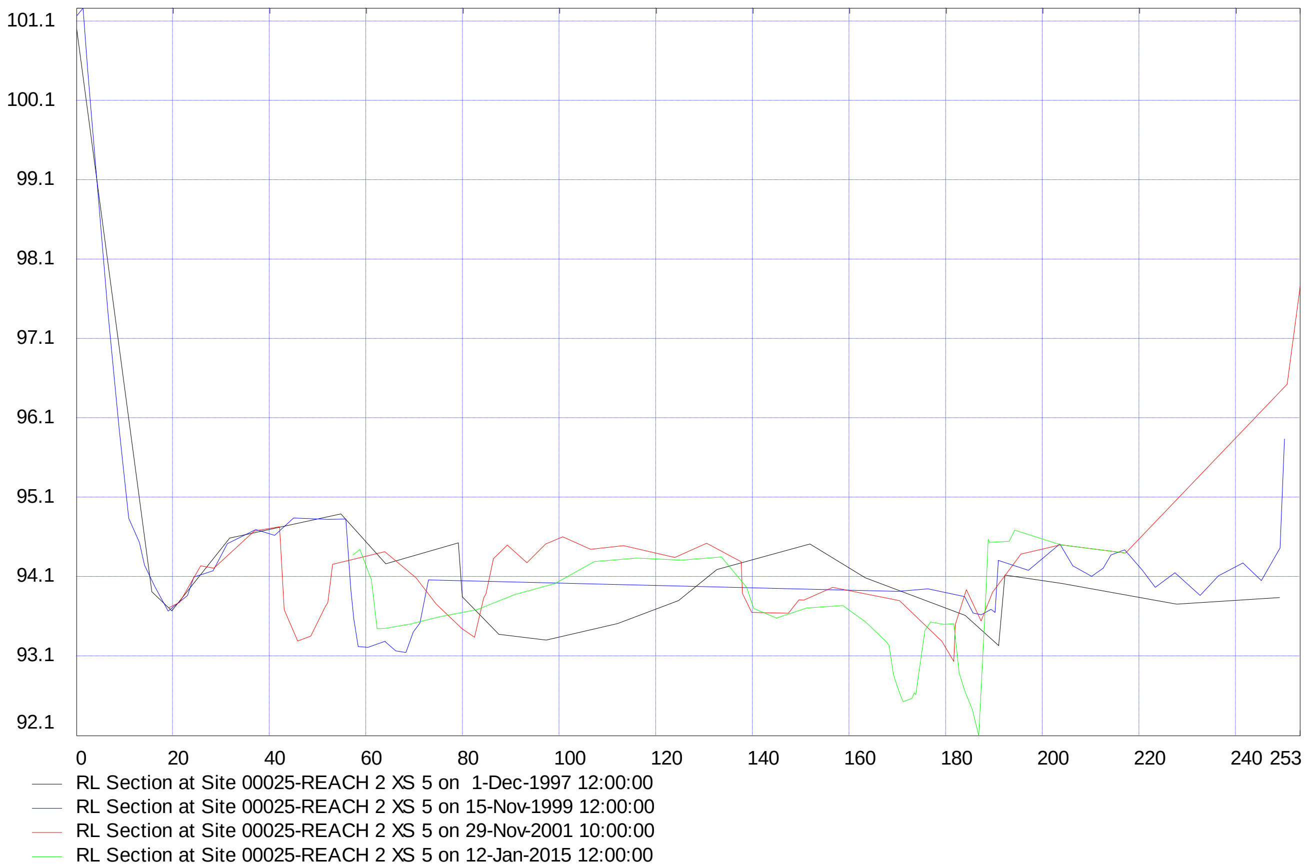
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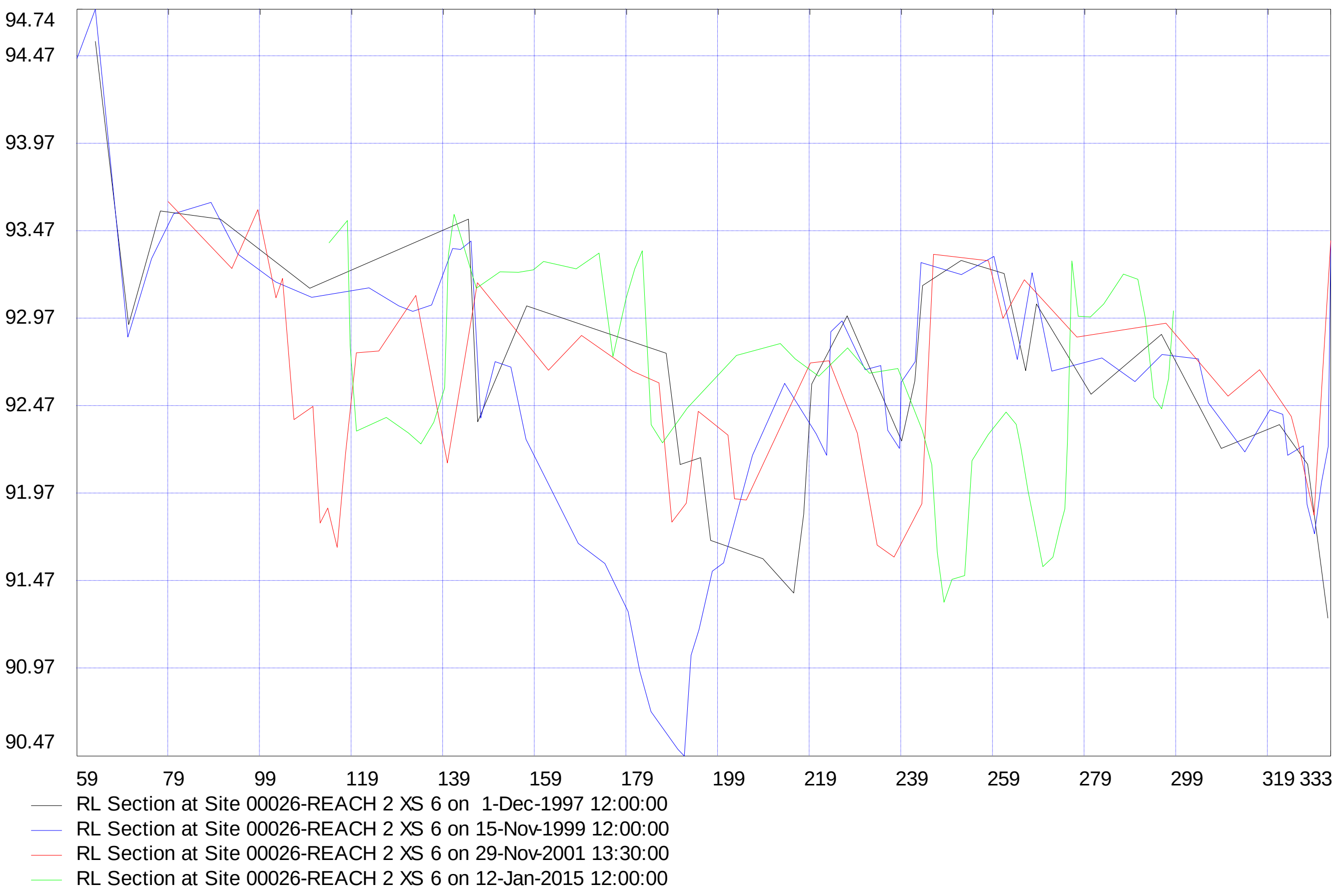
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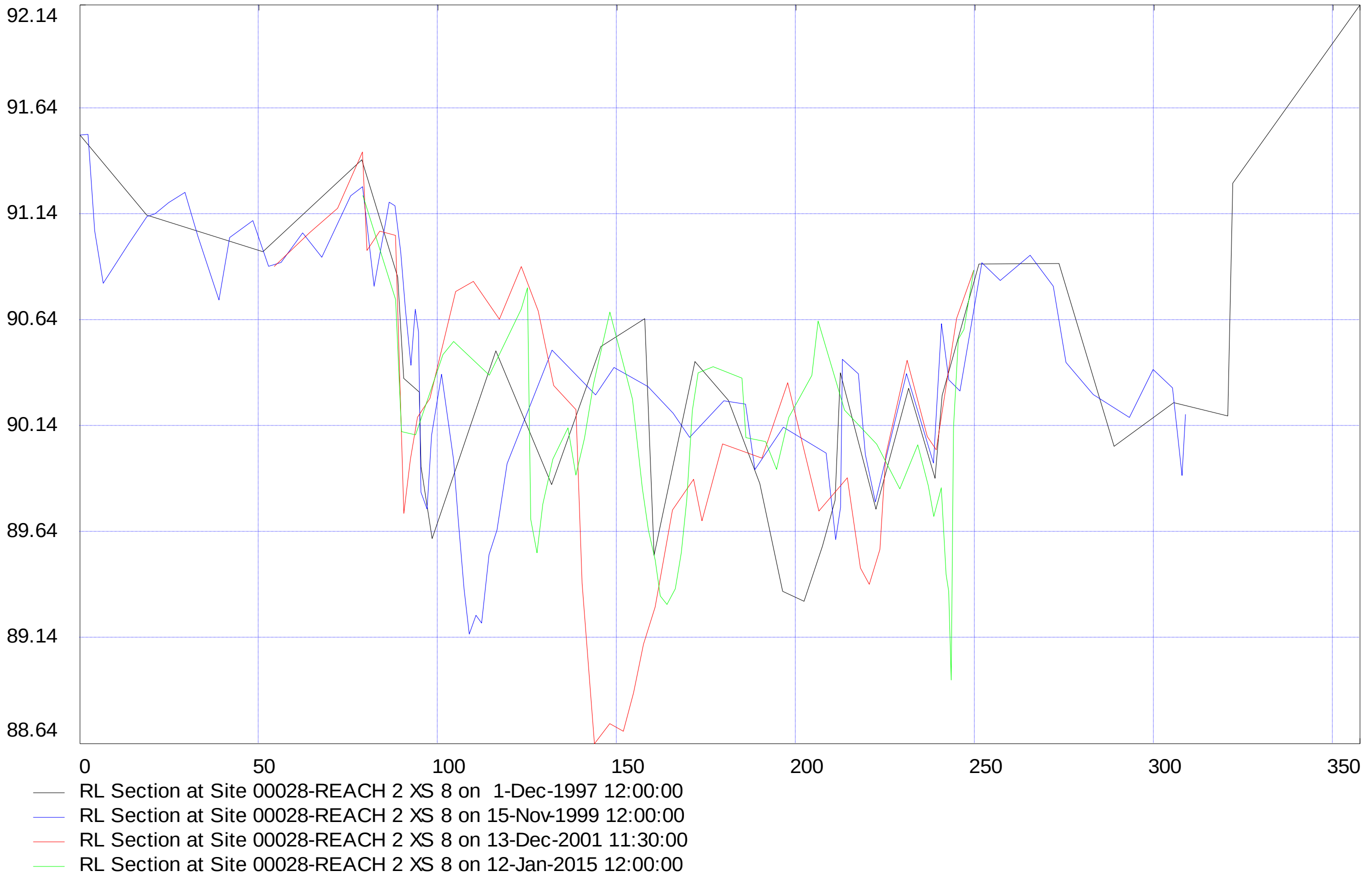
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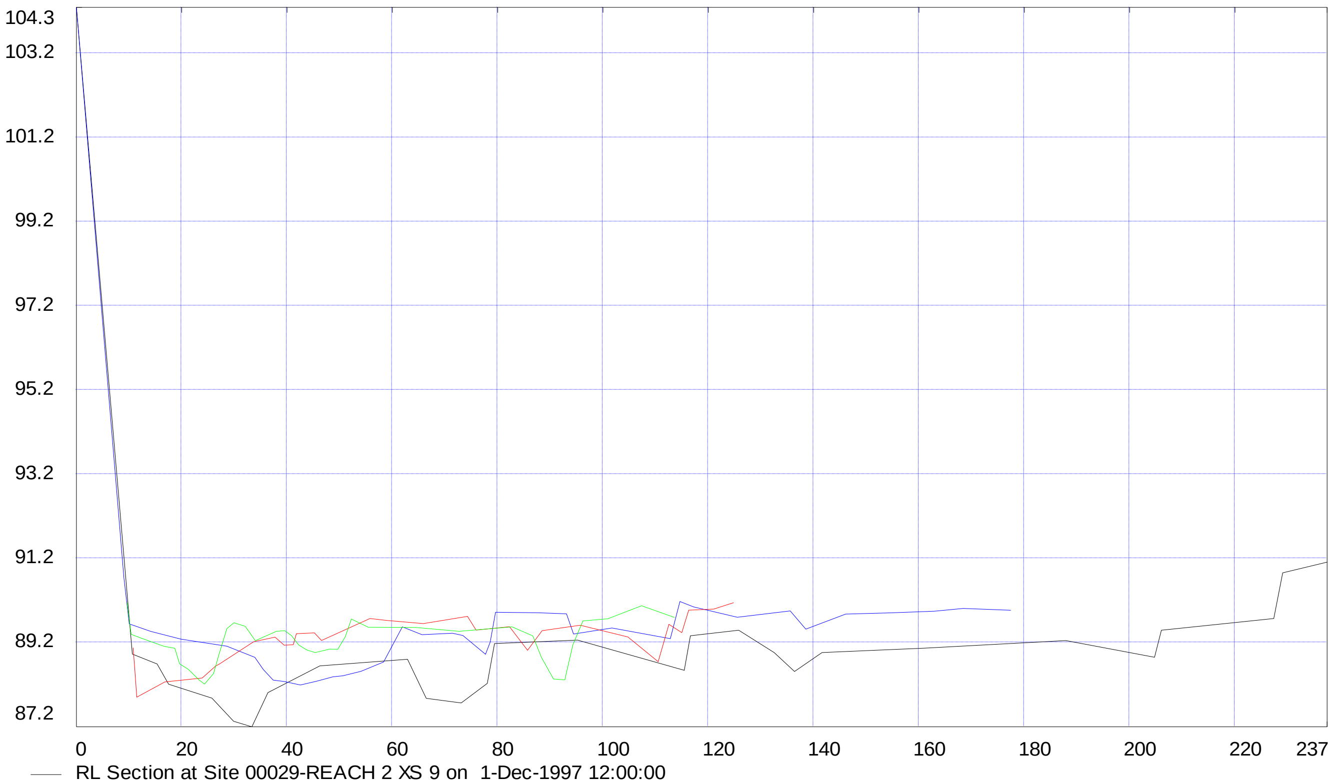

