Upper Manawatu & Lower Mangahao Gravel Resource Study

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EXECUTIVE SUMMARY

This study examines the gravel resource in the Upper Manawatu and Lower Mangahao Rivers based on an analysis of river cross section information and records of gravel extraction. It covers a 40 km reach of the Upper Manawatu River, from the Manawatu Gorge Bridge to a point just to the east of Oringi, and a 15 km reach of the Lower Mangahao River from its confluence with the Manawatu River.

It has been shown that between 1996 and 2014 the total volume of gravel in the Upper Manawatu River between the Manawatu Gorge and the 93 mile mark would have increased by approximately 150,000 m^3 if no extraction of gravel had taken place.

The upstream end of the reach, between the 87 and 93 mile marks, has experienced a degradation of gravel, with approximately 237,000 m^3 more gravel leaving the reach than entering it. Whilst gravel extraction has occurred in this reach it doesn't fully account for the lost volume. This may be due to a starvation of the gravel supply to the upper end of the study reach. This will be investigated further as part of the South East Ruahine Gravel Resource Study.

The middle part of the study reach, between the 78 and 87 mile marks appears to be in a dynamic equilibrium. That is, the volumes of degradation are balanced by the volumes of aggradation in this section.

The downstream end of the study reach has experienced a significant amount of aggradation with approximately 300,000 m^3 of gravel being deposited between the Manawatu Gorge and Ngawaparua Bridge.

Records show that between 1996 and 2014, approximately 260,000 m^3 of gravels have been extracted from the study reach of the Upper Manawatu River. Currently gravels are extracted from the River under a global consent held by Horizons Regional Council's (HRC) Operations Group. This consent allows for 40,000 m^3 of gravel to be extracted from the Upper Manawatu River annually.

This study has shown that the volumes of gravel available for extraction under the existing global consent are sustainable and appropriate to ensure that the flood carrying capacity of the Upper Manawatu River is not compromised.

This study has also shown that there is an on-going aggradation of the gravel resource in the Lower Mangahao River. It has been shown that the rate of aggradation would allow for approximately 12,500 m^3 of gravel to be sustainably extracted from the river annually.

This means that the supply of gravel exceeds the 8,000 m^3 per year that the global consent currently allows to be extracted from the river. Hence, if the Scheme Manager feels that there is a need to increase the rate of gravel

extraction allowed from the Lower Mangahao River, for river management purposes, this study would support such an increase.

The gravel resource should continue to be monitored by the Scheme Manager and the rivers should be surveyed again as part of the fluvial monitoring programme in the 2023-24 summer.

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Upper Manawatu & Lower Mangahao Gravel Resource Study

1. Introduction

This study examines the gravel resource in the Upper Manawatu and Lower Mangahao Rivers based on an analysis of river cross section information and records of gravel extraction. It covers a 40 km reach of the Upper Manawatu River, from the Manawatu Gorge Bridge to a point just to the east of Oringi, and a 15 km reach of the Lower Mangahao River from its confluence with the Manawatu River.

2. Background

The Manawatu River rises in the Southern Ruahine Ranges. The total catchment area is approximately 6,000 km^2, of which 60% is to the east of the ranges. Water from the eastern part of the catchment discharges through the Manawatu Gorge before meeting the Tasman Sea at Foxton. The river upstream of the gorge is known as the Upper Manawatu River.

The Mangahao River rises in the Northern Tararua Range and flows northwards to its confluence with the Upper Manawatu River between Balance and Woodville.

Both the Upper Manawatu and Mangahao Rivers have gravel beds between their headwaters and the Manawatu Gorge. Most of the time gravel remains stationary, but in times of flood the river moves gravel in the downstream direction. Most of this gravel is eventually deposited on beaches upstream of the Manawatu Gorge which acts as a throttle to flood flows causing water to pond in this area.

The Upper Manawatu River, between the Manawatu Gorge and Oringi, and the Lower Mangahao River between the Manawatu Confluence and Mangahao are managed under the Upper Manawatu and Lower Mangahao Scheme (the Scheme).

The Scheme was established in the early 1950s in response to a petition to the Manawatu Catchment Board from landowners to prevent erosion of productive farmland on the alluvial terraces along the two rivers. The Scheme undertakes river control works on about 60 km of river channel.

2.1 Gravel Management through Global Consents

A review of the Scheme in 1997 identified that gravel extraction was an important tool used to manage the level and alignment of the river bed. This gravel extraction is currently managed by HRC under a global consent that covers the reaches of the rivers that fall within the Scheme area.

The original global consent, granted in 2001 allowed for 30,000 m^3 of gravel to be extracted from the Upper Manawatu and 6,000 m^3 from the Lower Mangahao annually.

In 2010, a new global consent was sought and granted. The consent renewal followed three large flood events (of greater than a 50 year return period) in 2001 and 2004. These large flood events caused a large volume of gravel to be deposited on the beaches of the Upper Manawatu and Lower Mangahao Rivers. The new global consent allows for the extraction of:

1. 20,000 m^3 of gravel per year from the Upper Manawatu River between the Upper Gorge Bridge and Ngawaparua Bridge;
2. 40,000 m^3 of gravel for the first three years of the consent and 20,000 m^3 for the following seven years of the consent from the Upper Manawatu River between Ngawaparua Bridge and Weber Road Bridge; and

3. 8,000 m^3 of gravel from the Mangahao River between the confluence with the Manawatu River and a point 2 km upstream of the Tararua Road Bridge.

3. Survey Data

3.1 Upper Manawatu

Over the period 1976-2014 a total of 33 cross sections (the locations of which can be seen in Appendix A) have been surveyed at various times.

Table 3.1 summarises the survey history of each cross section.

Table 3.1 - Summary of Upper Manawatu River Cross Section Surveys 1976-2014

Cross Section	Description	Chainage (km)	Nov-1976	Aug-1980	Dec-1985	Aug-Sept-1996	May-2000	Aug-Oct-2001	Mar-2002	Jan-2014
3400944	68 Mile	9.44								
3401104	69 Mile	11.04								
3401265	70 Mile	12.65								
3401426	71 Mile	14.26								
3401587	72 Mile	15.87								
3401748	73 Mile	17.48								
3401909	74 Mile	19.09								
3402070	75 Mile	20.7								
3402160	SH2 Bridge Upstream	21.6								
3402172	Rail Bridge Upstream	21.72								
3402231	76 Mile	22.31								
3402392	77 Mile	23.92								
3402553	78 Mile	25.53								
3402714	79 Mile	27.14								
3402875	80 Mile	28.75								
3403036	81 Mile	30.36								
3403197	82 Mile	31.97								
3403358	83 Mile	33.58								
3403518	84 Mile	35.18								
3403679	85 Mile	36.79								
3403840	86 Mile	38.4								
3403920	86.40 Mile	39.2								
3403964	86.62 Mile	39.64								
3404001	87 Mile	40.01								
3404162	88 Mile	41.62								
3404323	89 Mile	43.23								
3404484	90 Mile	44.84								
3404504		45.04								

3404524		45.24								
3404544		45.44								
3404645	91 Mile	46.45								
3404806	92 Mile	48.06								
3404967	93 Mile	49.67								

As Table 3.1 shows, not all cross sections were surveyed in each survey. Surveys of the cross sections at all of the mile marks were obtained in 1976, 1996 and again in 2014.

In addition, a number of cross sections, at approximately three mile intervals, were surveyed in 2000, 2001 and again in 2002.

It is important to note that the benchmarks used in the 1976 survey were destroyed before the 1996 survey. As such, the reinstated benchmarks may not be in the same position as the original ones and hence, care must be taken when comparing the cross sections.

3.1.1 Cross Section Adjustments

To be able to perform a useful analysis of any changes in the gravel resource overtime it is necessary to compare cross sections that were surveyed at different times.

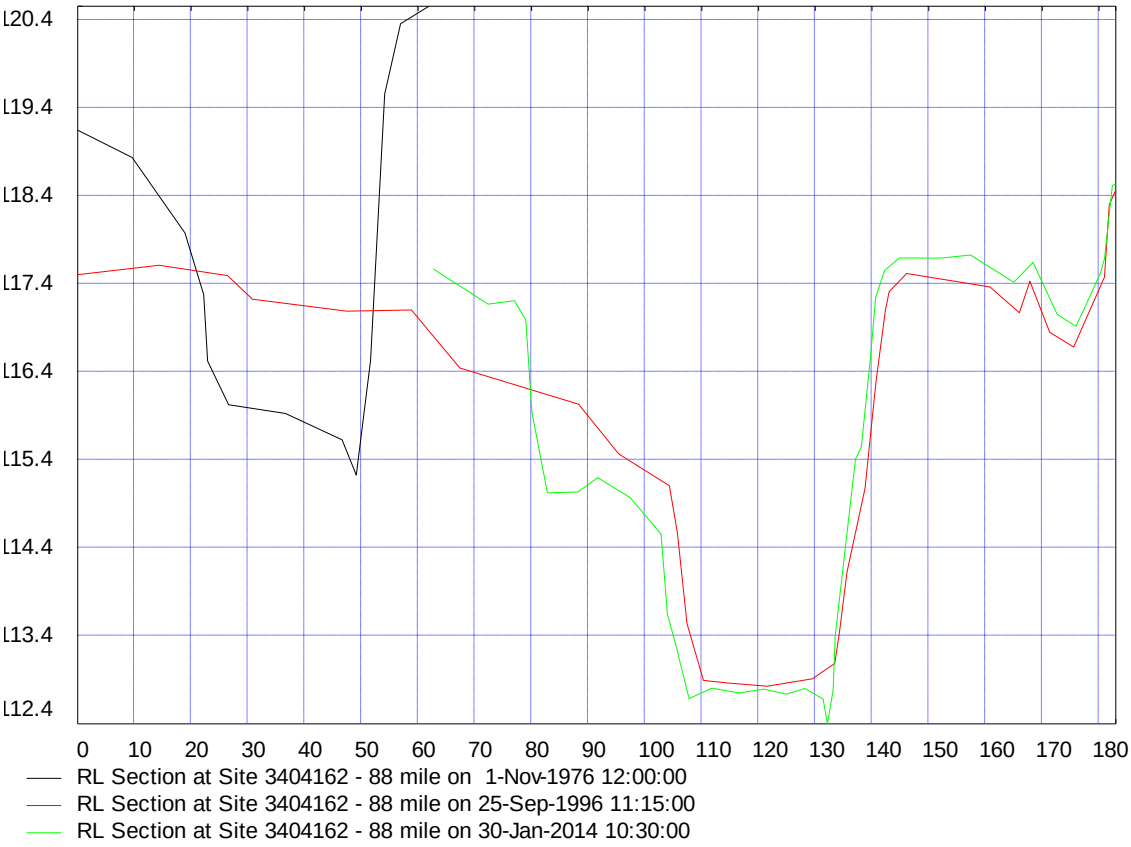
After over plotting a number of cross sections, it is apparent that not all of the surveys covered the whole cross section between the left and right benchmarks. Where a survey did not cover the whole channel between the assumed bank markers, the data was extended by matching the data with that from the survey that most closely matched the one under consideration.

Additional consideration has been given to cross sections where the active channel of the river has moved considerably overtime. At these cross sections, adjustments have been made to the offset of the survey data so that the active channel of the river aligns with that recorded in other cross sections.

3.1.1.1 Change of Datum at the 88 Mile Mark

When the surveyed cross sections at the 88 mile mark were over plotted and visually inspected, a large discrepancy was noted between the results of the 1976 and later surveys. This is clearly seen in Figure 3.1, below, which shows an over plot of the various surveys at the 88 mile benchmark.

Figure 3.1 - Cross Sectional Surveys at the 88 Mile Benchmark



It would appear from this information, that the Manawatu River was some 3 m higher in 1976 than it currently is. Whilst it is acknowledged that river levels can and do change overtime, a fluctuation of this magnitude is rather unexpected.

Although a fluctuation in the bed level of a gravel bed river can reasonably be expected, such a large change in the ground level at the banks of the river is not.

It is considered that the differences in survey levels are due to a mistake in datum adjustments after the 1976 benchmarks were destroyed before the 1996 survey was undertaken.

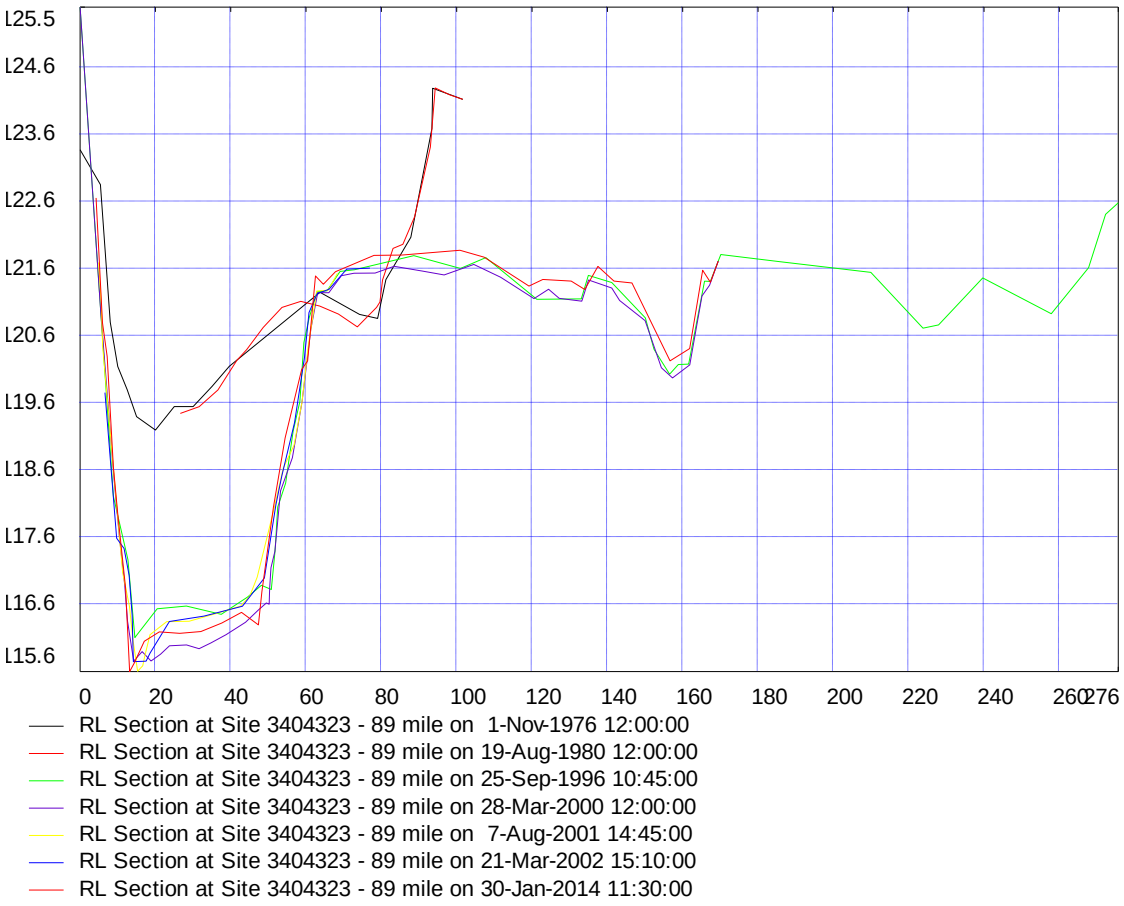
To enable a useful analysis of cross sectional change overtime to be undertaken, the levels surveyed in 1976 have been lowered by 3 m to bring them into line with those surveyed in 1996 and in 2014.