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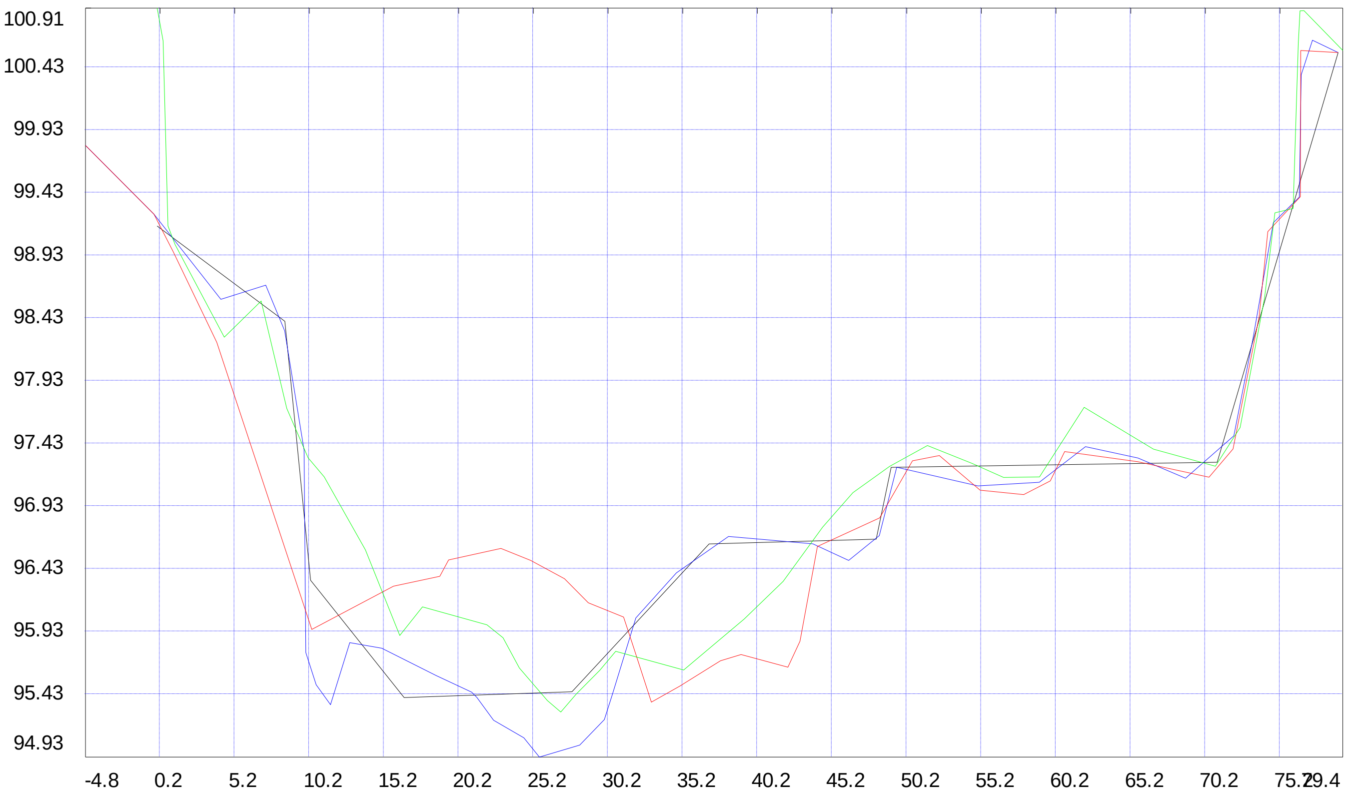

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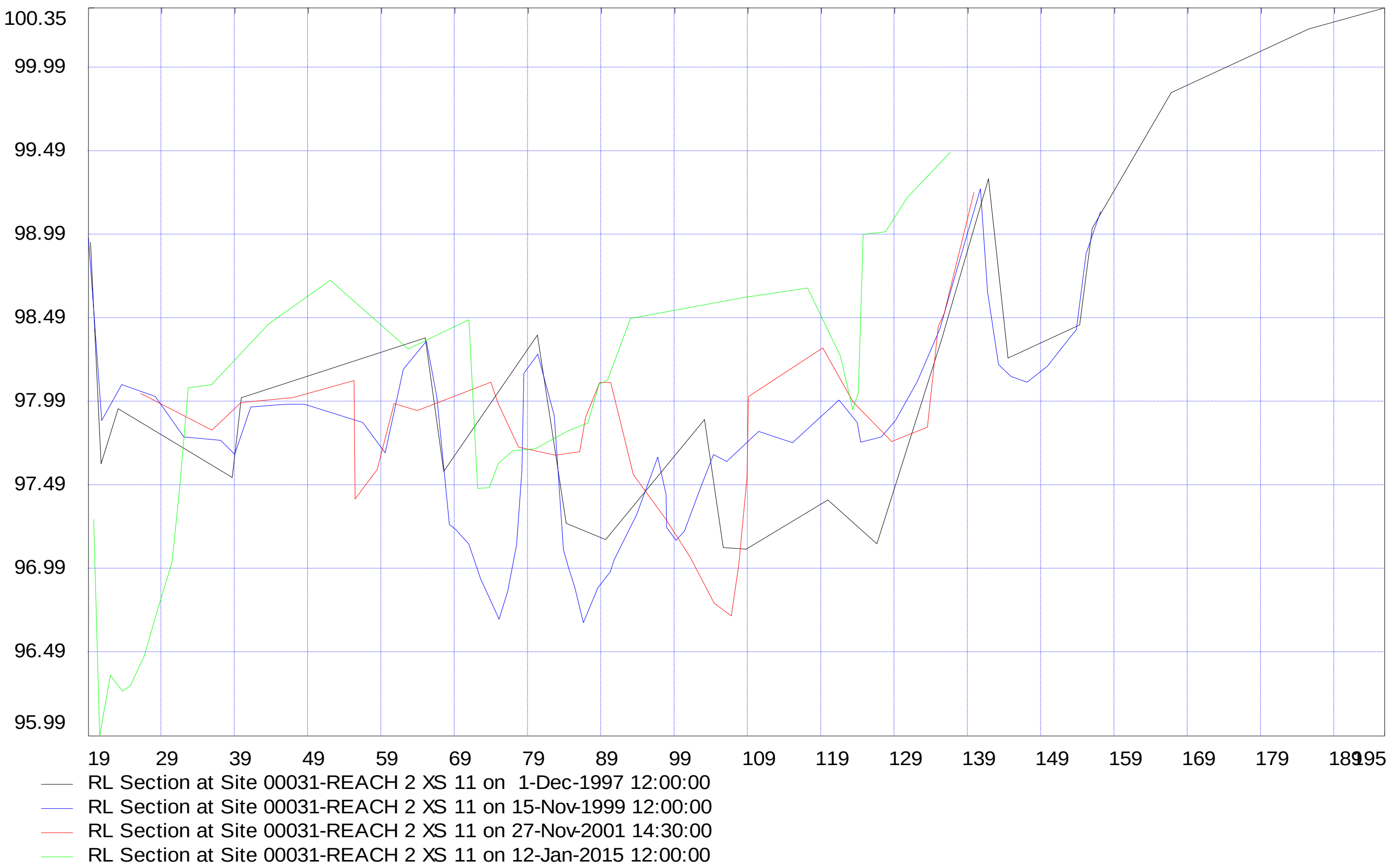
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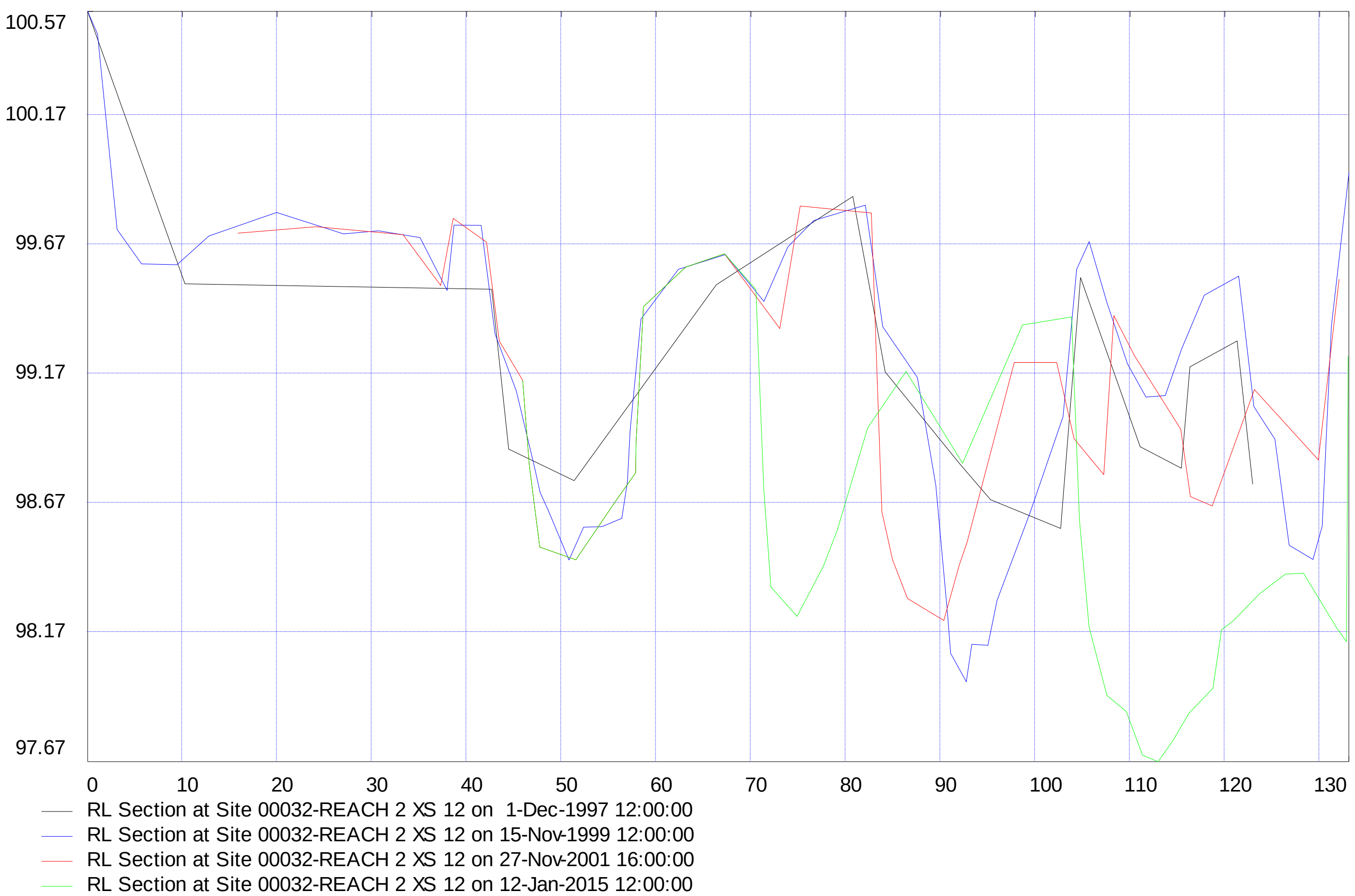
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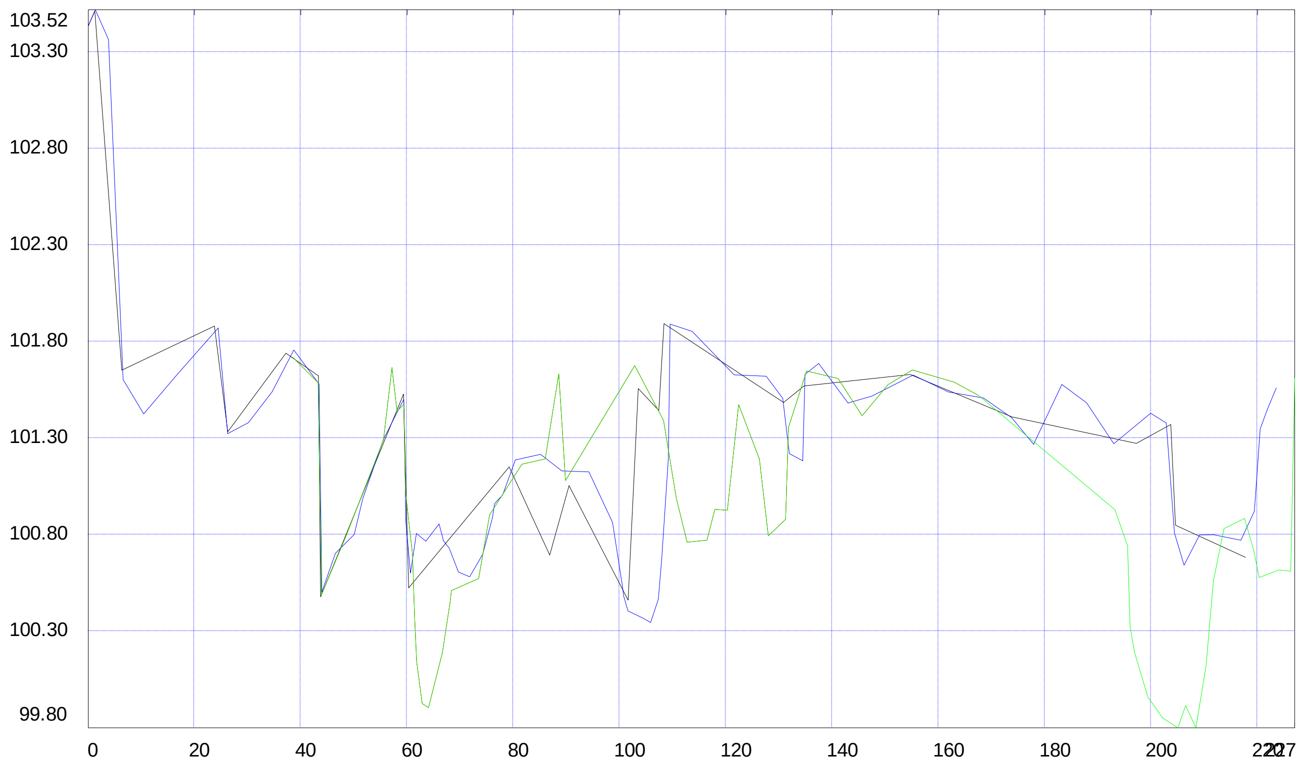

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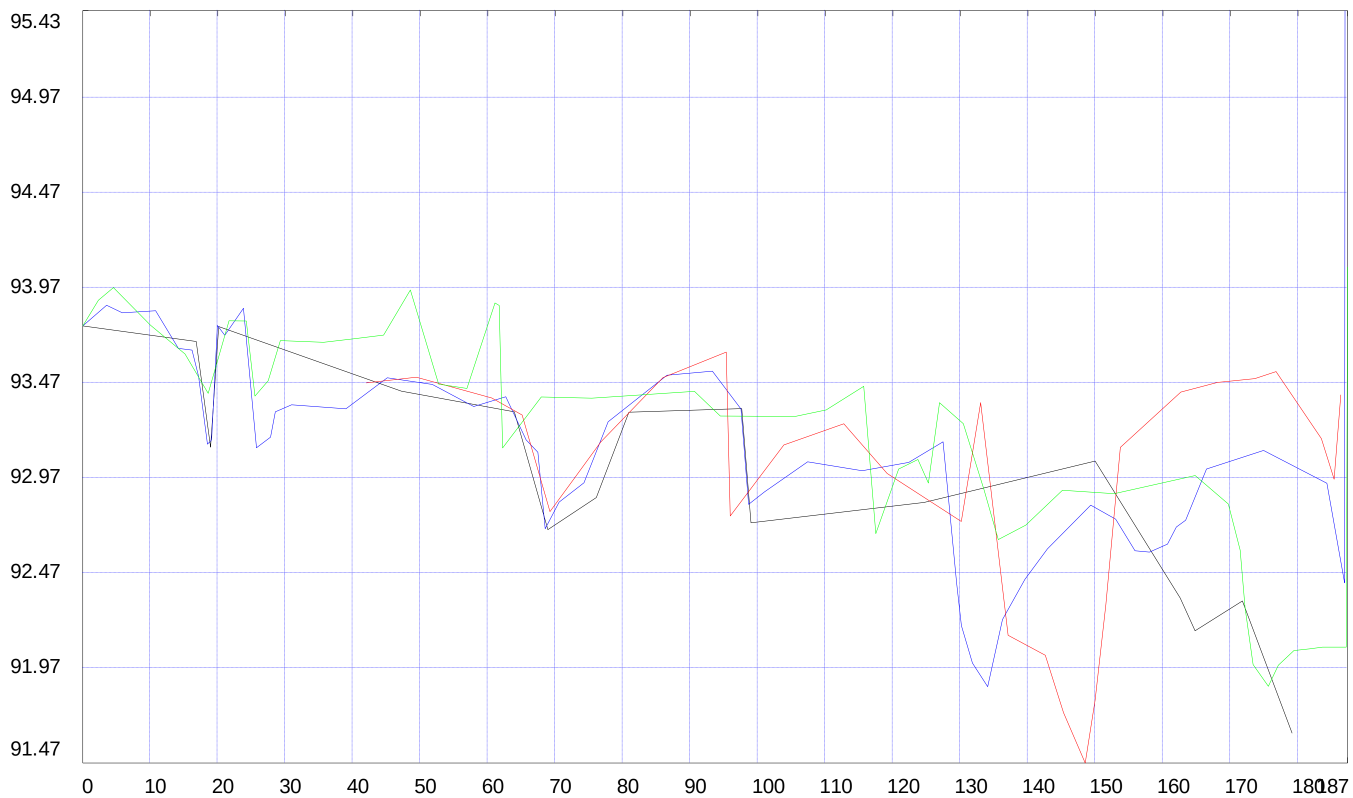

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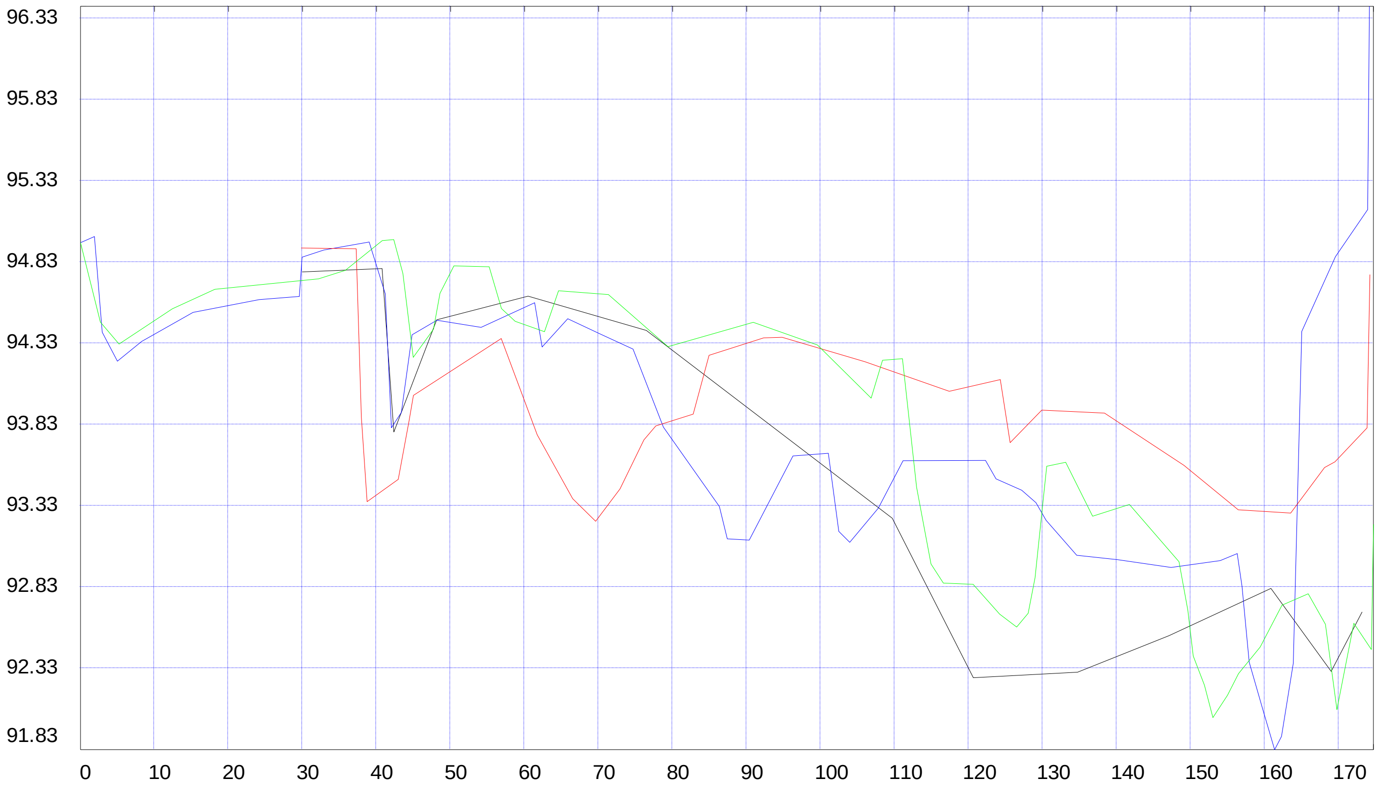