3.1.1.2 Change of Datum at the 89 Mile Mark

When the surveyed cross sections at the 89 mile mark were over plotted and visually inspected a large discrepancy was noted between the results of the surveys conducted in 1976 and 1996 and those conducted in later years. This

is clearly seen in Figure 3.2, below, which shows an over plot of the various surveys at the 89 mile benchmark.

Figure 3.2 - Cross Sectional Surveys at the 89 Mile Benchmark



These surveys suggest that the level of the Manawatu River and surrounding land has fallen by some 2.6 m between 1980 and 1996. As with the surveyed levels at the 88 mile cross section, it is considered that this large change is likely due to an error in datum adjustments after the benchmarks were destroyed before the 1996 survey was undertaken.

To enable a useful analysis of cross sectional change overtime to be undertaken, the levels surveyed in 1976 and 1980 have been lowered by 2.6 m to bring them into line with those measured by later surveys.

A summary of the adjustments made to the Upper Manawatu survey data is shown in Table 3.2.

A full copy of the adjusted over plotted cross sections of the Upper Manawatu River can be seen in Appendix C.

Table 3.2 - Adjustments made to the Upper Manawatu Survey Data

Cross Section Number	Cross Section Description	Adjustments Made
3400944	68 Mile	The left bank of the 2014 survey has been extended by matching it to the 2000 survey.
3401104	69 Mile	The right bank of the 1976 survey has been extended by matching it to the 1996 survey.
3401426	71 Mile	The right bank of the 1976 survey has been extended by matching it to the 2000 survey. Additionally the left bank of the 2014 survey has been extended by matching it to the 1976 survey.
3402070	75 Mile	The left bank of the 2014 survey has been extended by matching it to the 1976 survey.
3402392	77 Mile	The right banks of both the 1976 and 2014 surveys have been extended by matching them to the 1996 survey.
3402553	78 Mile	The offsets of the 1976 survey have all been increased by 105 m.
3403840	86 Mile	The right banks of the 1976 survey have been extended by matching them to the 2001 survey. Additionally the left banks of the 2014 survey have been extended by matching them to the 1996 survey.
3404162	88 Mile	The offsets of the 1976 survey have all been increased by 100 m. All reduced levels in the 1976 survey have been lowered by 3 m.
3404323	89 Mile	All reduced levels in the 1976 survey have been lowered by 2.6 m.
3404645	91 Mile	The left banks of both the 1976 & 2014 surveys have been extended by matching them to the 1996 survey.
3404967	93 Mile	The right banks of both the 1976 & 1996 surveys have been extended by matching them to the 2014 survey.

3.2 Lower Mangahao

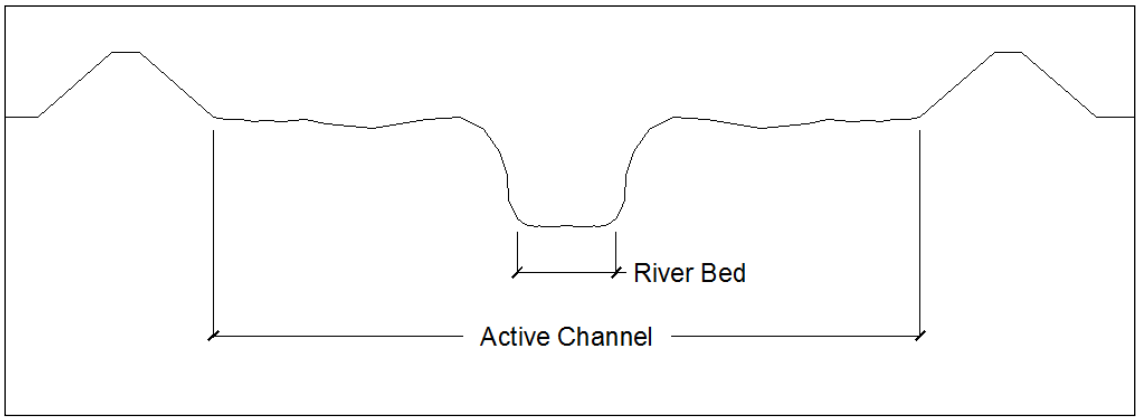
Eleven cross sections of the Lower Mangahao River were surveyed in November 1996 and again in March 2014. The locations of these cross sections can be seen in Appendix B.

4. Analysis of Cross Section Data

4.1 Mean Bed Levels

The mean bed level of each cross section was calculated using HILLTOP Hydro software. The extents of the bed of the river at each cross section were determined by visual examination of the cross sections. For the purposes of this analysis the bed of the river has been considered to be the bottom of the channel that continuously has water flowing above it as illustrated by the simplified river channel cross section in Figure 4.1.

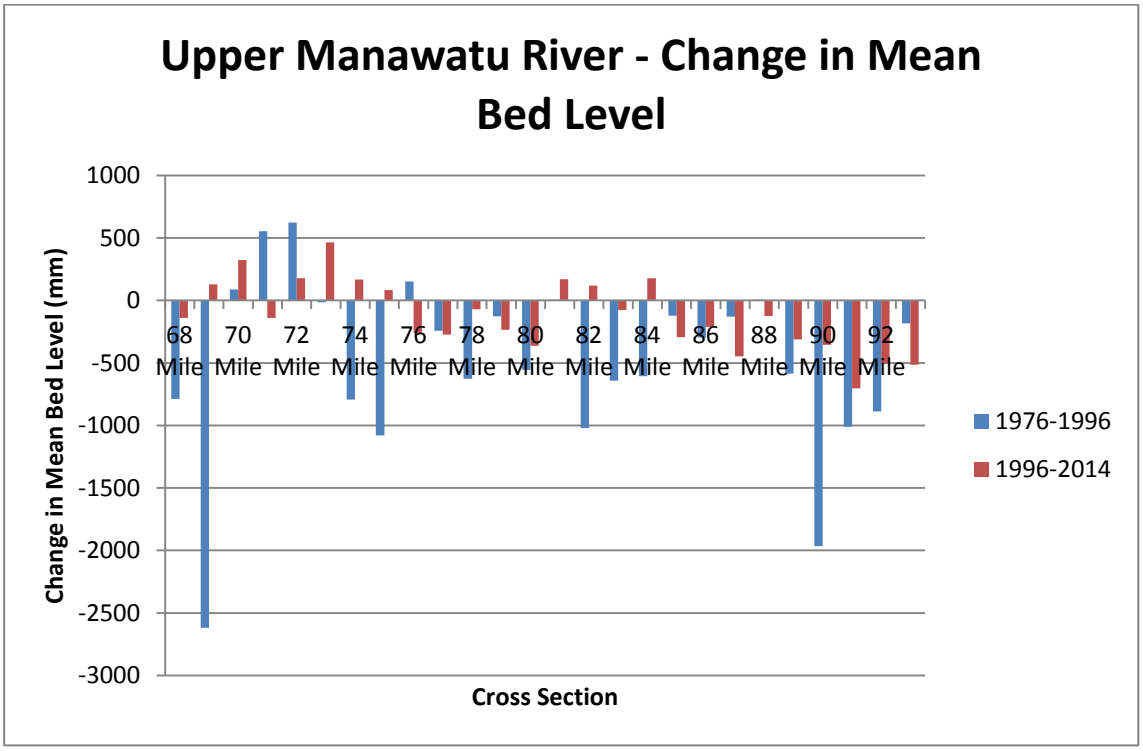
Figure 4.1 - Typical River Channel Cross Section



4.1.1 Upper Manawatu River

Figure 4.2 shows the change in the mean bed levels at the mile marks along the Upper Manawatu Rivers between the surveys completed in 1976, 1996 and 2014. For clarity this graph is reproduced in Appendix F.

Figure 4.2 - Upper Manawatu River, Change in Mean Bed Level



As the graph clearly illustrates, the mean bed level of the Upper Manawatu River, between the 85 and 93 mile marks, has dropped since 1976. This reach of the river is clearly degrading and this pattern is observed over both the 1976-1996 and 1996-2014 timeframes.

4.1.1.1 1976-1996

As Figure 4.2 shows, the mean bed level of the Upper Manawatu River generally fell between 1976 and 1996. However, a small amount of bed aggradation was seen between the 70 and 72 mile marks.

Whilst many of the surveyed cross sections saw only a small drop in mean bed level that one would expect to see within the natural variation of the bed level, a number of cross sections experienced a much more significant drop in bed levels. Cross sections surveyed at the 69 and 90 mile marks saw the bed drop by approximately 2.5 and 2 m respectively.

Whilst these drops may be seen as dramatic, one must consider the dynamic nature of the river system, and consider the times when the cross sections were surveyed. The 1976 survey was taken not long after Ex-Tropical Cyclone Alison hit New Zealand in March of 1975.

According to NIWA[1] the rainfall associated with this event was an extreme event with 612 mm of rain recorded at the Pohangina Saddle over a 72 hour period. This has been estimated to be an event with a return period of greater than 150 years. Large flood flows were seen in the Upper Manawatu River and its tributaries which mobilised large quantities of gravel. Indeed NIWA report that "the Kumeti River bed was lifted 4 ft (1.2 m) by stones and rubble brought down by the floods."

It is therefore reasonable to assume that when the survey in 1976 was conducted the mean bed level of the Upper Manawatu River would have been significantly higher than normal. As such, the large drops in bed level seen between 1976 and 1996 are likely to be due to the river bed returning to its natural level as the 'slug' of gravel associated with Cyclone Alison moved its way downstream.

4.1.1.2 1996-2014

During the period 1996-2014 the changes in mean bed level of the Upper Manawatu River were much less pronounced than those seen in the earlier time period. Generally, the bed of the river has degraded in the reach above the 76 mile mark, and there has been aggradation between the 75 mile mark and the Manawatu Gorge.

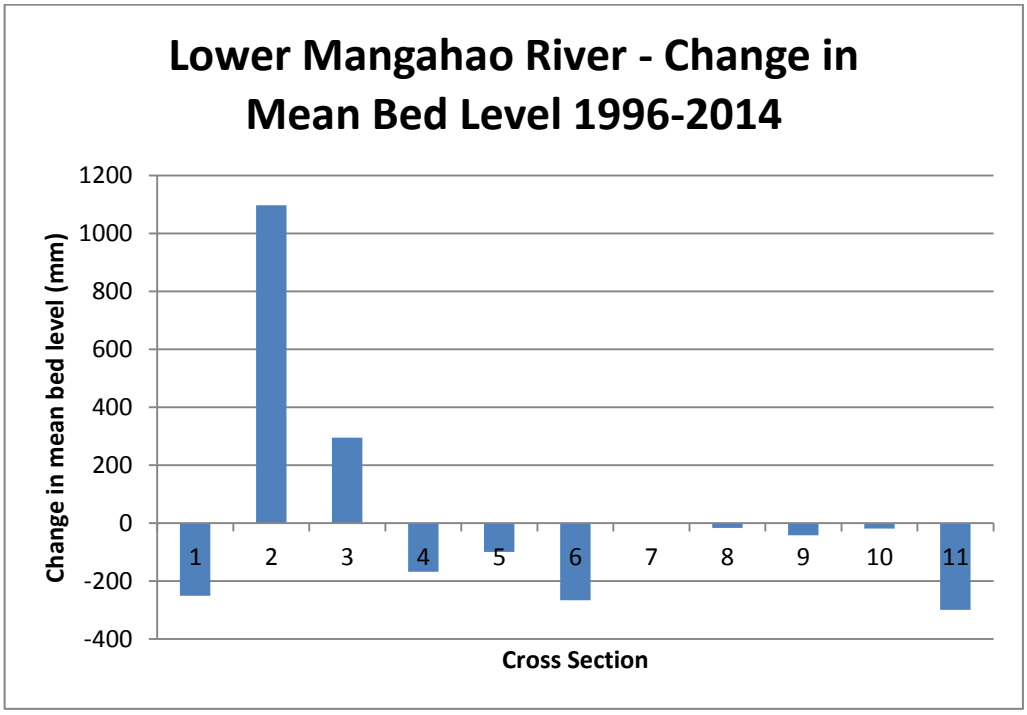
Most of the observed changes in mean bed level have been of a magnitude that one would expect to see in the natural variation of a gravel bed river (+/- 300 mm). At the upstream end of the study reach, above the 91 mile mark, the degradation has been around 500 mm which is likely to be due to gravel extraction that has taken place in this reach.