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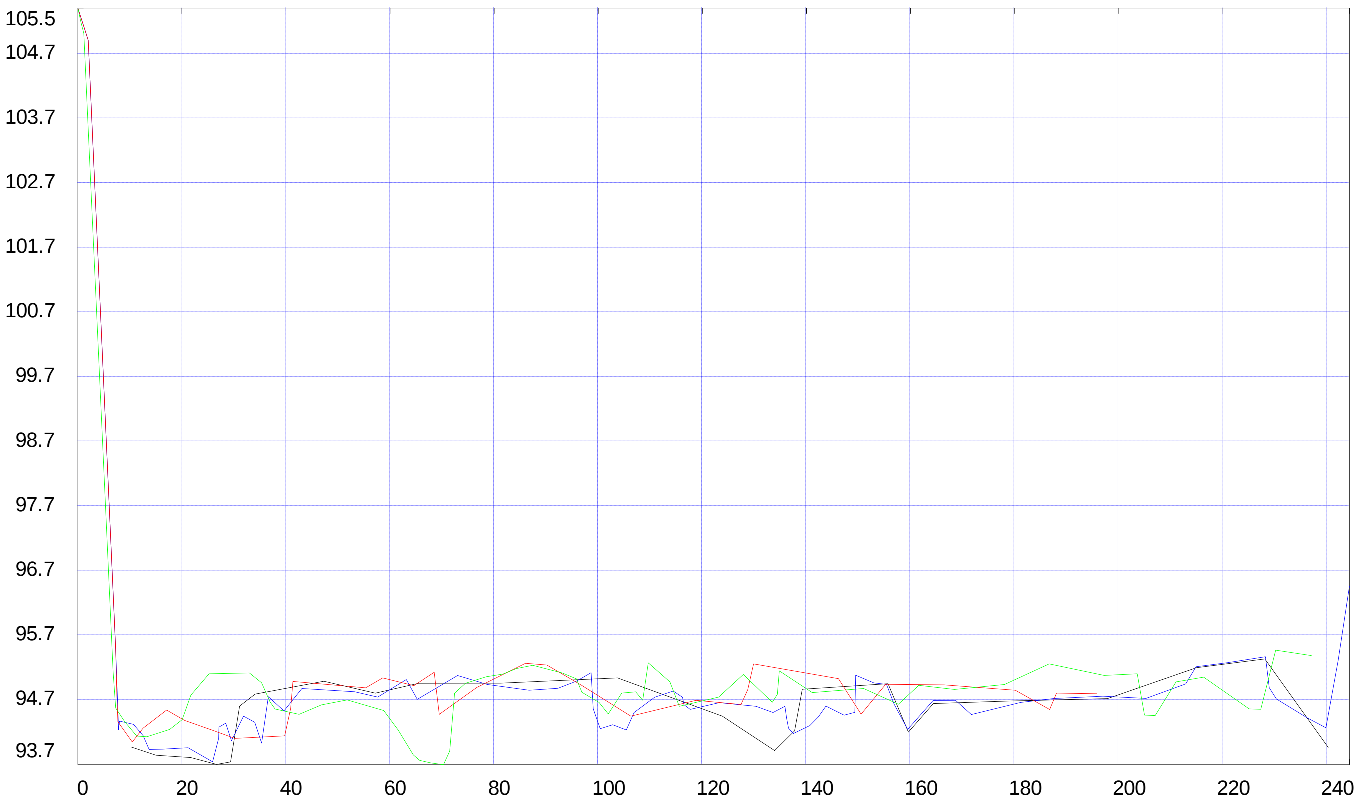

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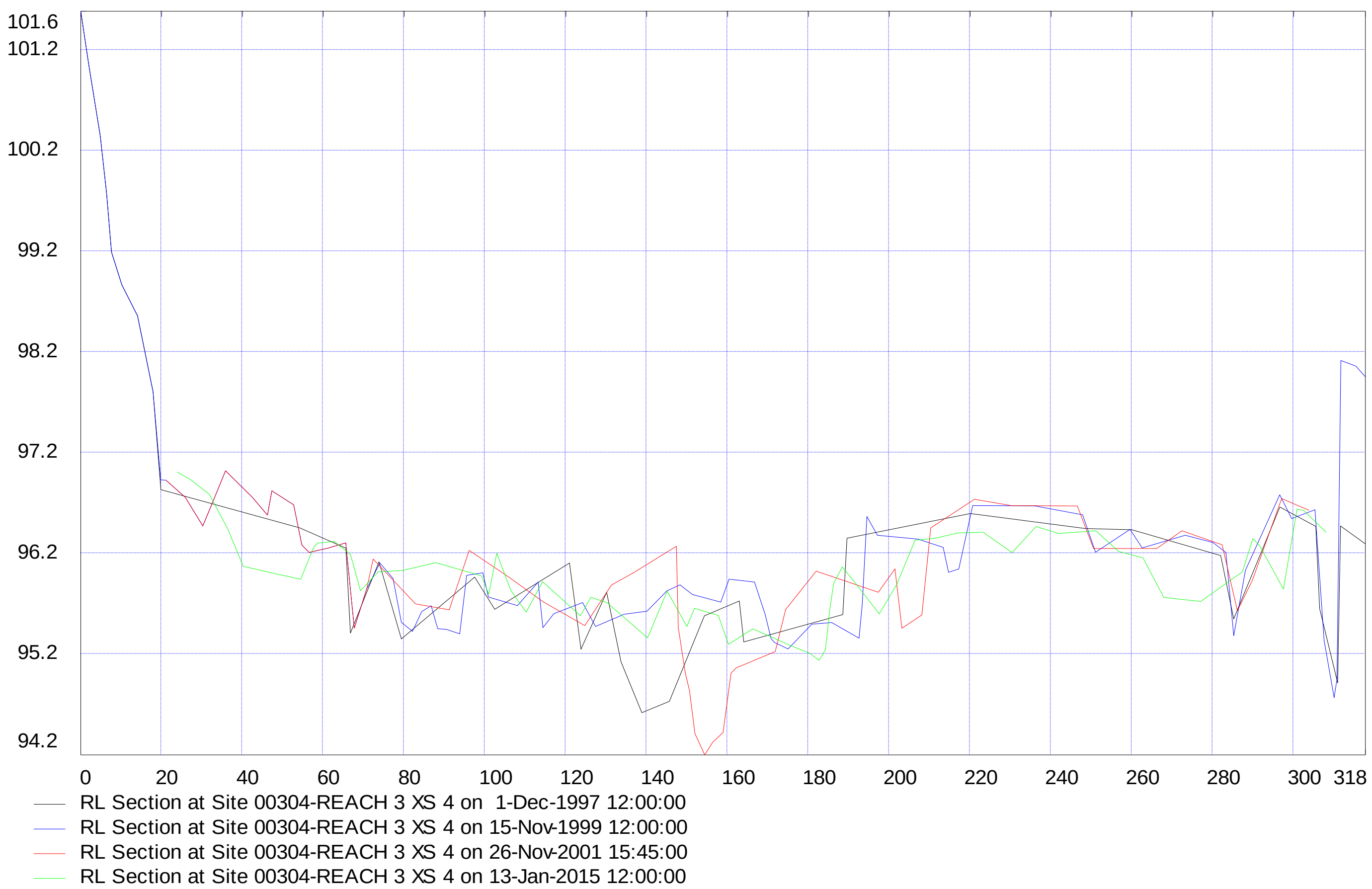
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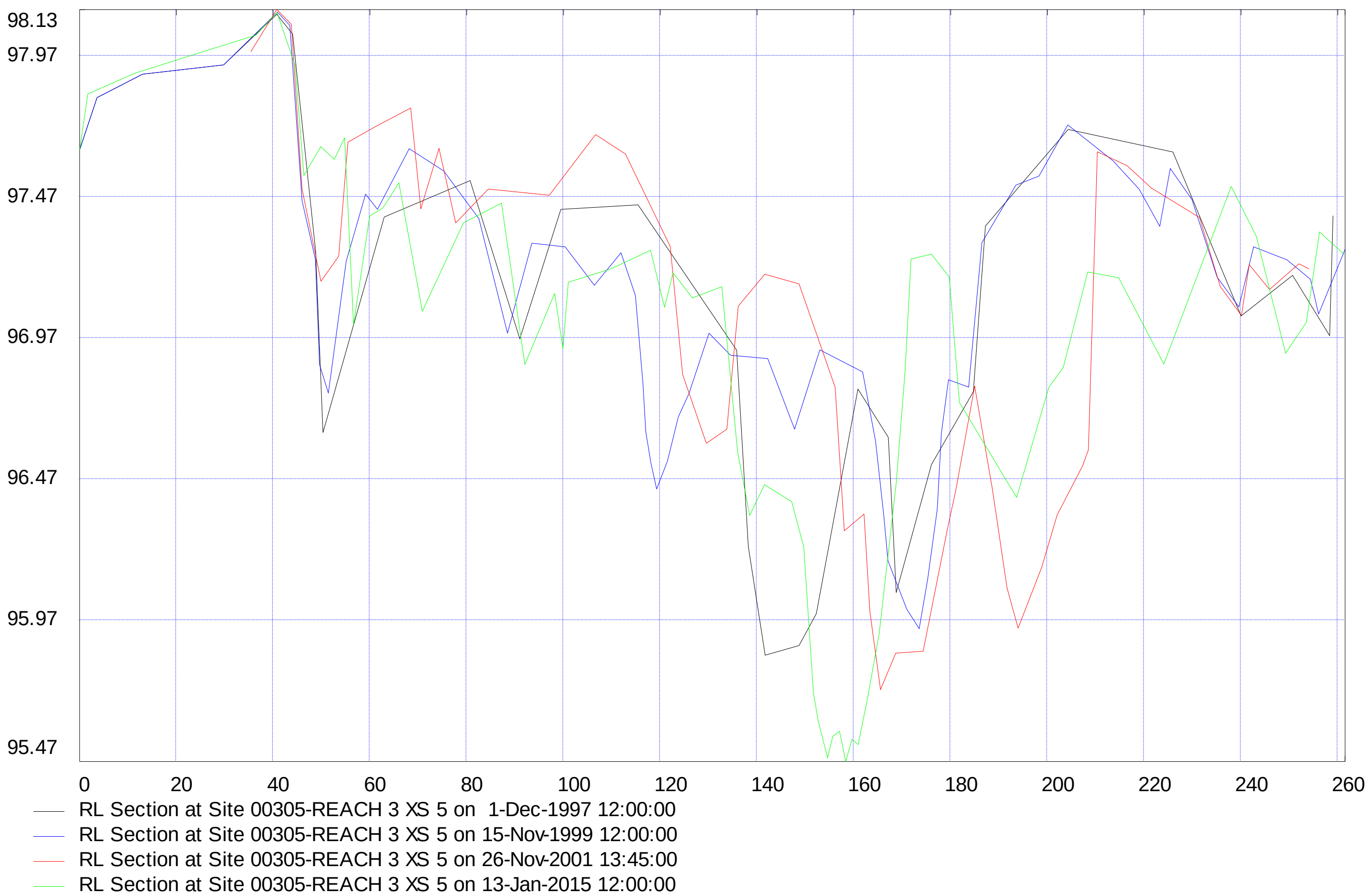
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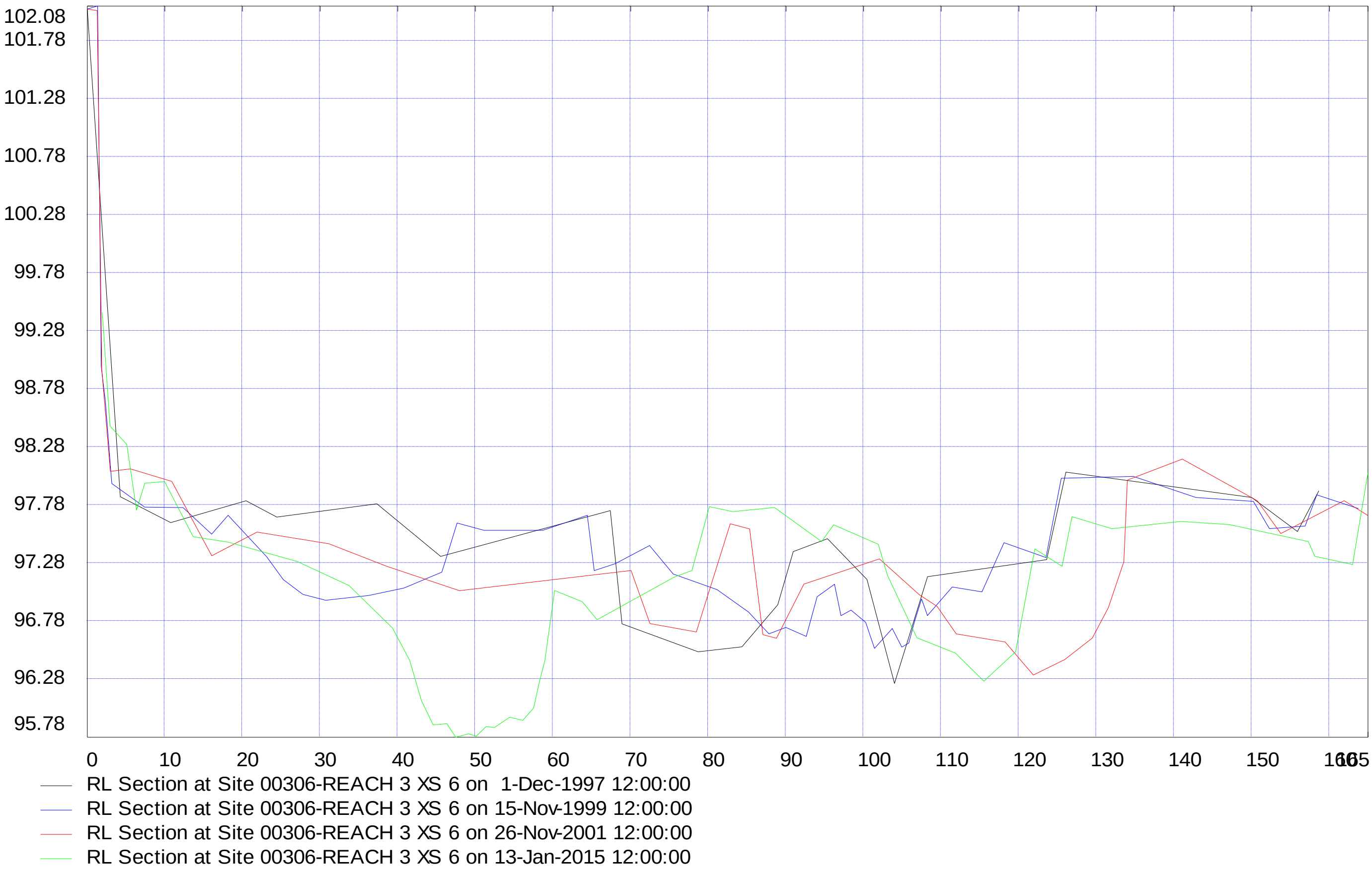
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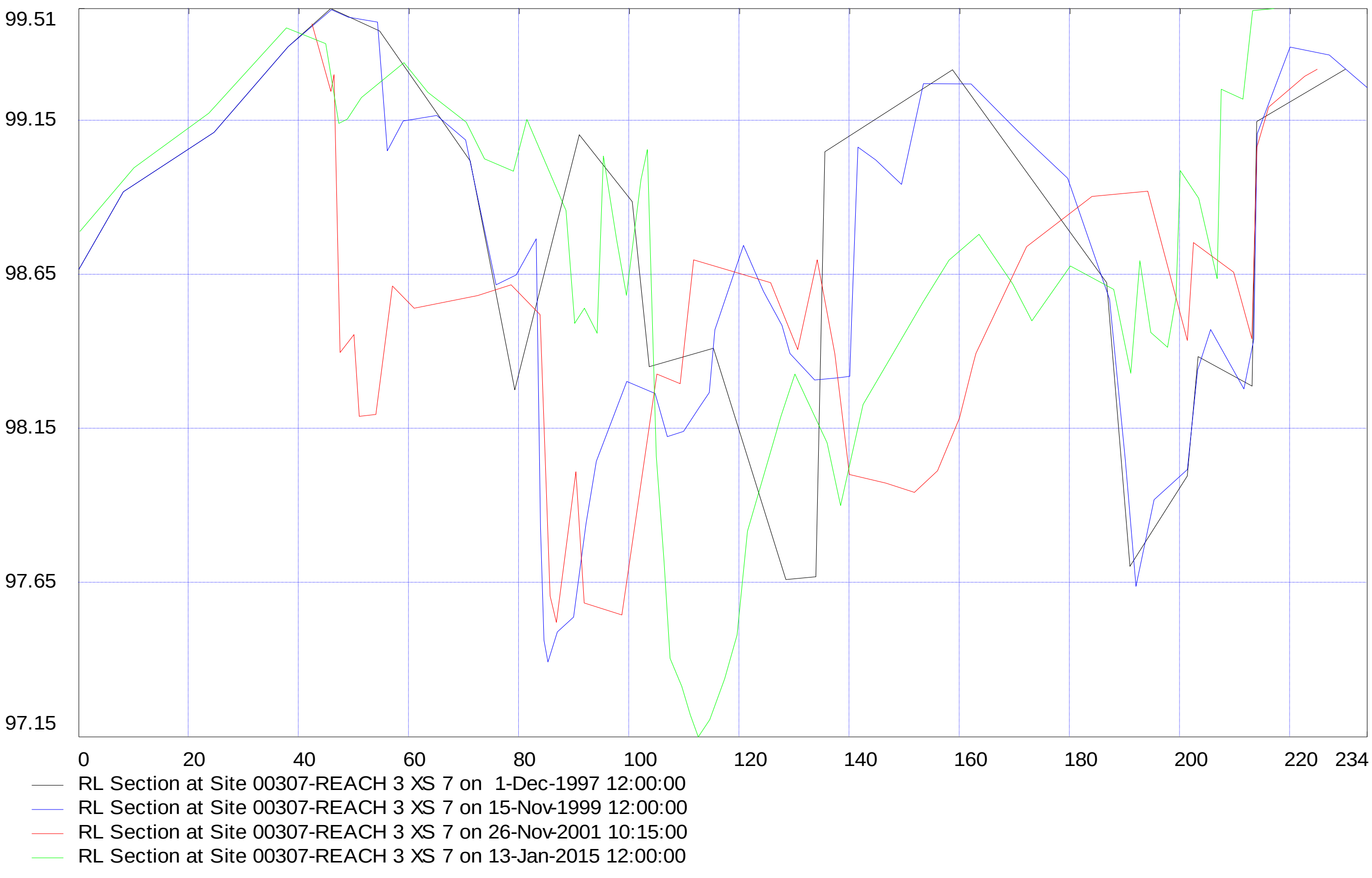
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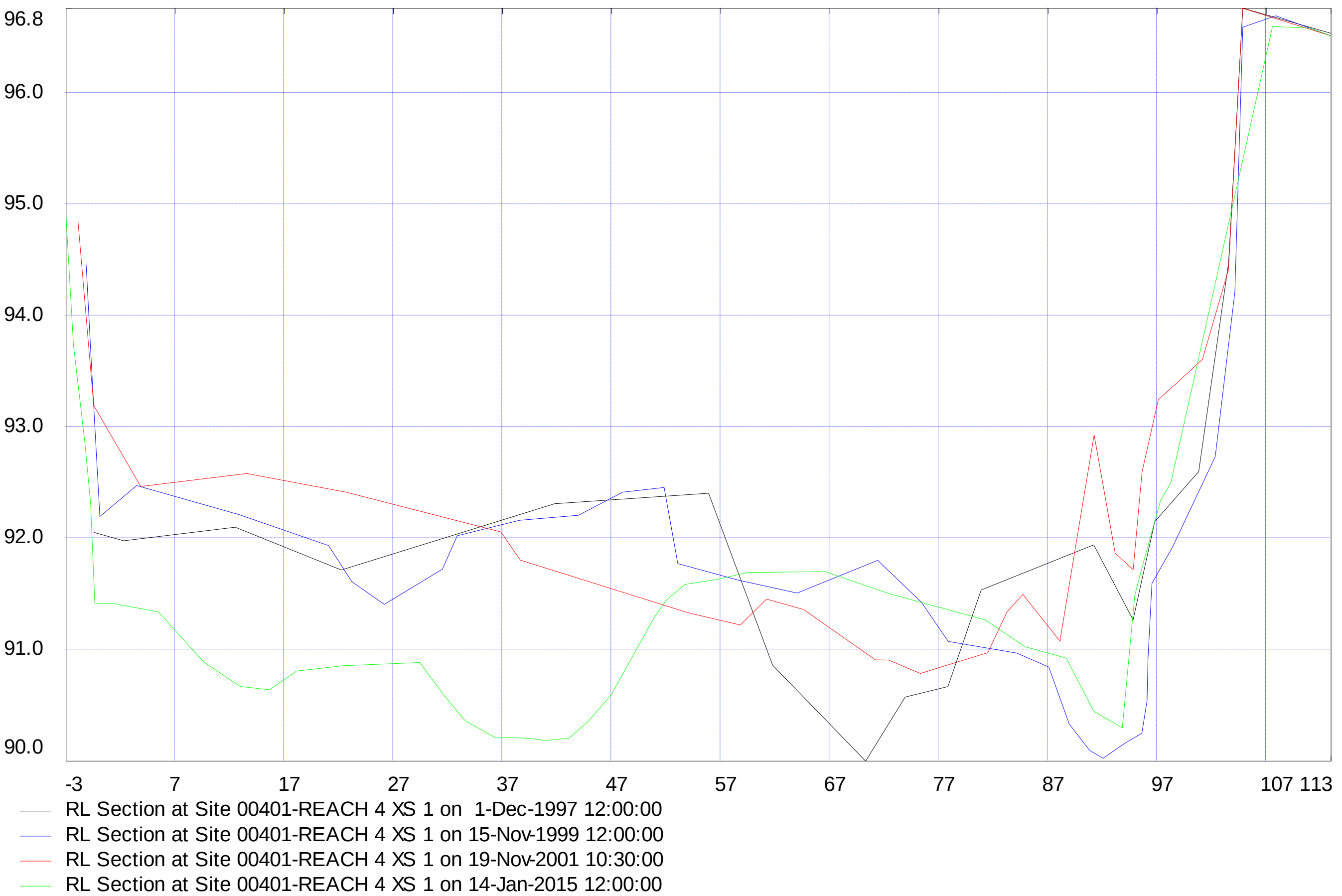
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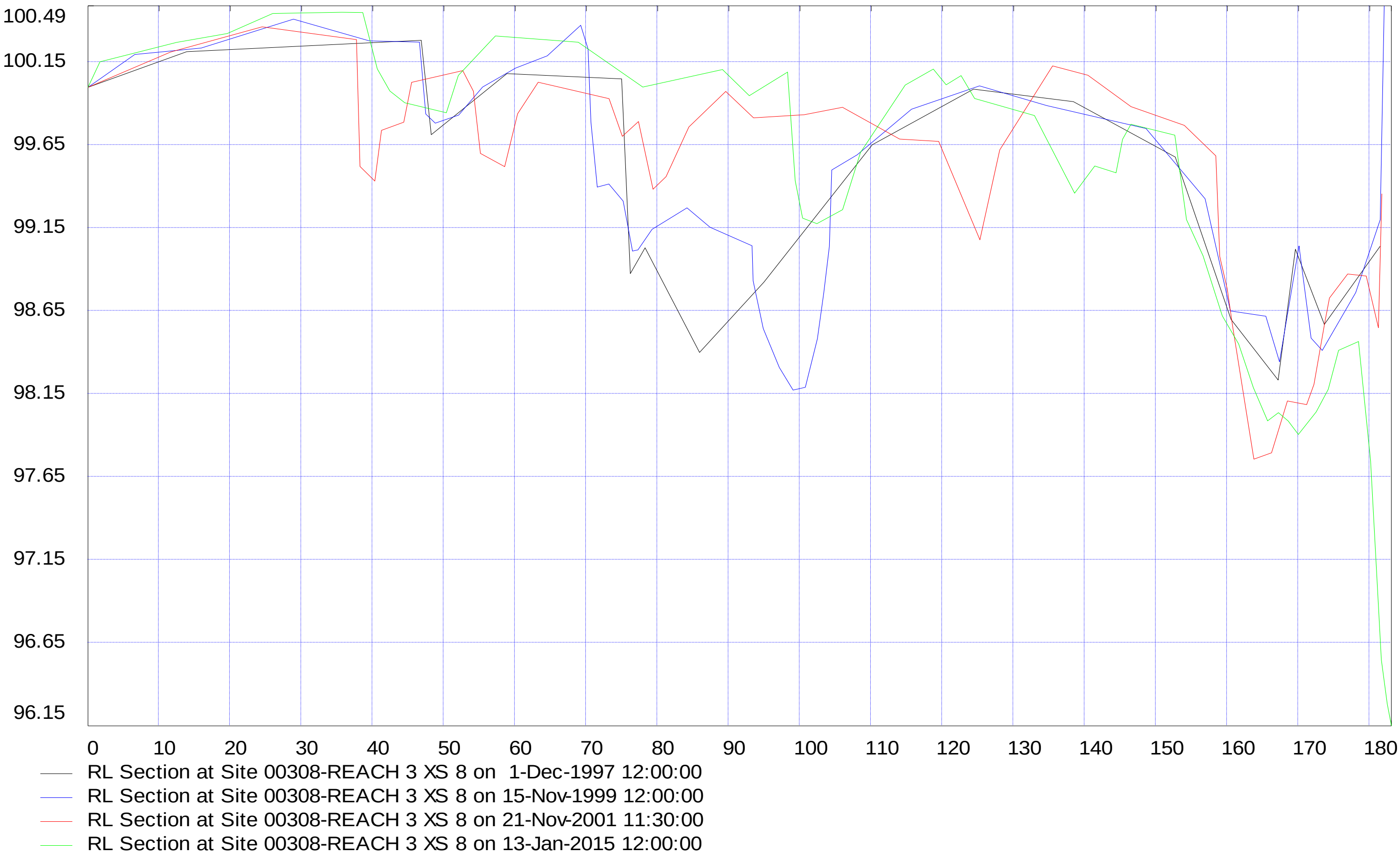
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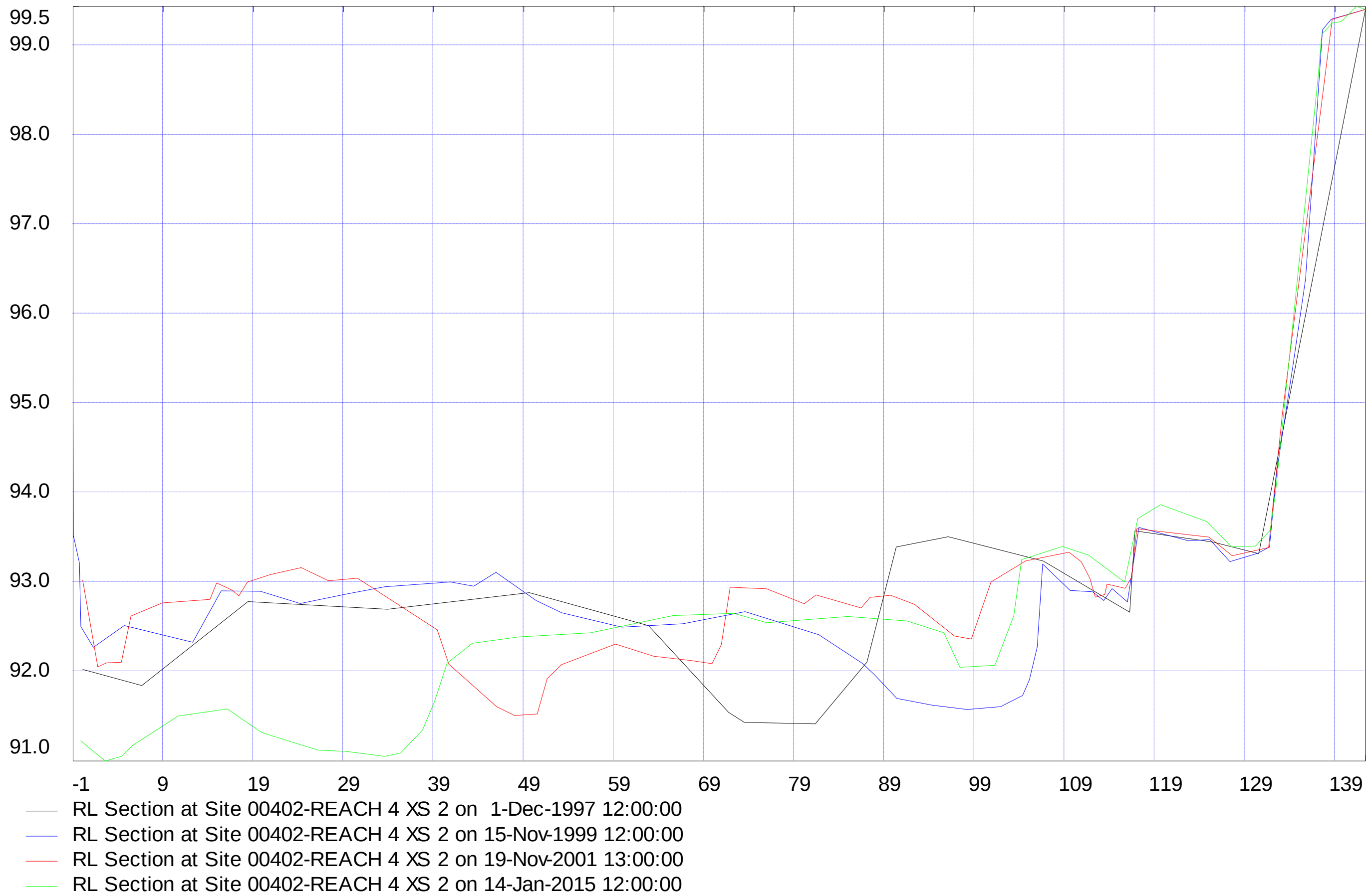
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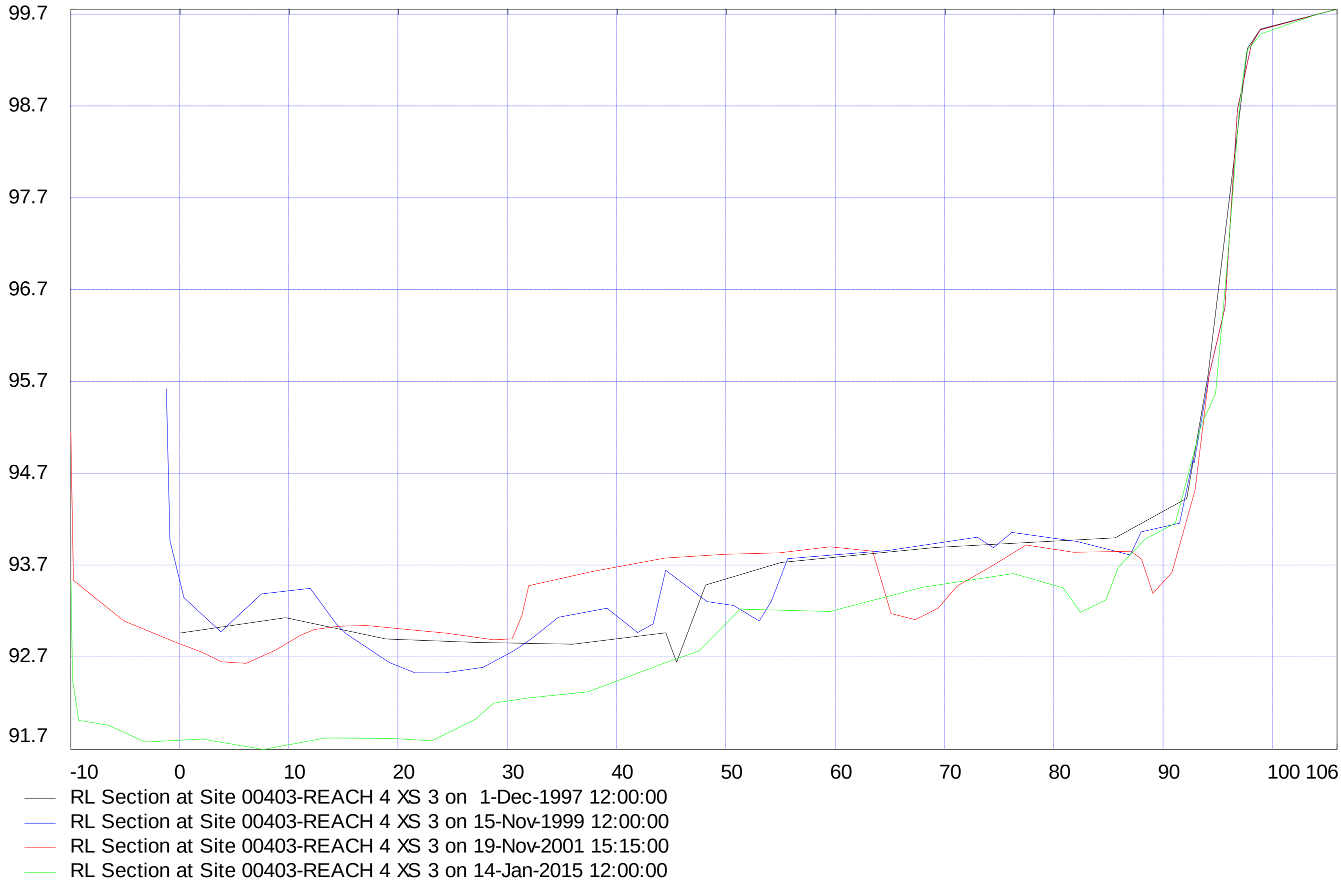
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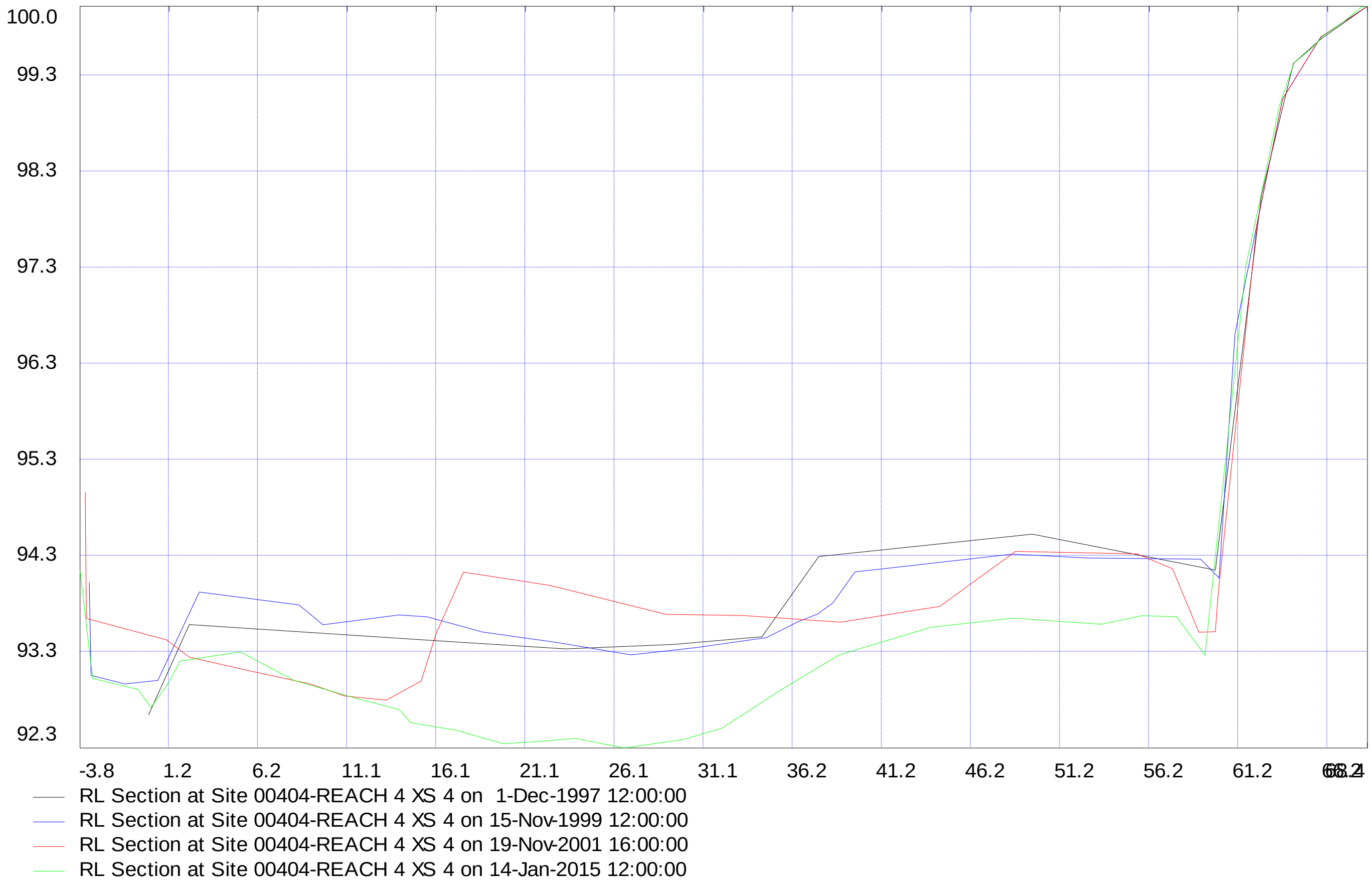
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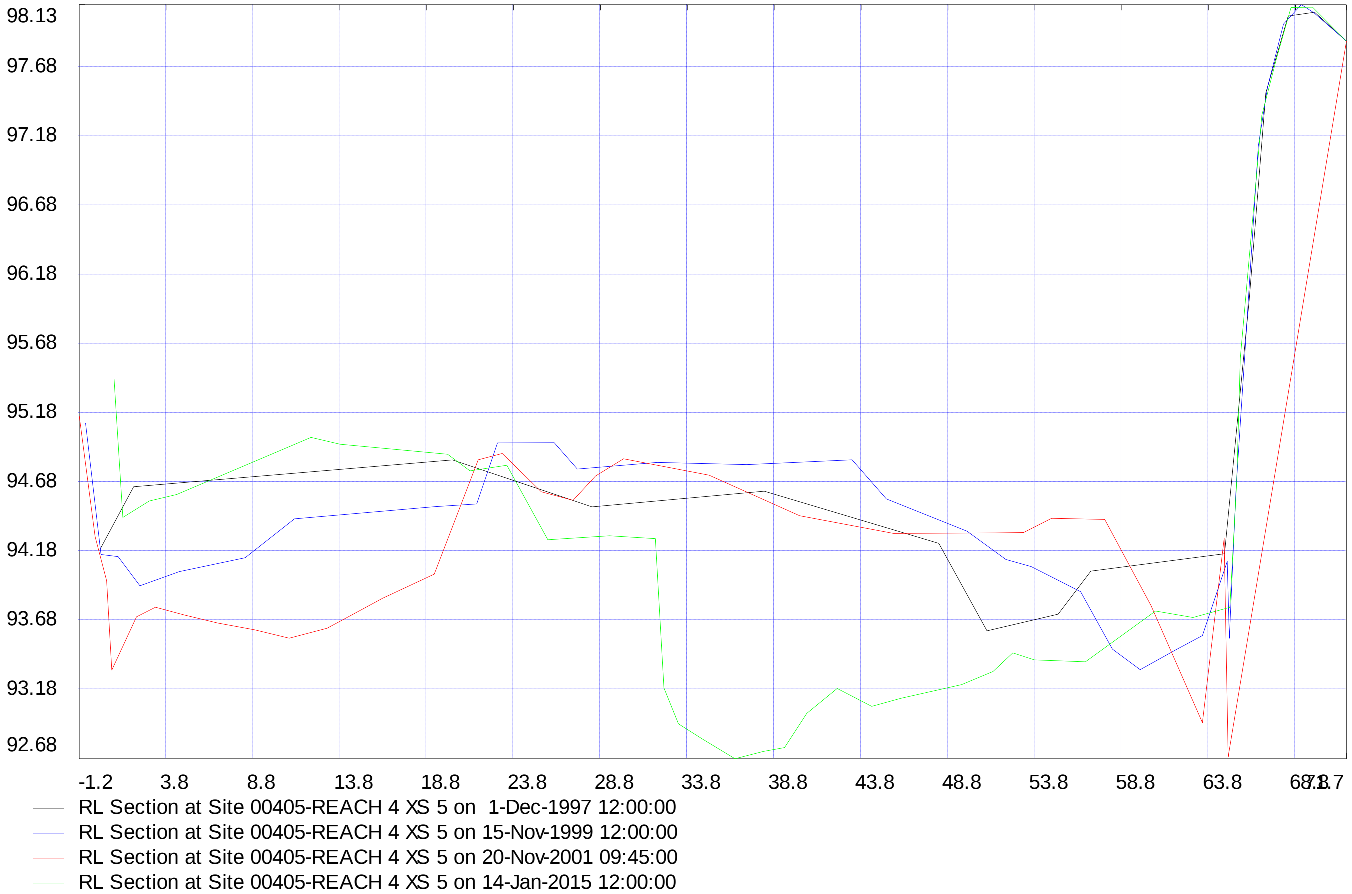
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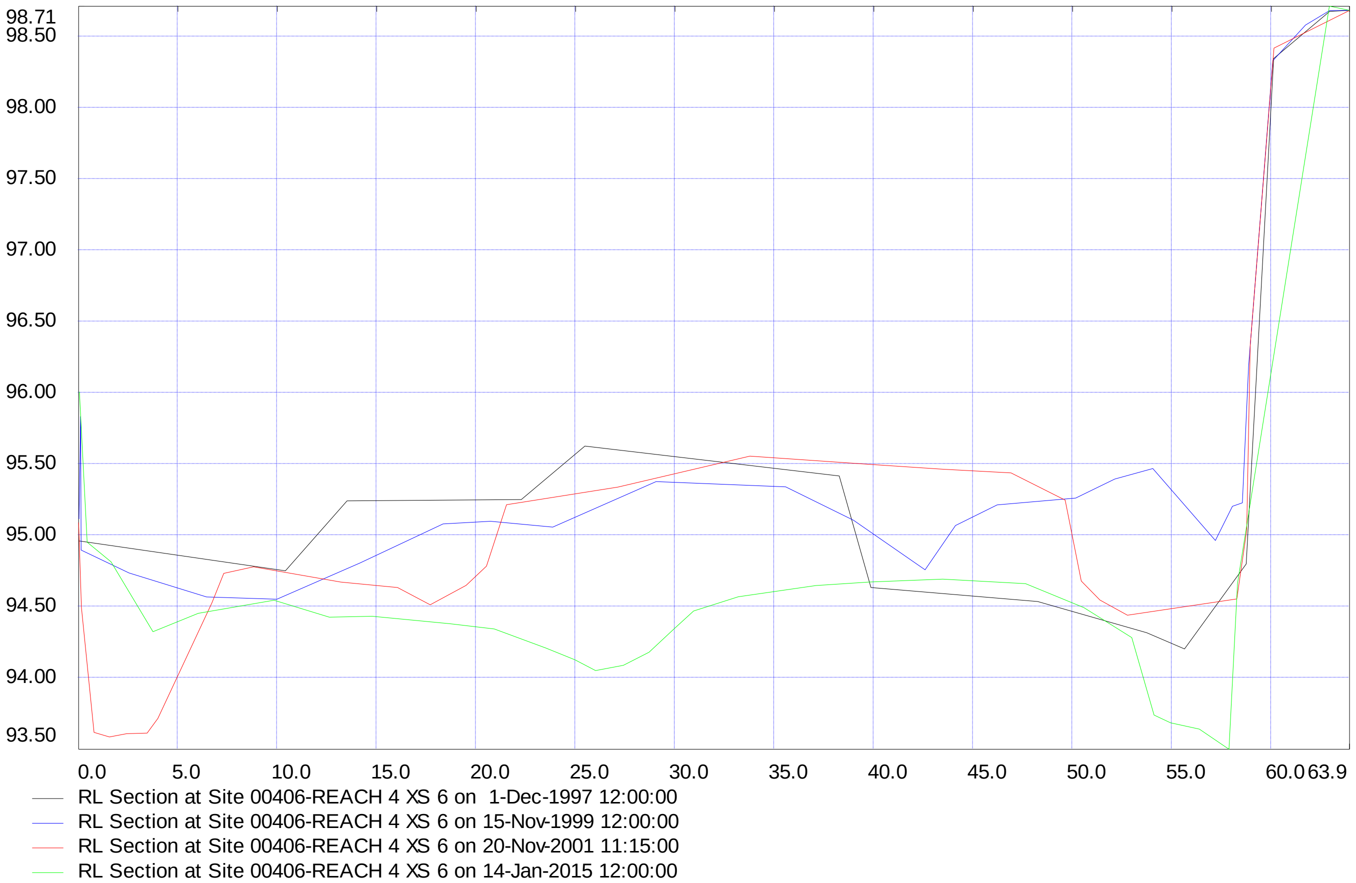
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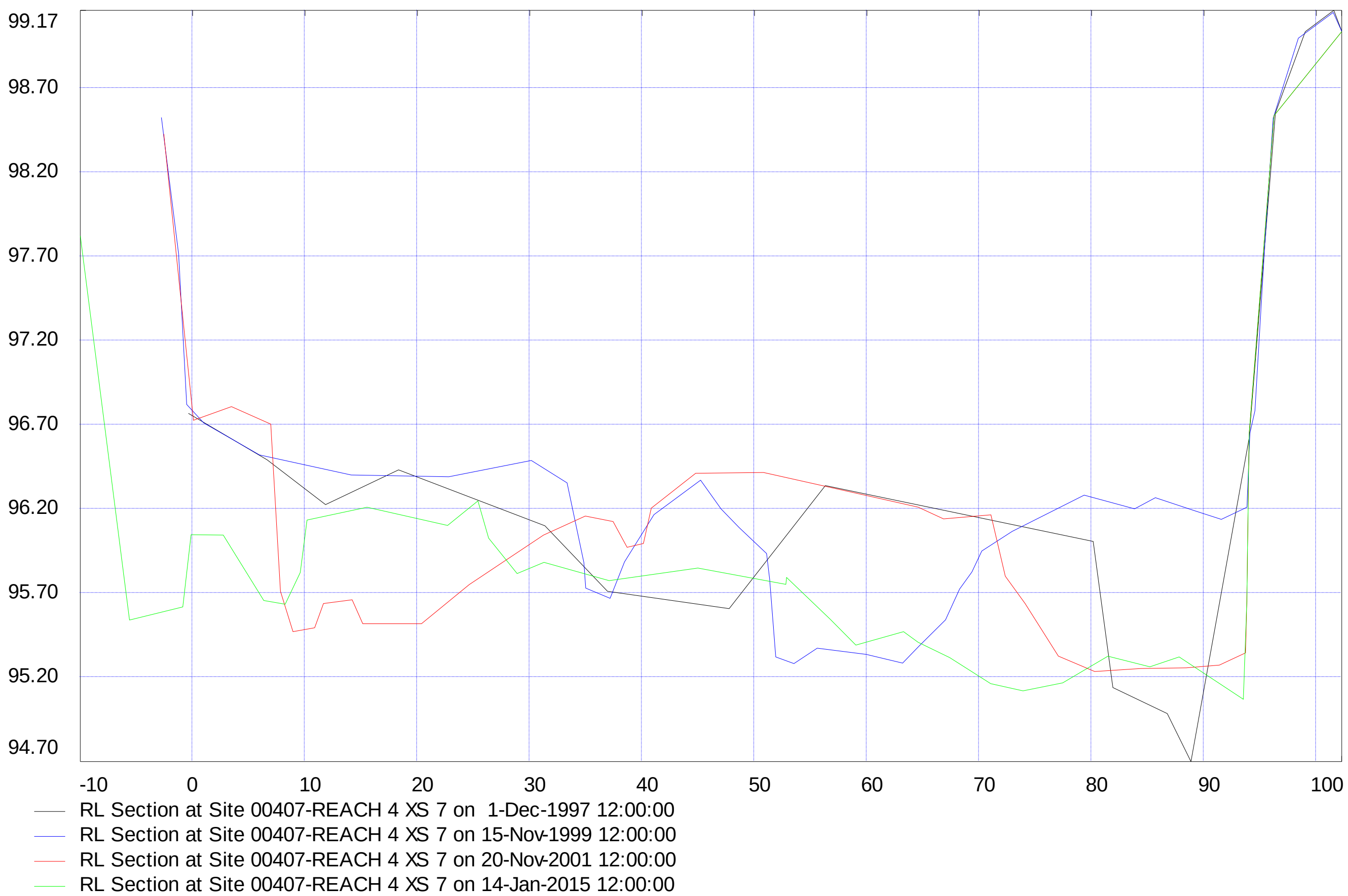
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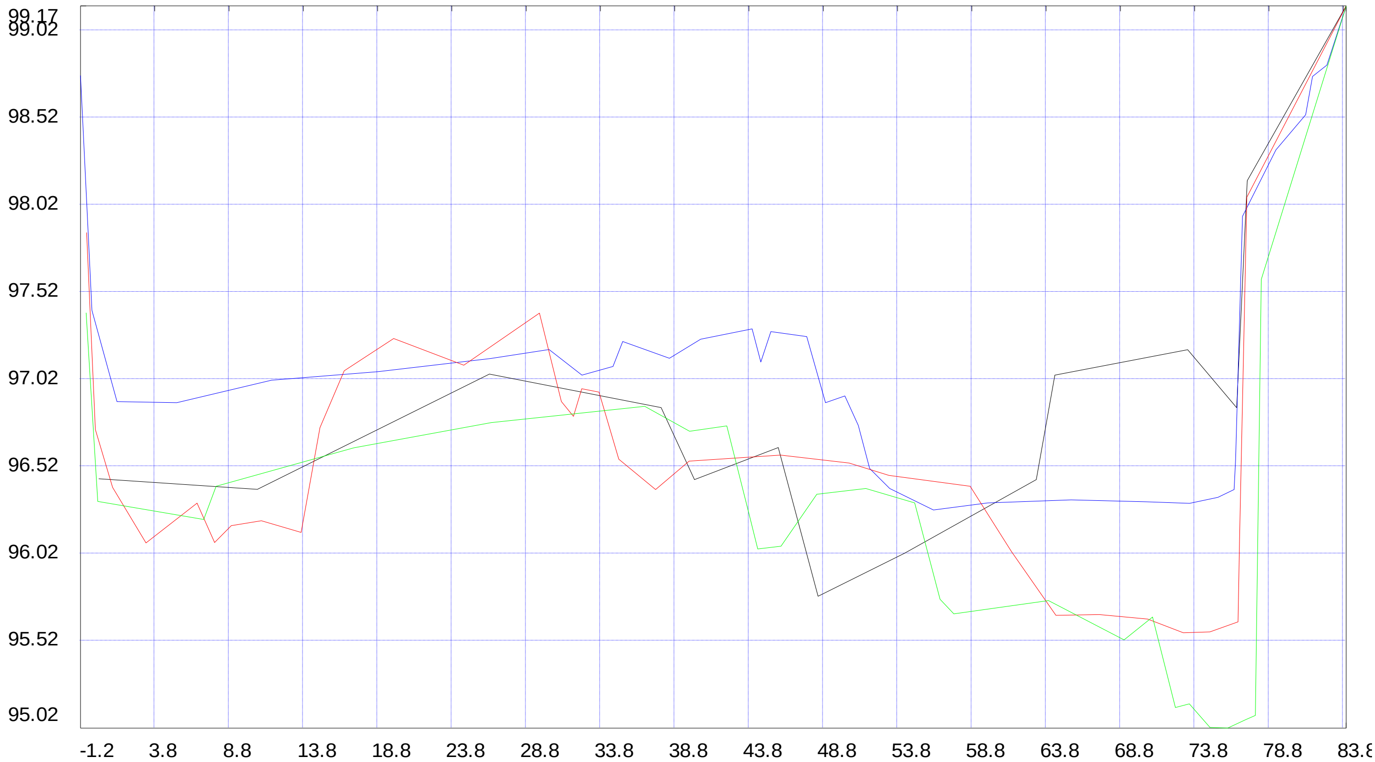