4.1.2 Lower Mangahao River

Figure 4.3 shows the change in mean bed level at each of the surveyed cross sections between 1996 and 2014.

[1] NIWA. NZ Historic Weather Events Catalog – March 1975 New Zealand Ex-tropical Cyclone Alison (1975-03-10). Retrieved January 27, 2015, from http://hwe.niwa.co.nz/event/March_1975_New_Zealand_Ex-tropical_Cyclone_Alison

Figure 4.3 - Lower Mangahao River, Change in Mean Bed Level



The mean bed level has been relatively stable in the Mangahao River with very little change at most cross sections between 1996 and 2014. The survey information suggests that the bed of the Mangahao River has risen significantly at cross section 2. However, this result should be ignored as the river channel has changed significantly at this location and as a result the survey benchmarks have been realigned, meaning that the two surveys are not comparable.

This channel migration is illustrated by Photograph 4.1, from 1997, and Photograph 4.2, from 2011, which show the left and right bank benchmarks as surveyed in 1996.

Photograph 4.1 - Lower Mangahao XS2, 1997

Photograph 4.2 - Lower Mangahao XS2, 2011

4.2 Gravel Volume

To assess the changes in the volume of gravel in the rivers, it is assumed that the bed and beaches of the river are predominately gravel.

To calculate the volume of gravel in the rivers HILLTOP Hydro software was used to calculate the area beneath the cross sections and an assumed datum of 0 m. These cross sectional areas were then integrated over the distance between adjacent cross sections to obtain a volume. These volumes calculated for each survey were then compared to obtain a change in volume overtime.

A copy of the processed data can be seen Appendix E.

4.2.1 Upper Manawatu River

Figure 4.4, overleaf, shows how the volume of gravel in the Upper Manawatu River has change over the 18 years between 1996 and 2014. For clarity this graph is reproduced in Appendix F.

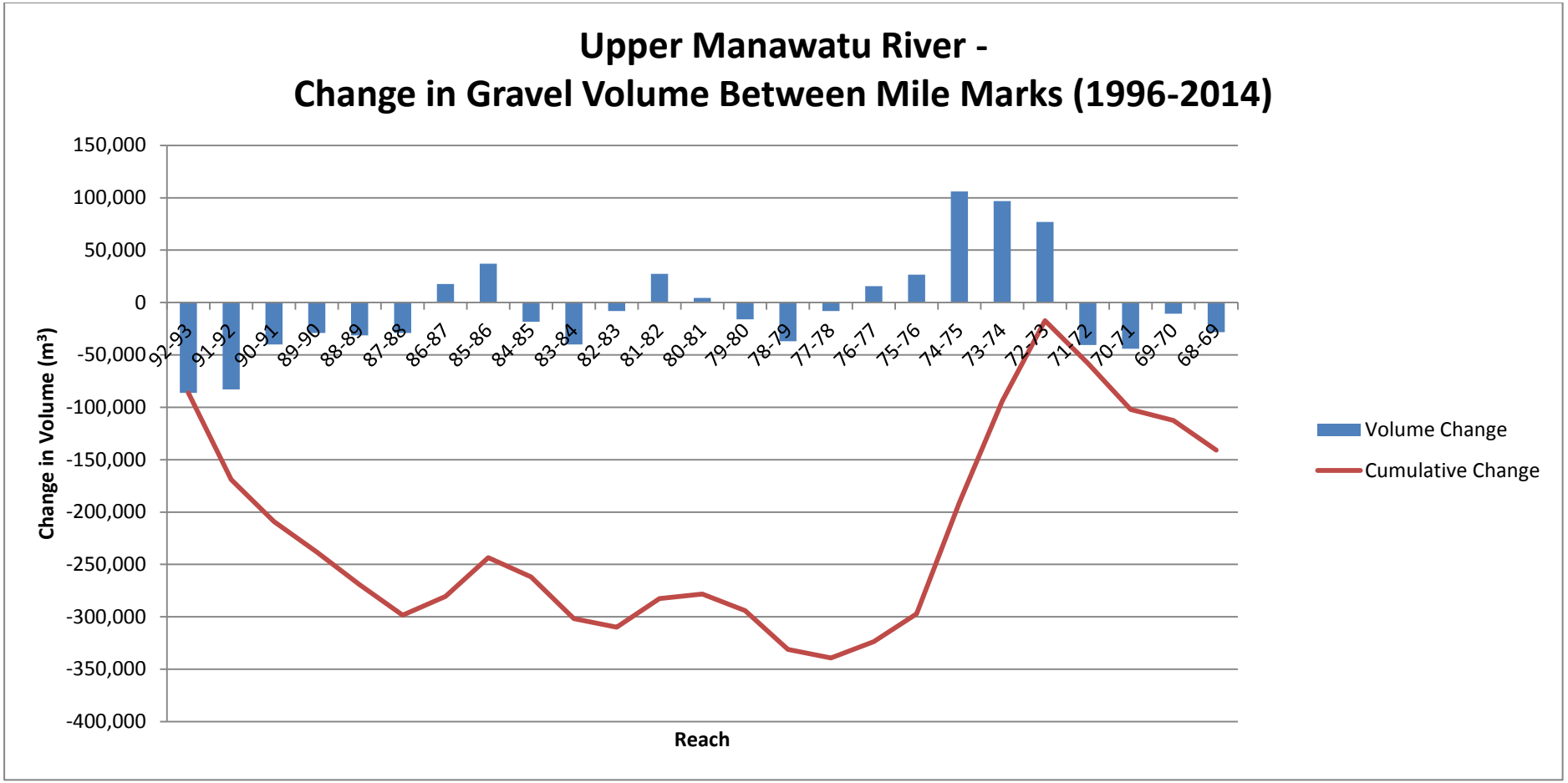
The graph shows how the volume of gravel has changed both between mile marks and as a cumulative total from the upstream end of the study reach. As can be seen, there has been a degradation of the gravel resource in the upstream part of the reach, between the 87 and 93 mile marks.

The gravel volume between the 77 and 87 mile marks has fluctuated, over the 18 year timeframe, with some sections aggrading and some degrading. This is the kind of natural fluctuation one would expect to see in a gravel bed river as pulses of gravel work their way downstream.

Between the 72 and 77 mile marks there has been a considerable aggradation of the gravel resource in the river. Interestingly, as the cumulative change line shows, the total volume of aggradation in this part of the river roughly balances that which degraded in the upper part of the study reach.

Downstream of the 72 mile mark there has been a degradation of the gravel resource in the river meaning that there has been a cumulative degradation, of approximately 150,000 m^3 of gravel in the study reach of the Upper Manawatu River.

Figure 4.4 - Upper Manawatu River, Change in Gravel Volume



4.2.2 Lower Mangahao River

Figure 4.5 shows how the volume of gravel in the Lower Mangahao River has changed between the surveys taken in 1996 and 2014.

The graph shows that the volume of gravel between cross sections 8 and 11 has remained fairly constant while there has been an aggradation of the gravel resource between cross sections 3 and 8.

Figure 4.5 also suggests that there has been a significant degradation of the gravel resource at the downstream end of the Lower Mangahao River between cross section 3 and the confluence with the Upper Manawatu River. However, this result is very heavily influenced by the large change in cross sectional area at cross section 2. As discussed in Section 4.1.2, the river channel has migrated significantly at this location and hence meaningful comparisons cannot be made between the surveys taken in 1996 and 2014.

To compensate for this inaccuracy the volumes of gravel in the Lower Mangahao River were re-calculated with cross section 2 removed. The volume in this reach of the river was calculated by integrating the cross sectional areas at cross sections 1 and 3 over the distance between them. The results of these adjusted calculations can be seen in Figure 4.6.

The updated graph shows that there has been a pattern of aggradation in the Lower Mangahao River between 1996 and 2014 which has seen a cumulative increase of approximately 212,000 m^3 of gravel.

Figure 4.5 - Lower Mangahao River, Change in Gravel Volume

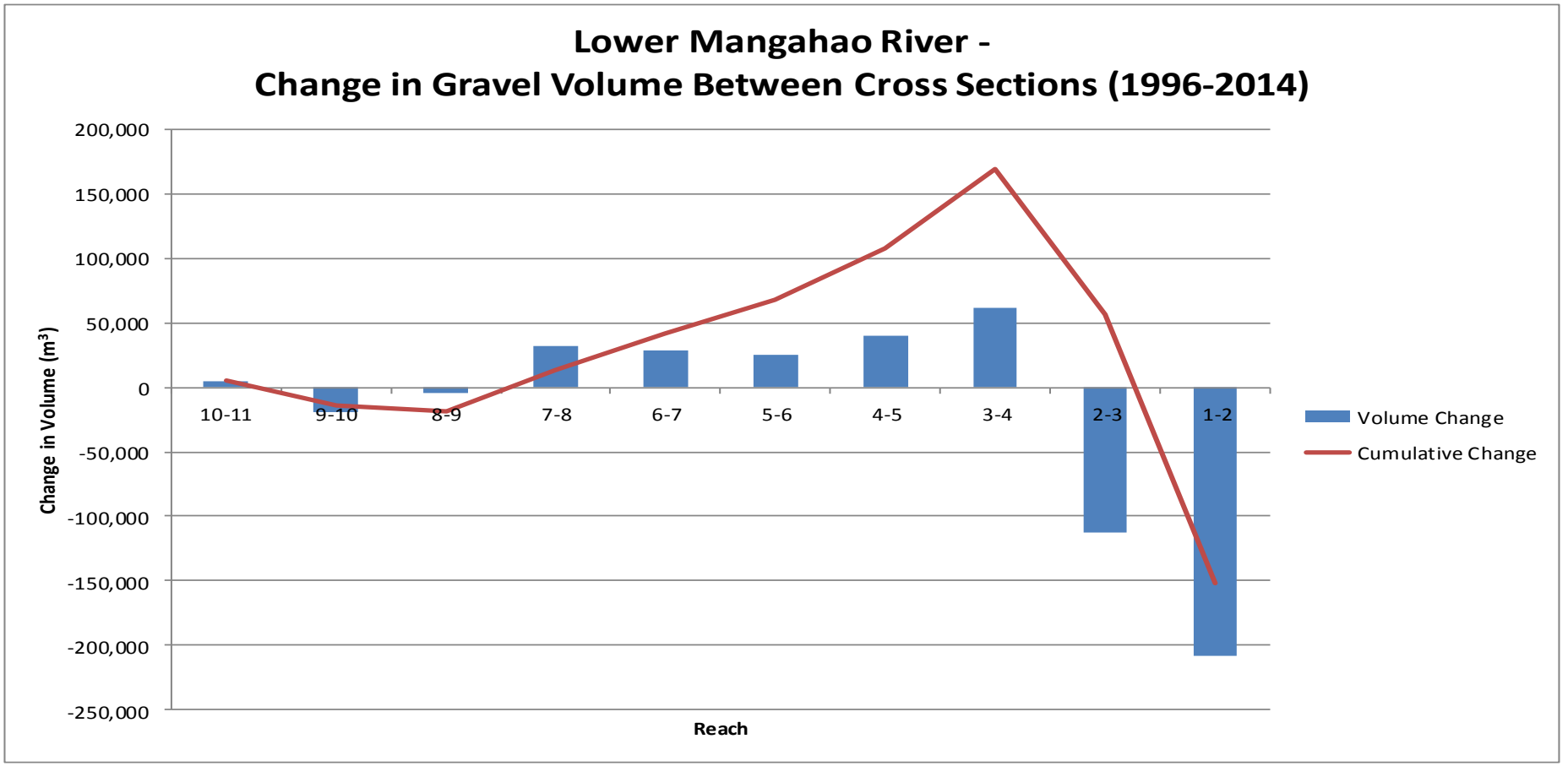
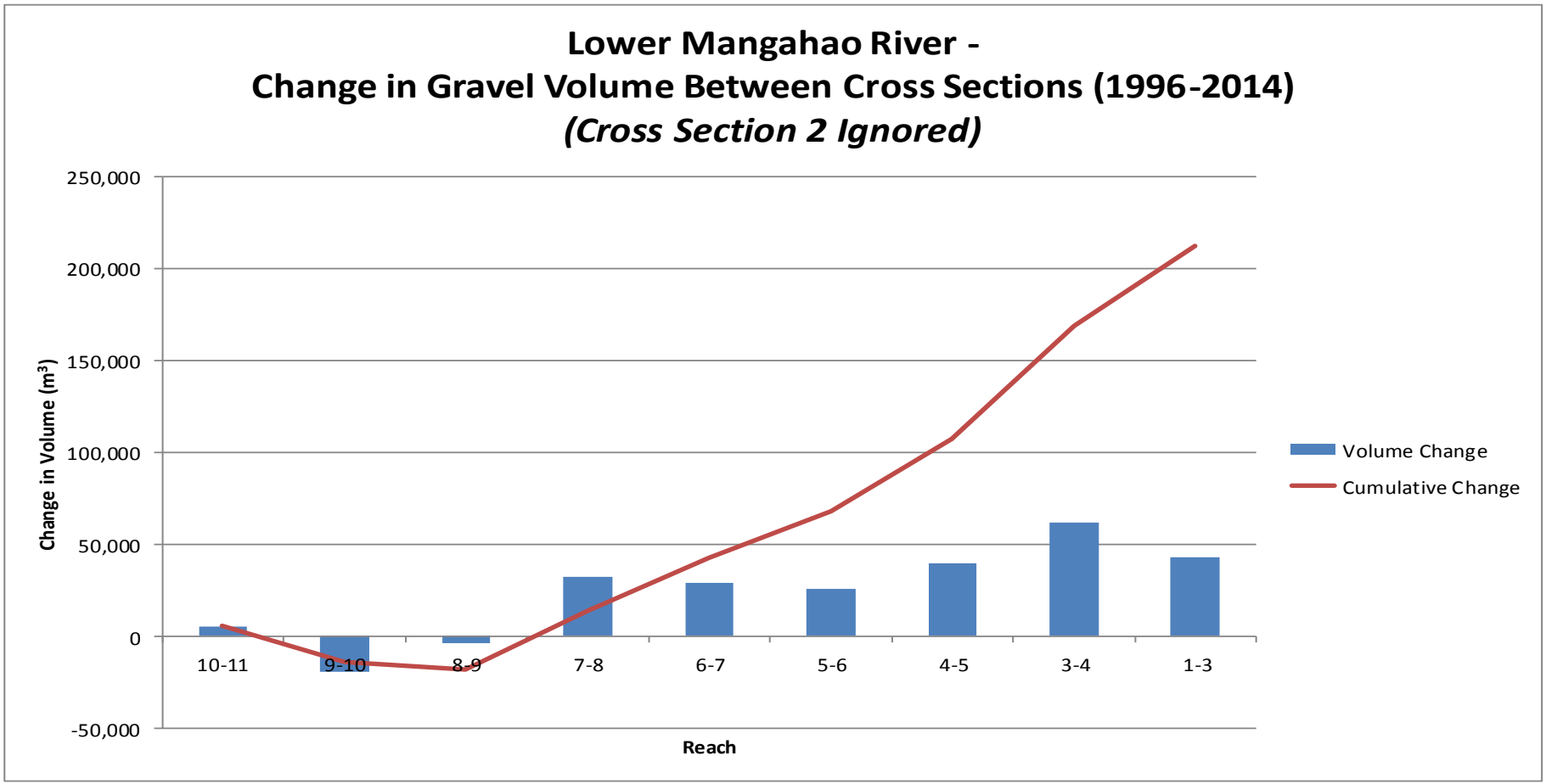


Figure 4.6 - Lower Mangahao River, Change in Gravel Volume (Cross Section 2 Ignored)



5. Gravel Extraction

Historically gravel has been extracted from the Upper Manawatu and Lower Mangahao Rivers and used in a variety of roading and other construction works.