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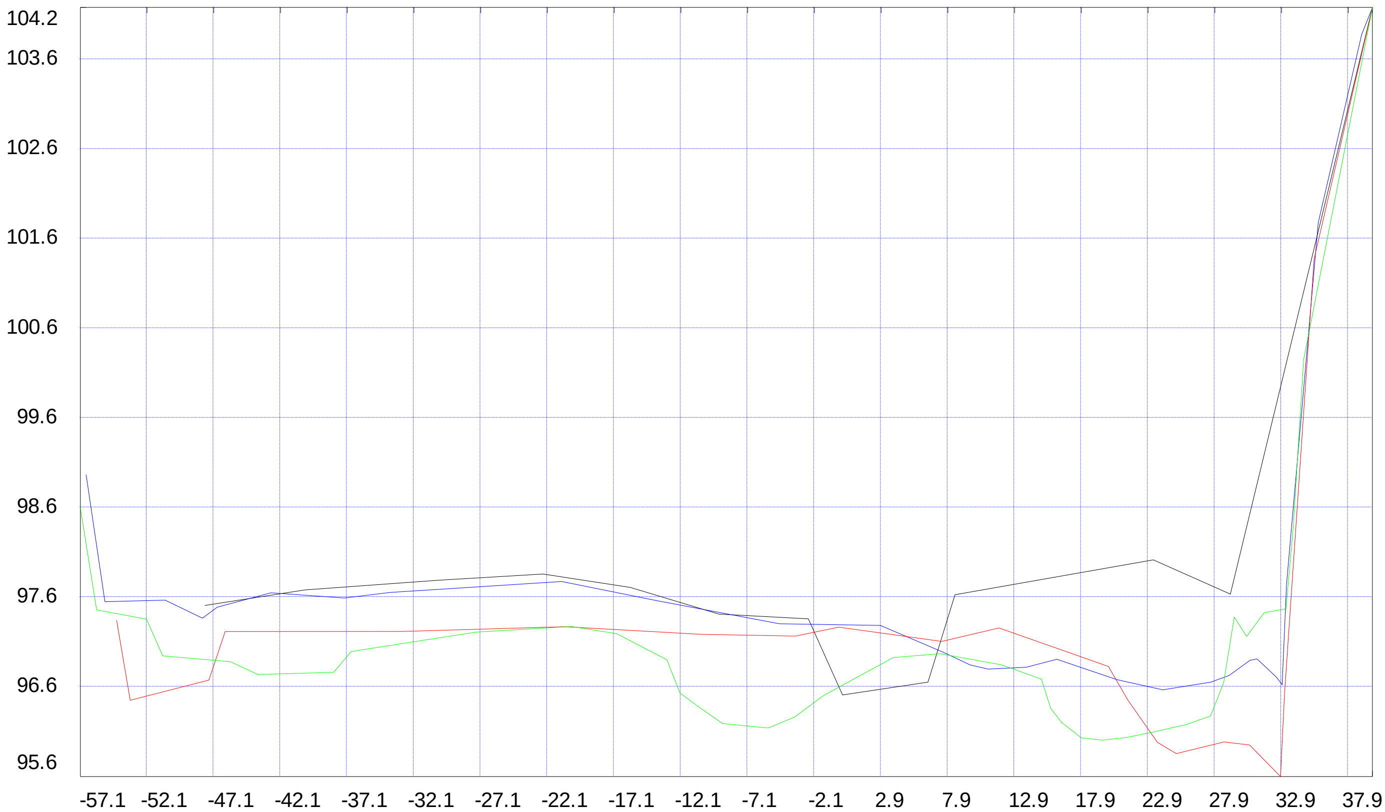

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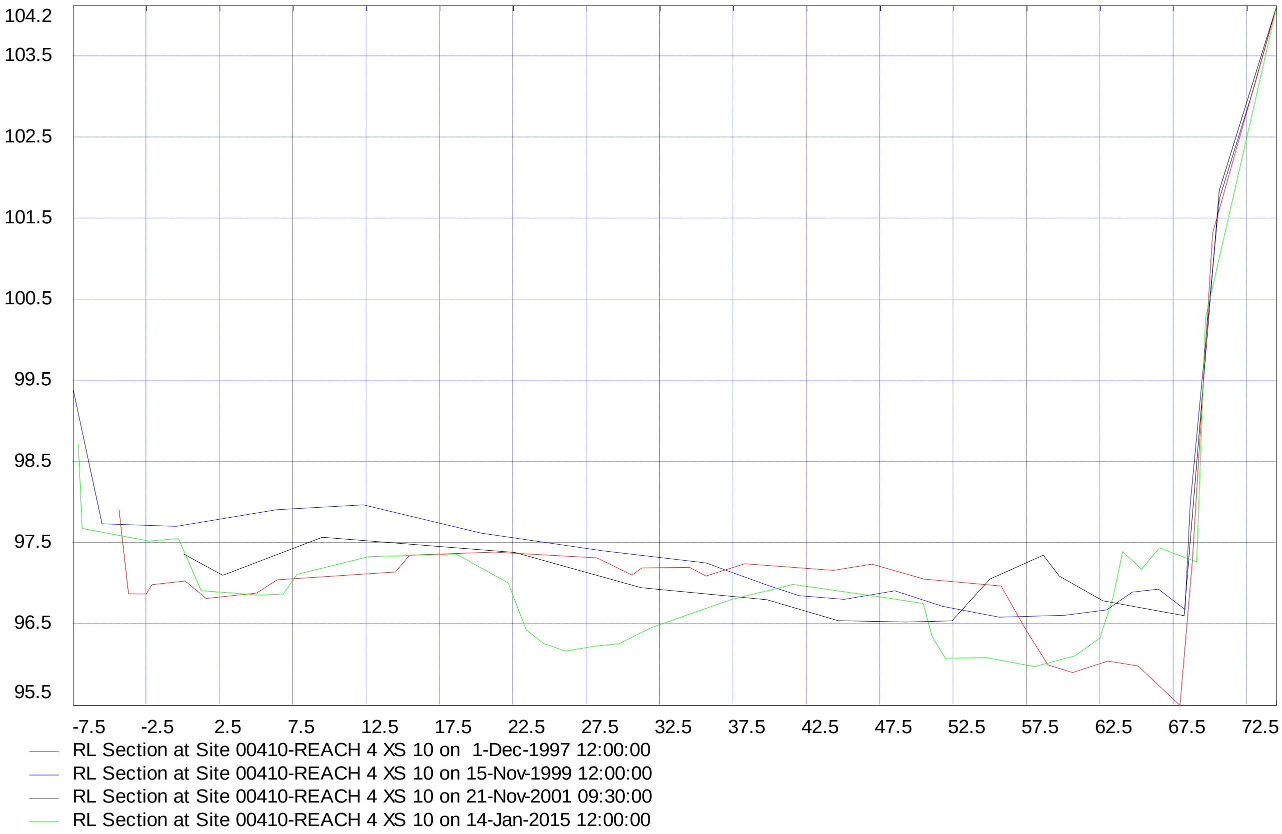
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13. Appendix C