These extractions used to be managed through individual consents. Since 2001 the gravel resource in these rivers has been managed through global consents held by HRC's Operations Group.

The volume of gravel extracted under each of the consents is recorded and held in the R2D2 database managed by HRC.

5.1 Upper Manawatu River Gravel Extraction

The volumes of gravel extracted from the Upper Manawatu River between October 1996 and December 2013 have been obtained from the R2D2 database.

The volumes of gravel extracted have been allocated to section of the river between mile marks according to the consents under which they were extracted.

The quantities of gravel extracted under the global consents are a little more awkward to assign to individual sections of the river as they are not recorded in this way in R2D2. Through consultation with HRC's Area Engineer responsible for the management of the global consents, the quantities recorded into R2D2 were split into those extracted from the reach below Ngawaparua Bridge and those extracted from the river above the bridge.

These volumes were then pro-rated through the reaches according to the historical rates of extraction in these reaches. Table 5.1, overleaf, summarises the volumes of gravel extracted from the Upper Manawatu River between the 1996 and 2014 surveys. A full record of the gravel extraction from the study reach of the river can be seen in Appendix D.

Table 5.1 – Volume of Gravel Extracted, Upper Manawatu River 1996-2014

Reach (Mile Marks)	Volume of gravel extracted (m^3)
68-69	30,161
69-70	33,271
70-71	30,161
71-72	30,486
72-73	0
73-74	0
74-75	0
75-76	3,567
76-77	3,125
77-78	22,614
78-79	11,152
79-80	0
80-81	0
81-82	0
82-83	0
83-84	6,073
84-85	2,812
85-86	13,145
86-87	13,145
87-88	0
88-89	0
89-90	0
90-91	4,836
91-92	4,836
92-93	51,591
Total	***260,975***

5.2 Lower Mangahao Gravel Extraction

The R2D2 database records show that between 1996 and 2014 approximately 14,000 m^3 of gravel were extracted from the Lower Mangahao River.

6. Results

6.1 Upper Manawatu River

Figure 6.1 shows the change in the volume of gravel in the Upper Manawatu River between 1996 and 2014 when the volumes that have been extracted under consents have been taken into consideration. That is, the graph gives an indication of how the volume of gravel in the river may have changed if no extraction had taken place. For clarity this graph has been reproduced in Appendix F.

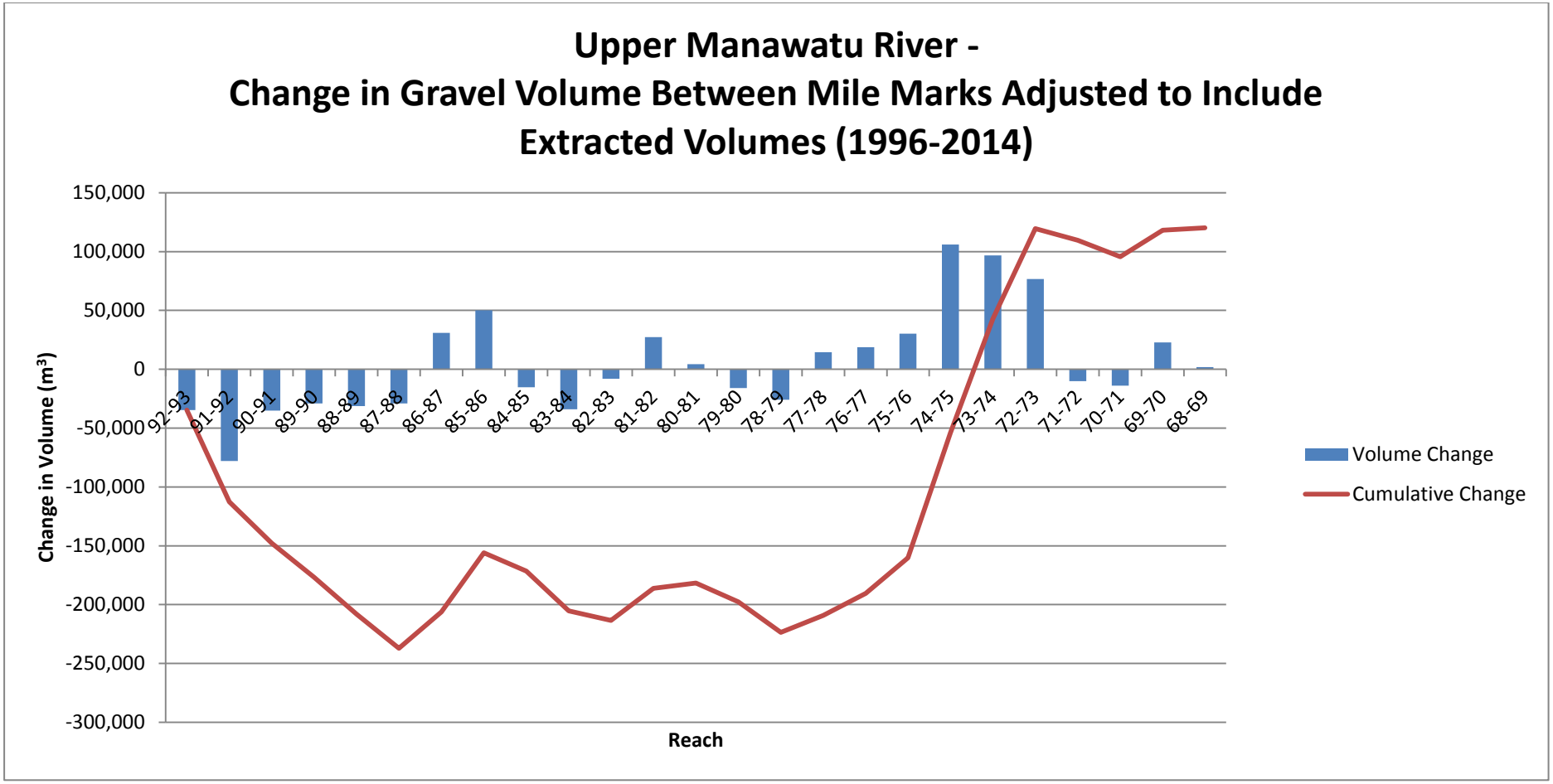
These results show that the upstream end of the study reach is degrading, with approximately 237,000 m^3 less gravel present in 2014 than in 1996.

The gravel resource in the middle of the study reach, between the 78 and 87 mile marks appears to be in a dynamic equilibrium. That is the volumes of degradation are balanced by the volumes of aggradation in this section.

Between the 78 mile mark and the Manawatu Gorge there is noticeable aggradation of the gravel resource particularly between the 72 and 75 mile marks. Overall there has been a deposition of approximately 320,000 m^3 of gravel in this lower part of the study reach.

It can be summarised that, if no gravel extraction has occurred, over the period 1996 to 2014 the volume of gravel in the Upper Manawatu River would have increased by approximately 120,000 m^3

Figure 6.1 - Upper Manawatu River, Change in Gravel Volume Adjusted to Include Extracted Volume



6.2 Lower Mangahao River

The gravel volume analysis has shown that the between 1996 and 2014 the total volume of gravel in the Lower Mangahao River has increased by approximately 212,000 m^3. Additionally, over this time period 14,000 m^3 of gravel has been extracted from the river system.

It can, therefore, be surmised that there is a sustainable supply of approximately 12,500 m^3 of gravel to the Lower Mangahao annually.

7. Future Gravel Extraction

7.1 Upper Manawatu River

7.1.1 Existing Consent Conditions

Under the terms of the existing global consent for gravel extraction, 40,000 m^3 of gravel can be extracted from the study reach of the Upper Manawatu River each year. This volume is split so that 20,000 m^3 can be taken from the reach between the Manawatu Gorge Bridge and the Ngawaparua Bridge. The remaining 20,000 m^3 can be extracted from the study reach above the Ngawaparua Bridge.

7.1.2 Gravel Extraction Required for River Management Purposes

The Upper Manawatu River is managed by HRC's Operations Group as part of the Upper Manawatu and Lower Mangahao Scheme. The Scheme is managed to maintain the flood carrying capacity of the river as well as protection adjacent land from erosion. The management of the gravel in the river forms an important part of the overall Scheme management.

During a site visit with the Area Engineer responsible for the Scheme, the need for extraction of gravel from various locations along the river was discussed in terms of both flood and erosion control.

7.1.2.1 Ngawaparua Bridge to 93 Mile Mark

In the upstream part of the reach, above the 85 mile mark, there are a number of sites from which gravel has historically been taken. Generally, this reach of the river appears to be well managed. However, as noted by the Area Engineer, gravel extractors in this reach have recently encountered the Papa bedrock beneath the river gravels.

It is noted that there are a number of gravel beaches in this upper part of the reach that have become well armoured and vegetated. From a channel management point of view, it would be beneficial to remove this vegetation and some of this gravel to maintain the flood carrying capacity. Furthermore, this type of extraction would help to break up the armour layer and hence mobilise some of the gravel in the river system.

7.1.2.2 Manawatu Gorge Bridge to Ngawaparua Bridge

The lower part of the study reach has seen a lot of river gravels extracted to maintain the flood carrying capacity of the river. This extraction continues to be necessary as the beaches here continue to build-up.

7.1.3 Appropriateness of Consented Extraction Rates

7.1.3.1 Ngawaparua Bridge to 93 Mile Mark

Whilst this study has found that there has been a degradation of the gravel resource in the upstream part of this reach, which is backed up by the evidence of gravel extractors reaching the bed rock, there is a need to be able to remove some gravel from the river. The judicious removal of gravel from well armoured and vegetated beaches will help to maintain the flood carrying capacity of the channel as well as having the benefit of mobilising gravels in the active channel of the river.

The 20,000 m^3 per annum that the consent allows to be extracted from this reach will allow for this gravel to be extracted from the upper part of the reach, as well as from the large gravel beach that forms just upstream of the Ngawaparua Bridge around the 76 mile mark.

It is remembered that the consented volume is an upper limit and not the volume of gravel that will necessarily be extracted in any one year. As such this allowed volume will allow the Area Engineer to effectively manage this reach of the river.

7.1.3.2 Manawatu Gorge Bridge to Ngawaparua Bridge

This study has found that the supply of gravels to the lower part of the Upper Manawatu River has totalled approximately 300,000 m^3 over the 18 years between river surveys. This means that there is a sustainable supply of approximately 16,000 m^3 per annum that can be extracted from between the Manawatu Gorge and Ngawaparua Bridge.

Considering this it would appear that the currently consented 20,000 m^3 annual extraction is appropriate. This will allow the channel of the river to be maintained to ensure that the flood carrying capacity is not compromised.

7.2 Lower Mangahao River

Under the terms of the existing consent 8,000 m^3 of gravel can be extracted from the Lower Mangahao annually.

This study has shown that there is a sustainable supply of approximately 12,500 m^3 of gravel to this reach of the river annually.

The Lower Mangahao River is well managed under the Scheme and there are not presently any major constrictions affecting the flood carrying capacity of the river.

It is however noted that there are a number of gravel beaches that are building up and these may begin to present a problem in the future, either in terms of reduced channel conveyance or causing erosive pressures on the river banks.

It is possible that these gravel beaches could be reduced in size under the existing consent. However, this study suggests that the rates of aggradation may exceed the rate at which the consent allows gravel to be extracted.

8. Conclusion

This study has shown that between 1996 and 2014 the total volume of gravel in the Upper Manawatu River between the Manawatu Gorge and the 93 mile mark would have increased by approximately 120,000 m^3 if no extraction of gravel had taken place.

The upstream end of the reach, between the 87 and 93 mile marks, has experienced a degradation of the gravel resource, with approximately 237,000 m^3 more gravel leaving the reach than entering it. Whilst gravel extraction has occurred in this reach it doesn't fully account for the lost volume. This may be due to a starvation of the gravel supply to the upper end of the study reach. This will be investigated further as part of the South Eastern Ruahine Gravel Resource Study.

The middle part of the study reach, between the 78 and 87 mile marks appears to be in a dynamic equilibrium. That is the volumes of degradation are balanced by the volumes of aggradation in this section.