Gravel Extraction amounts per year

Year	Gravel Extraction Amounts (m^3)
1997	21209
1998	18332
1999	12377
2000	19193
2001	7606
2002	23610
2003	22750
2004	9554
2005	17080
2006	14927
2007	14083
2008	11737
2009	12280
2010	5570
2011	6712
2012	5920
2013	4900
2014	9100
2015	10700
2016	2955
2017	10000
Total	**260595**

Gravel Extraction amounts by consents

Consent Numbers	Gravel Extraction from 1997-1999 (m^3)	Gravel Extraction from 1999-2001 (m^3)	Gravel Extraction from 2001-2015 (m^3)
100066	50	150	300
100067	0	60	0
100116	3990	7389	15560
101010	0	0	11454
102350	0	0	55043
102703	0	0	22850
103146	0	0	7344

103568	0	0	1390
105039	0	0	25032
105040	0	0	7150
105732	0	0	0
6389	10291	0	0
7172	8723	21862	30406
7229	377	2109	0
913036	16110	0	0
Total	**39541**	**31570**	**176529**

Recent Consents	2016	2017
ATH-2004009899.04	2955	0
ATH-2010013015.02	0	10000
ATH-2010013016.02	0	0
ATH-2011013822.01	0	0
Total	**2955**	**10000**

Volume of gravel extracted at each gravel extraction site (m^3)

Gravel Extraction Site	1997-1999	1999-2001	2001-2015	Total
Pourangaki Site	0	60	1390	**1450**
Gorringes Site	25210	23971	111397	**160578**
McKinnon Site	50	150	300	**500**
McGregor Roache Site	14281	7389	63442	**85112**

14. References

Alexander, A. (2012). The Rangitikei River, its tributary waterways, and other Taihape waterways scoping report. Auckland, New Zealand.