The downstream end of the study reach has experienced a significant amount of aggradation with approximately 300,000 m^3 of gravel being deposited between the Manawatu Gorge and Ngawaparua Bridge.

After a consideration of the rates of gravel extraction allowed under the global consent it is not considered necessary to alter the quantities allowed to be extracted from the Upper Manawatu River at this time. However, the gravel resource should continue to be monitored by the Scheme Manager and the river should be surveyed again as part of the fluvial monitoring programme in the 2023-24 summer.

This study has also shown that there is an on-going aggradation of the gravel resource in the Lower Mangahao River. It has been shown that the rate of aggradation would allow for approximately 12,500 m^3 of gravel to be sustainably extracted from the river annually.

This means that the supply of gravel exceeds the 8,000 m^3 per year that the global consent currently allows to be extracted from the river. Hence, if the Scheme Manager feels that there is a need to increase the rate of gravel extraction allowed from the Lower Mangahao River, for river management purposes, this study would support such an increase.

Again, the gravel resource should continue to be monitored by the Scheme Manager and the river should be surveyed again as part of the fluvial monitoring programme in the 2023-24 summer.

Appendix A Location of Upper Manawatu Cross Sections

UPPER MANAWATU & LOWER MANGAHAO SCHEME
Cross Section Locations

0 500 1,000 m

NORTH


Woodville
Mangatainoka
Imagery Copyright © 2012 MW LASS Ltd / NZ Aerial Mapping Ltd
72 RB
72 LB *
73 LB *
73 RB
74 RB
75 RB
74 LB *
75 LB *
Key
benchmarks
Prepared by Operations - Investigations & Design
Drawn by J. Bell Dec 2014
Contains Crown Copyright Data
horizons regional council
UPPER MANAWATU & LOWER MANGAHAO SCHEME
Cross Section Locations
0
500
1,000
m
NORTH

horizons regional council | **UPPER MANAWATU & LOWER MANGAHAO SCHEME**
Cross Section Locations


85 RB *
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84 LB *
83 RB *
83 LB
82 RB
82 LB
81 RB *
81 LB
80 RB *
80 LB
79 RB
79 LB
Key
benchmarks
Imagery Copyright © 2012 MW LASS Ltd / NZ Aerial Mapping Ltd
Prepared by Operations - Investigations & Design
Drawn by J. Bell, Dec 2014
Contains Crown Copyright Data
UPPER MANAWATU & LOWER MANGAHAO SCHEME
Cross Section Locations
0
500
1,000
m
NORTH


Imagery Copyright © 2012 MW LASS Ltd / NZ Aerial Mapping Ltd
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87 LB *
86 RB
86 LB *
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85 LB
84 RB
84 LB *
Key
benchmarks
Prepared by Operations - Investigations & Design
Drawn by J. Bell. Dec 2014
Contains Crown Copyright Data
UPPER MANAWATU & LOWER MANGAHAO SCHEME
Cross Section Locations
0
500
1,000
m
NORTH


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93 LB
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91 RB
91 LB *
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90 LB *
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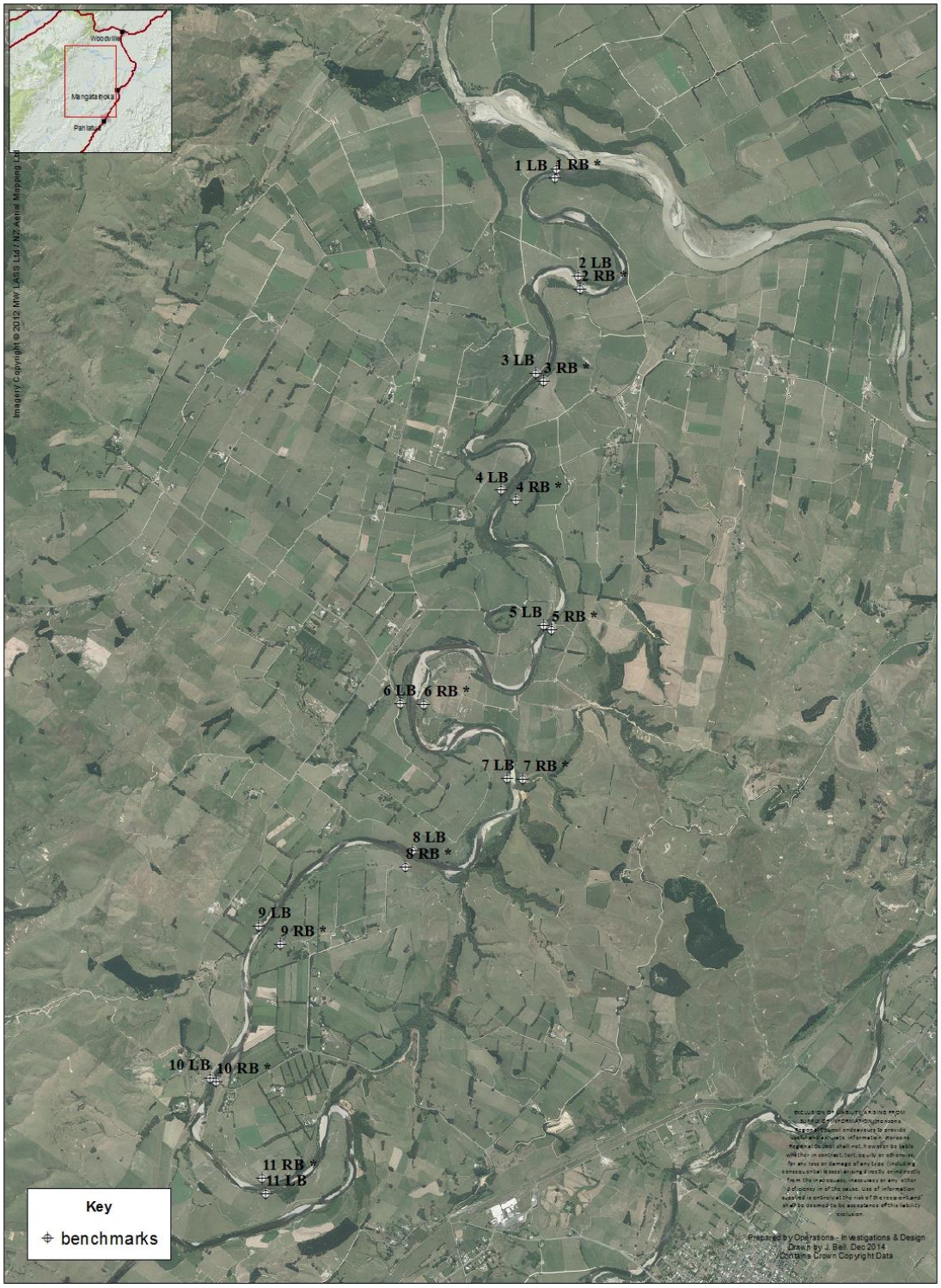
88 RB
88 LB *
Key
benchmarks
Imagery Copyright © 2012 MW LASS Ltd / NZ Aerial Mapping Ltd
Prepared by Operations - Investigations & Design
Drawn by J.Bell Dec 2014
Contains Crown Copyright Data
UPPER MANAWATU & LOWER MANGAHAO SCHEME
Cross Section Locations
0
500
1,000
m
NORTH

Appendix B Location of Lower Mangahao Cross Sections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Mangatainoka
Pahiatua
Imagery Copyright © 2012 MW LASS Ltd / NZ Aerial Mapping Ltd
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4 LB
4 RB *
5 LB
5 RB *
6 LB 6 RB *
7 LB 7 RB *
8 LB
8 RB *
9 LB
9 RB *
10 LB 10 RB *
11 RB *
11 LB
Key
benchmarks
Prepared by Operations- Investigations & Design
Drawn by J. Bell Dec 2014
Contains Crown Copyright Data
UPPER MANAWATU & LOWER MANGAHAO SCHEME
Cross Section Locations
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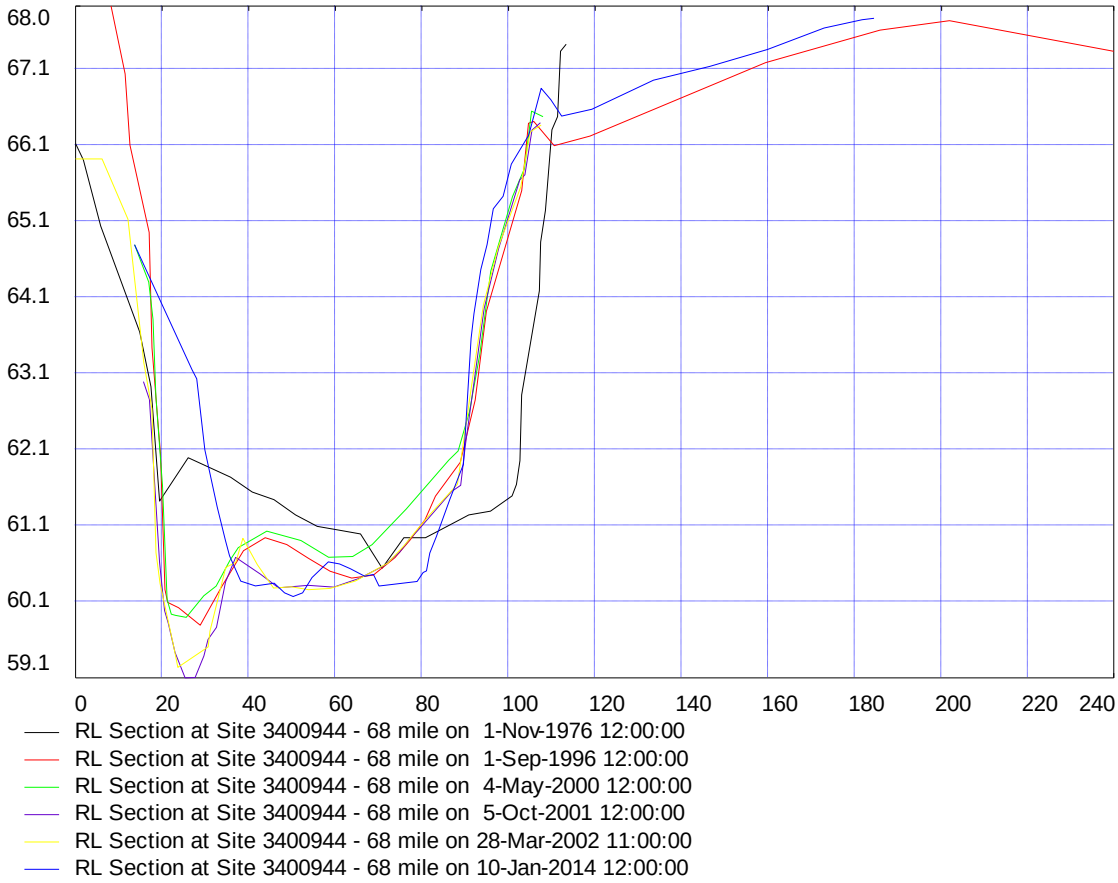
1,000
m
NORTH

Appendix C Upper Manawatu River – Adjusted Cross Sections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60
80
100
120
140
160
180
200
220
240
RL Section at Site 3400944 - 68 mile on 1-Nov-1976 12:00:00
RL Section at Site 3400944 - 68 mile on 1-Sep-1996 12:00:00
RL Section at Site 3400944 - 68 mile on 4-May-2000 12:00:00
RL Section at Site 3400944 - 68 mile on 5-Oct-2001 12:00:00
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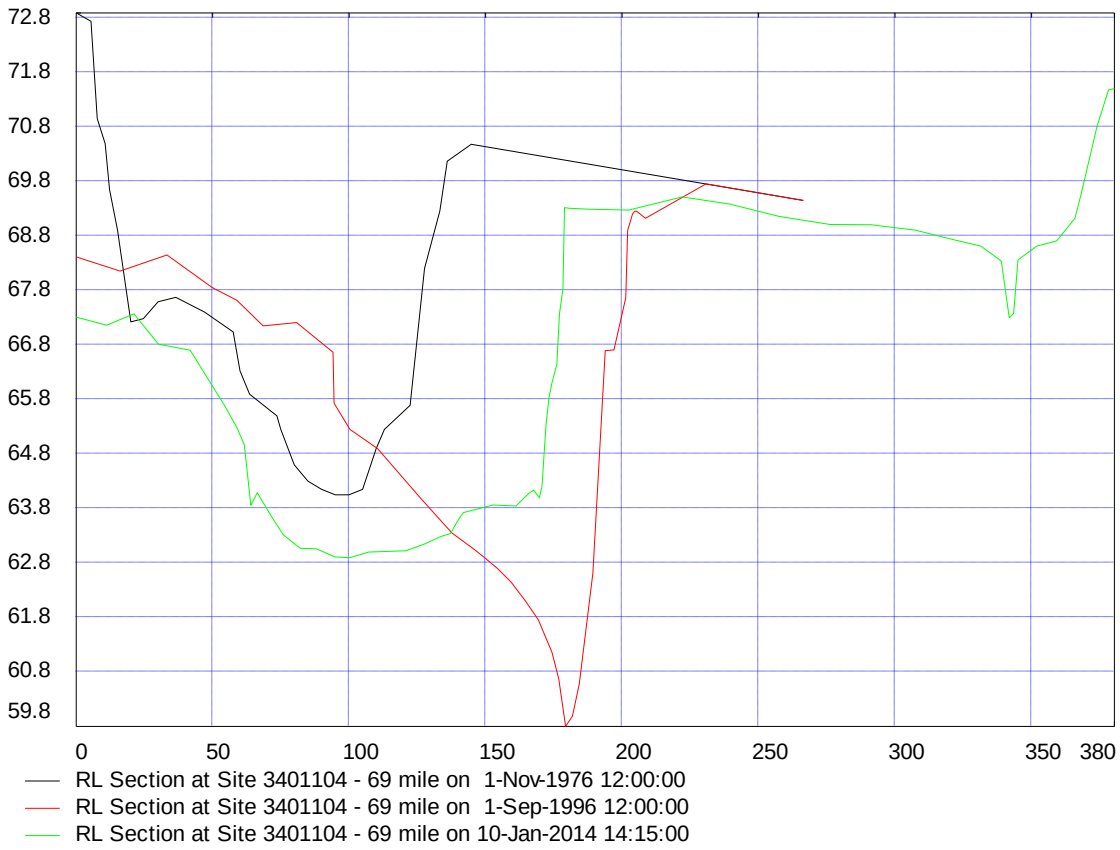
RL Section at Site 3400944 - 68 mile on 10-Jan-2014 12:00:00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0
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100
150
200
250
300
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RL Section at Site 3401104 - 69 mile on 1-Nov-1976 12:00:00
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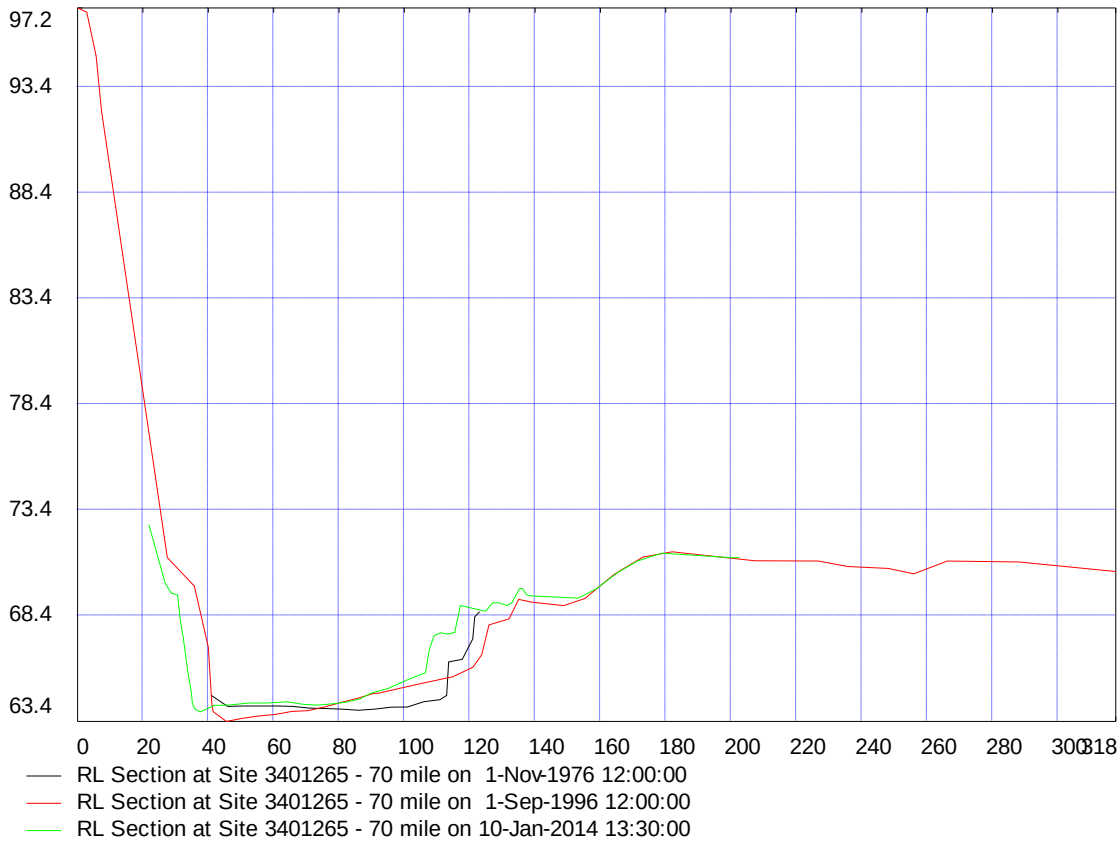
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200
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240
260
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300
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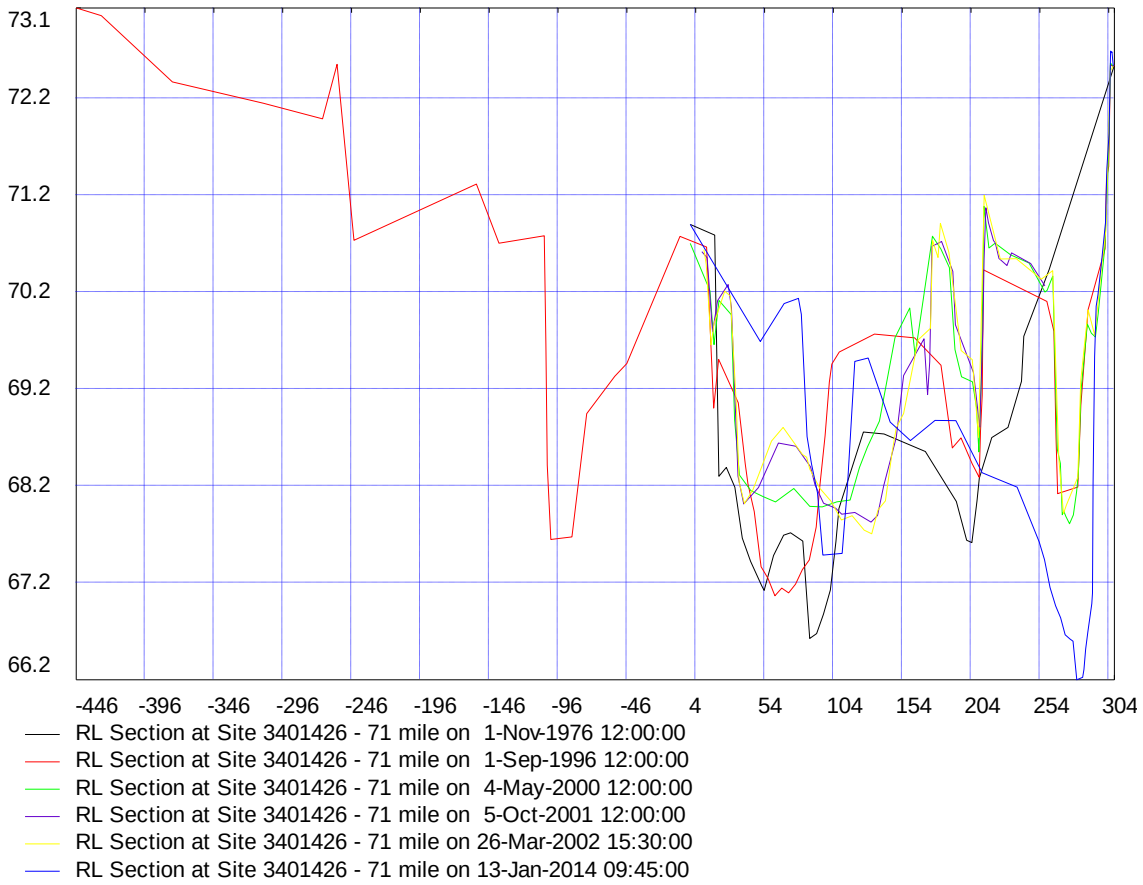
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RL Section at Site 3401426 - 71 mile on 1-Sep-1996 12:00:00
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RL Section at Site 3401426 - 71 mile on 5-Oct-2001 12:00:00
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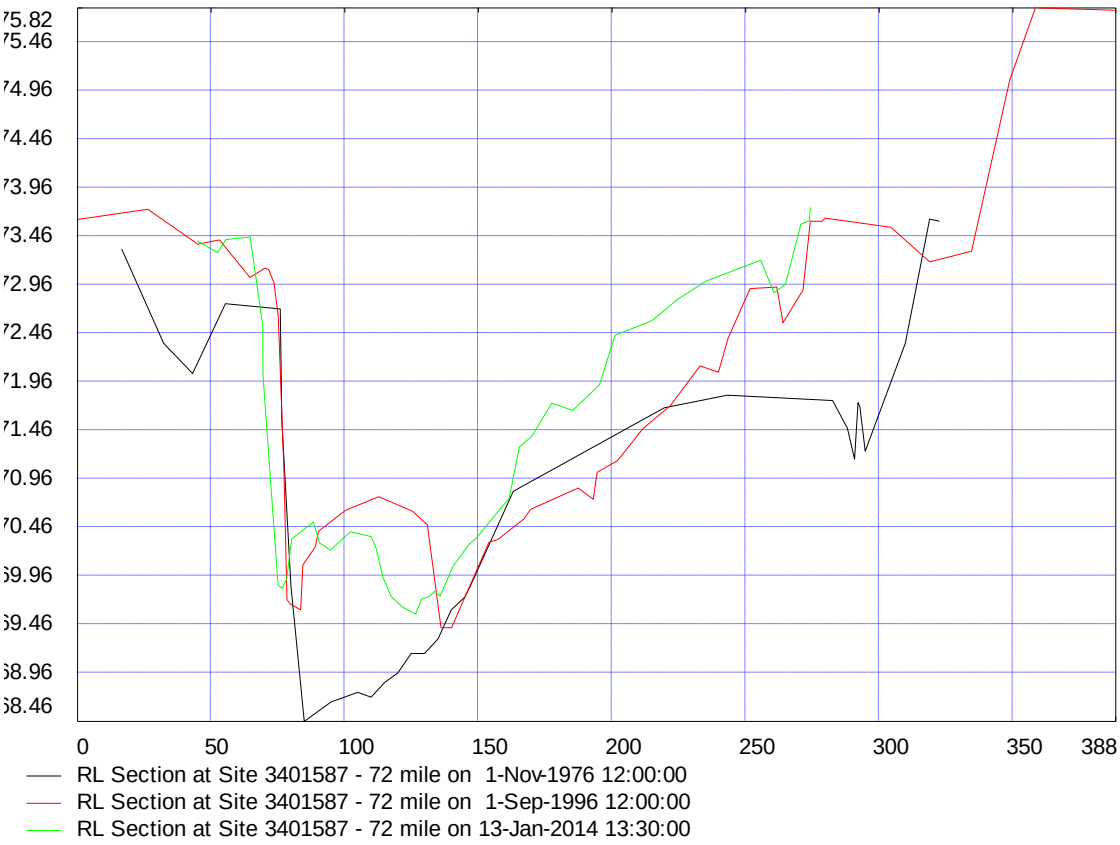
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200
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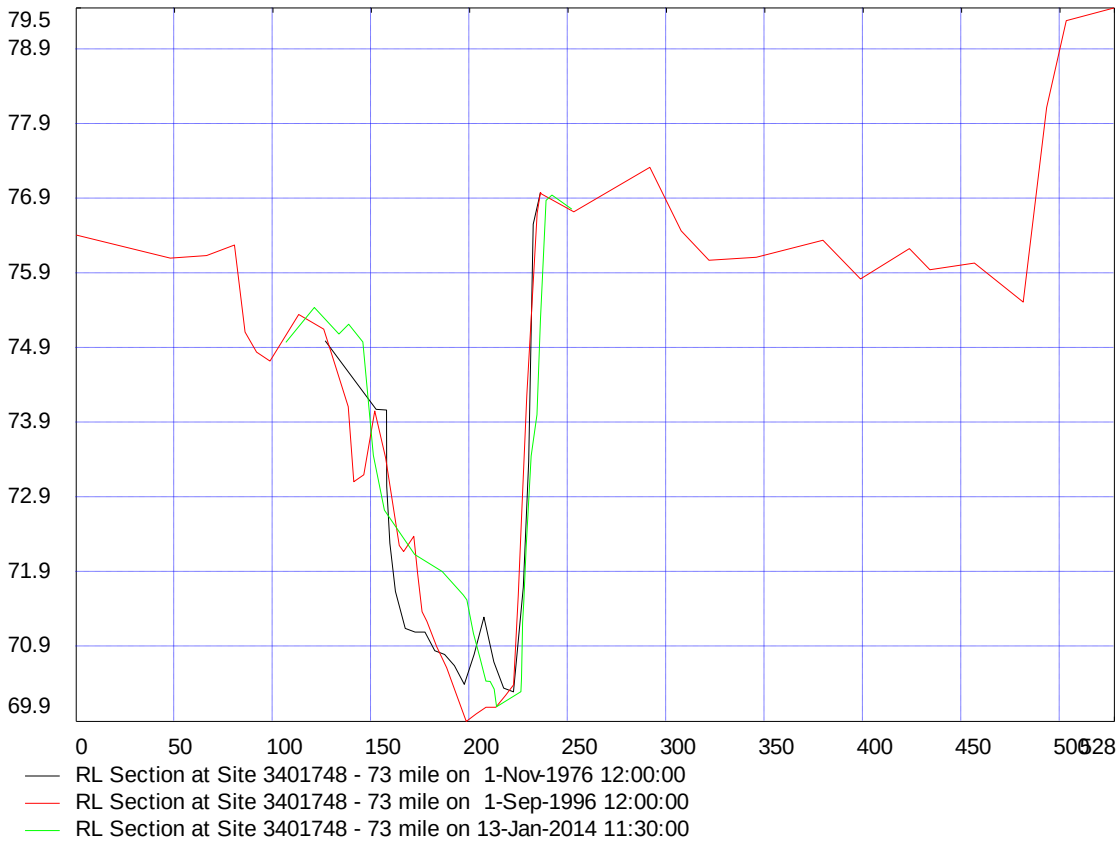
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76.1
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74.1
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71.1
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50
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150
200
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300
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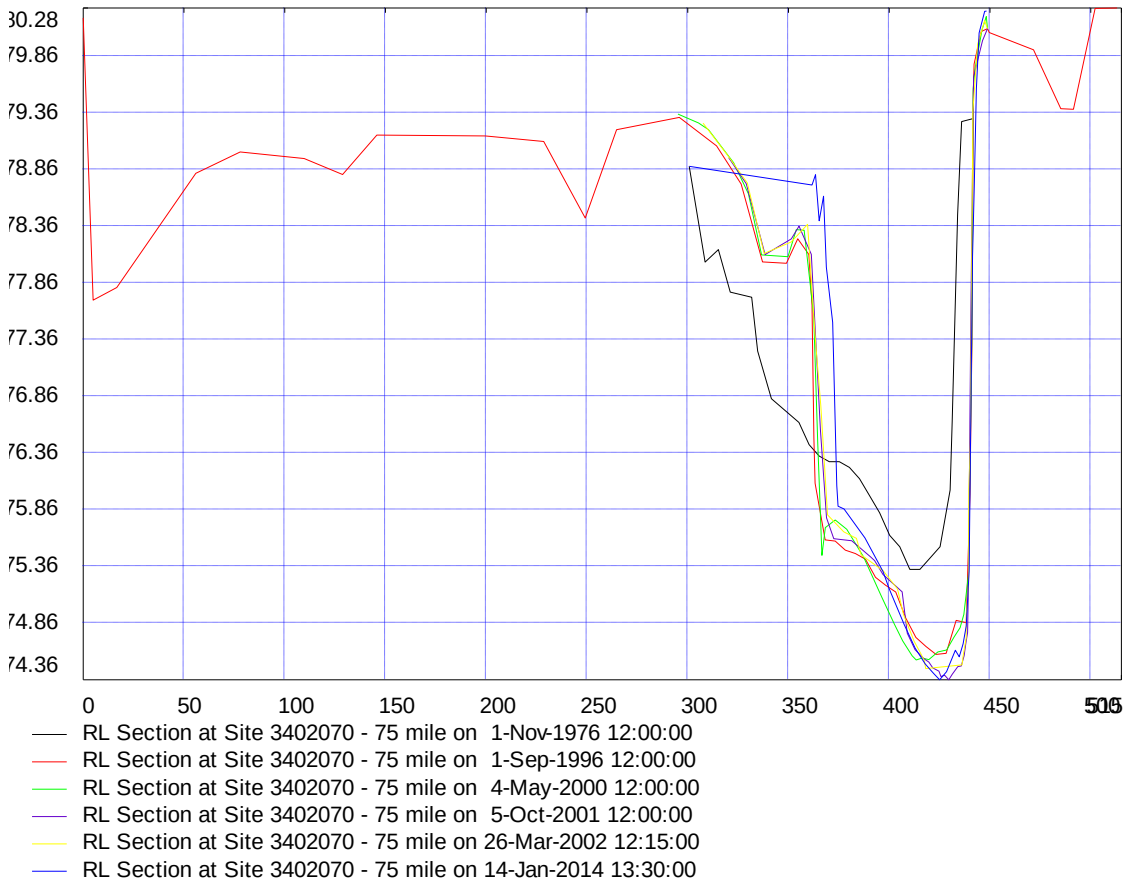
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300
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400
450
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RL Section at Site 3402070 - 75 mile on 1-Sep-1996 12:00:00
RL Section at Site 3402070 - 75 mile on 4-May-2000 12:00:00
RL Section at Site 3402070 - 75 mile on 5-Oct-2001 12:00:00
RL Section at Site 3402070 - 75 mile on 26-Mar-2002 12:15:00
RL Section at Site 3402070 - 75 mile on 14-Jan-2014 13:30:00


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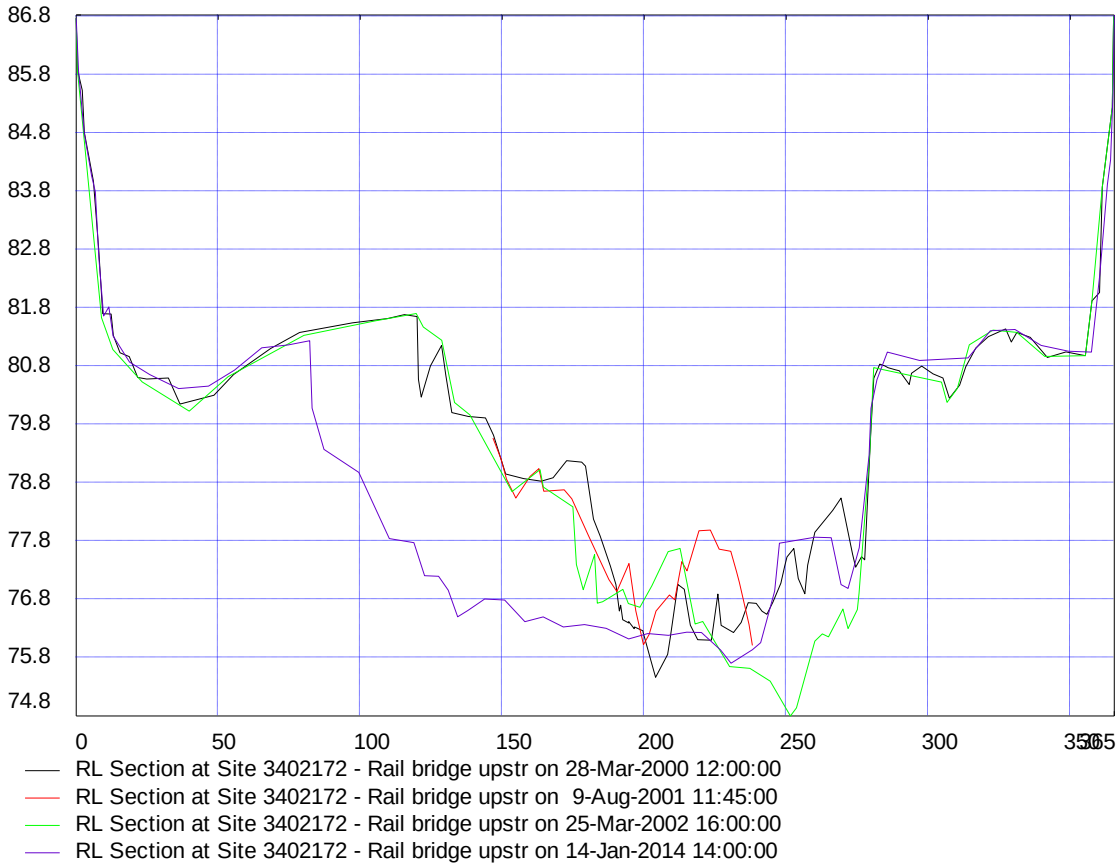
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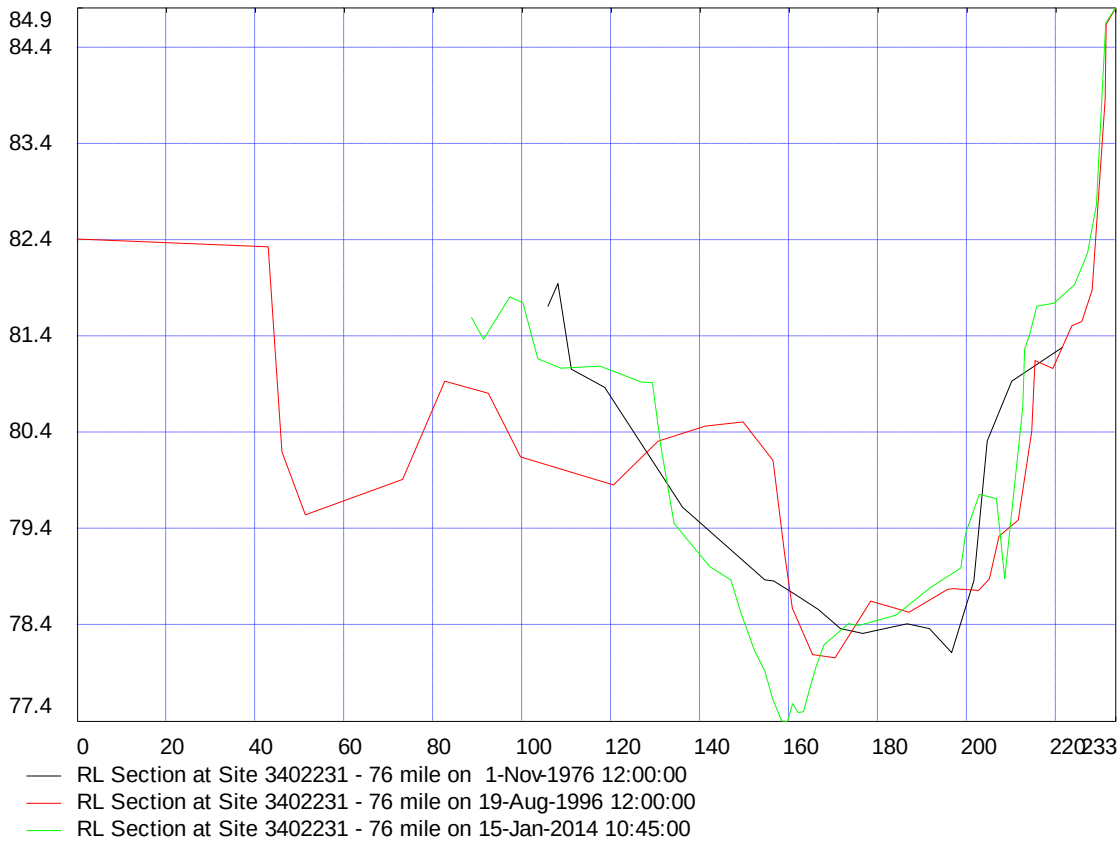
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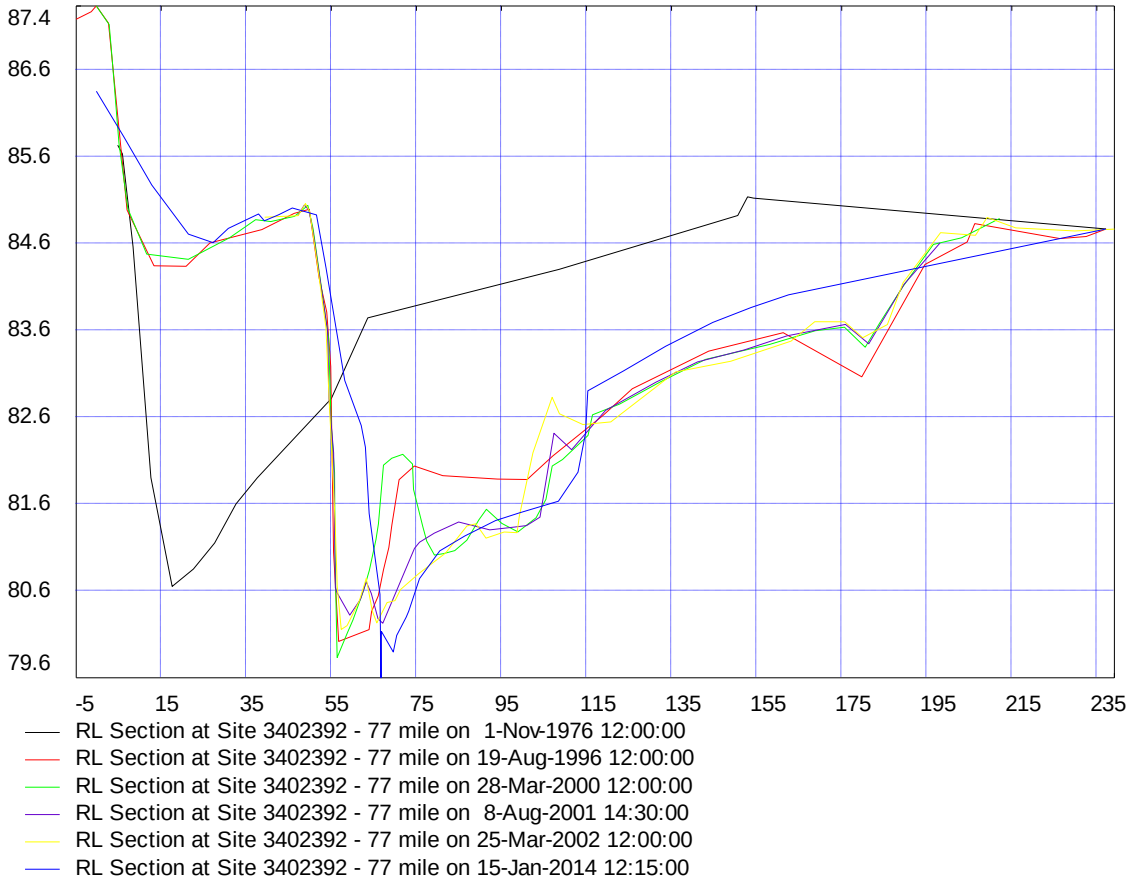
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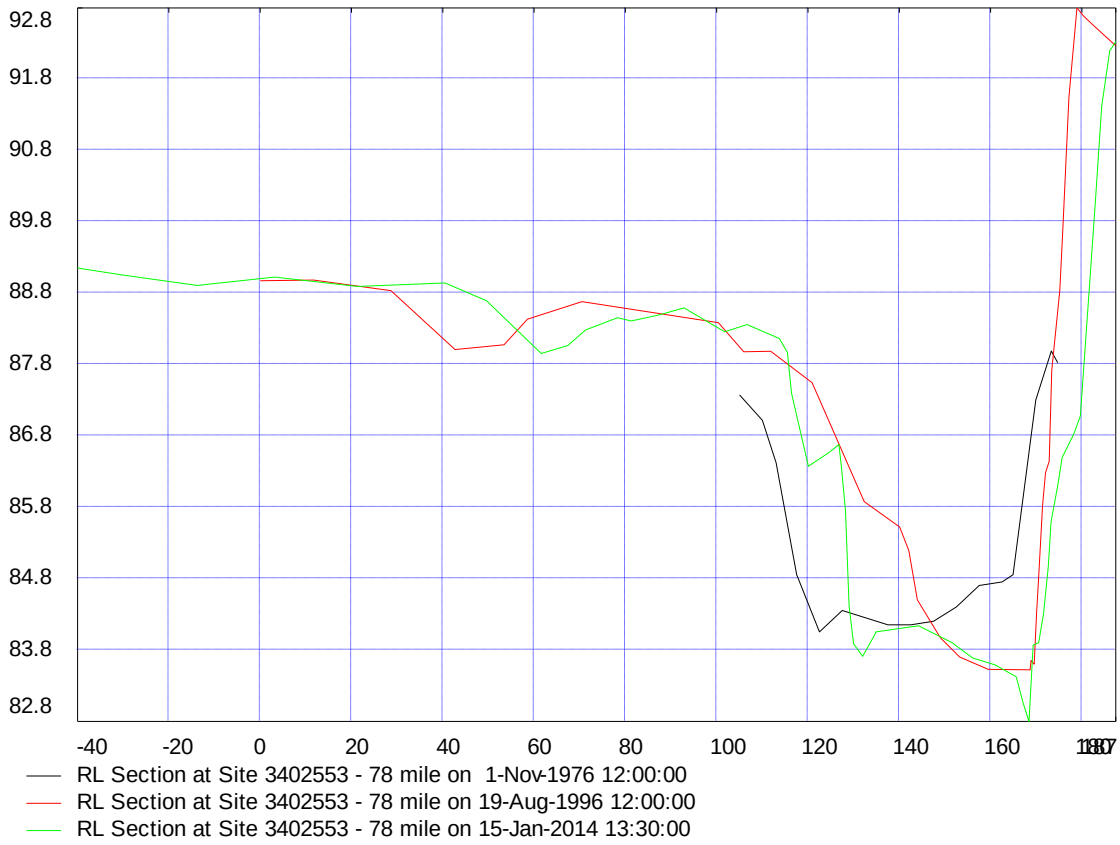
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40
60
80
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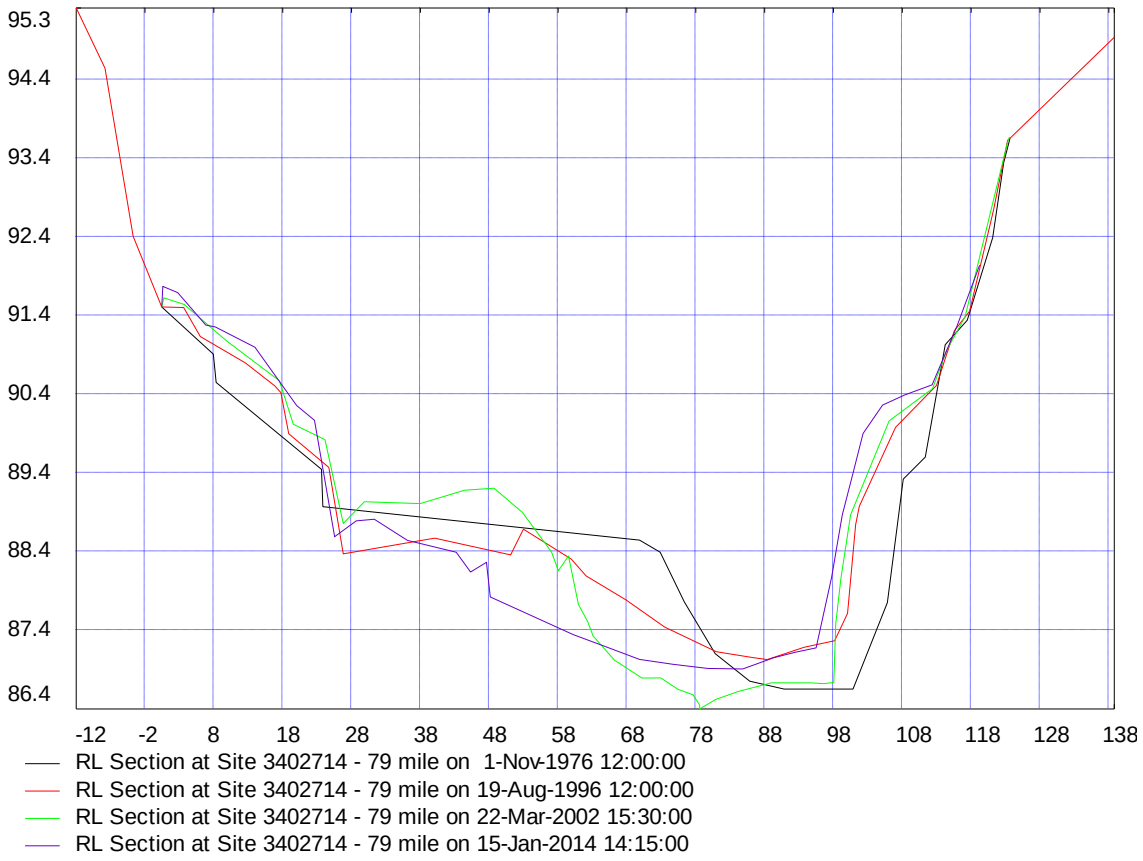
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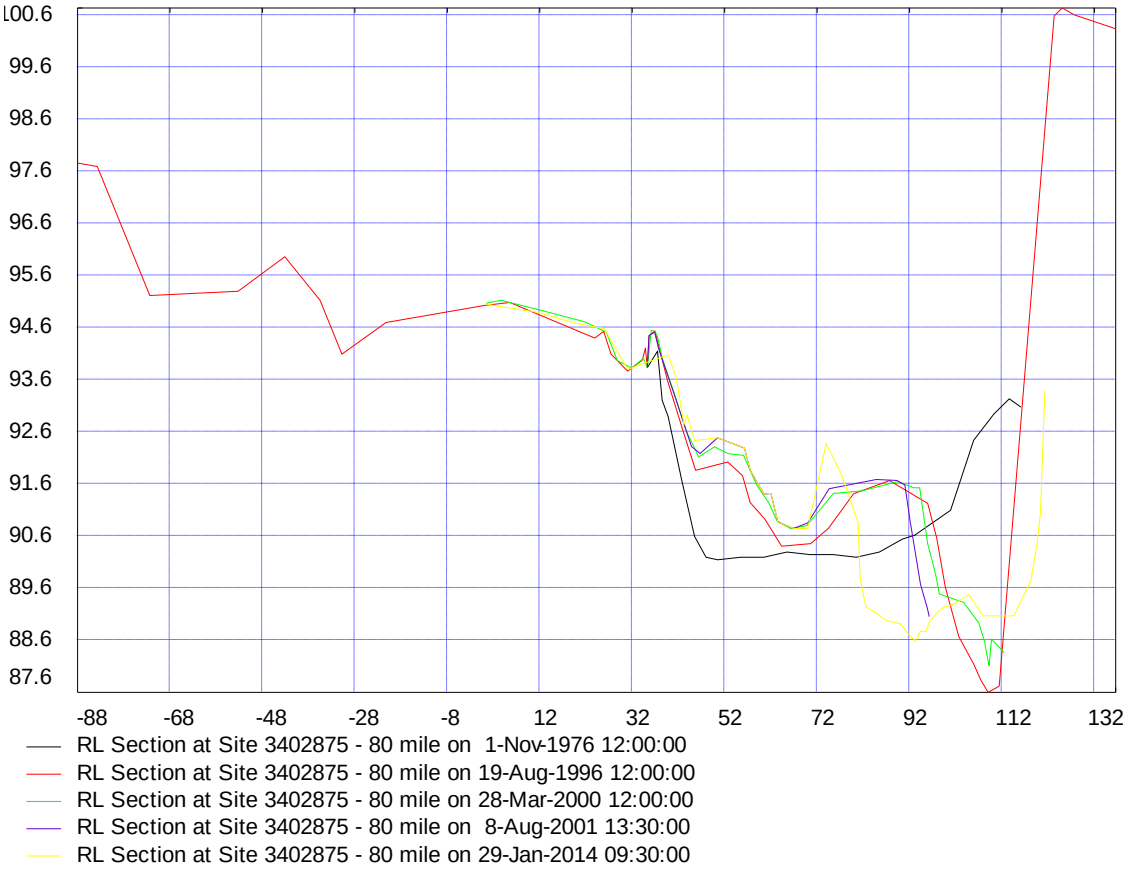
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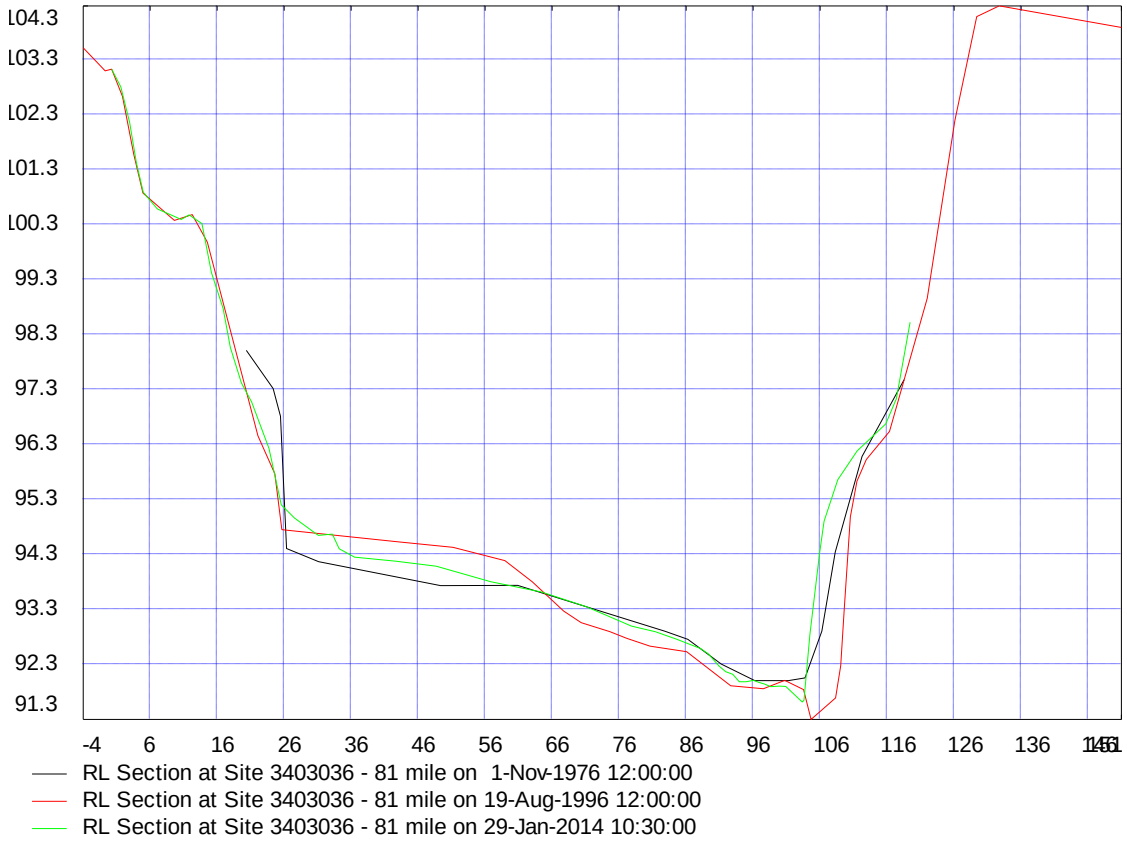
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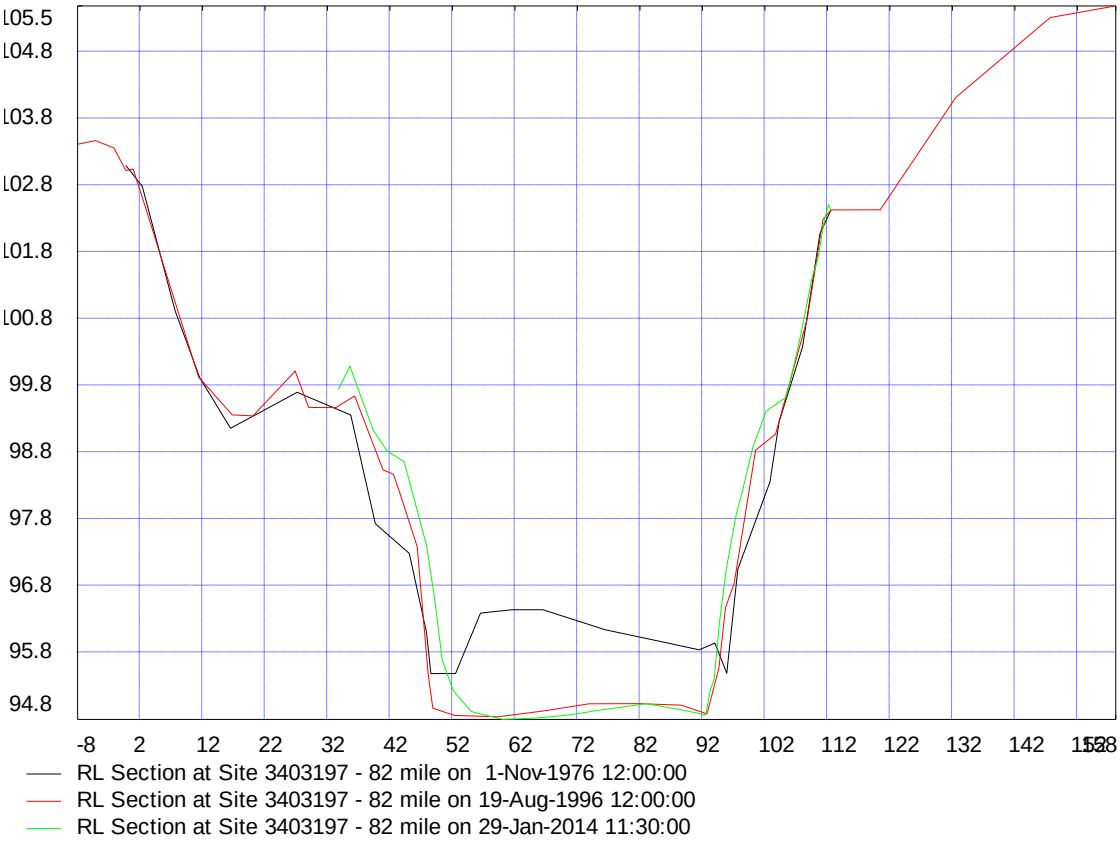
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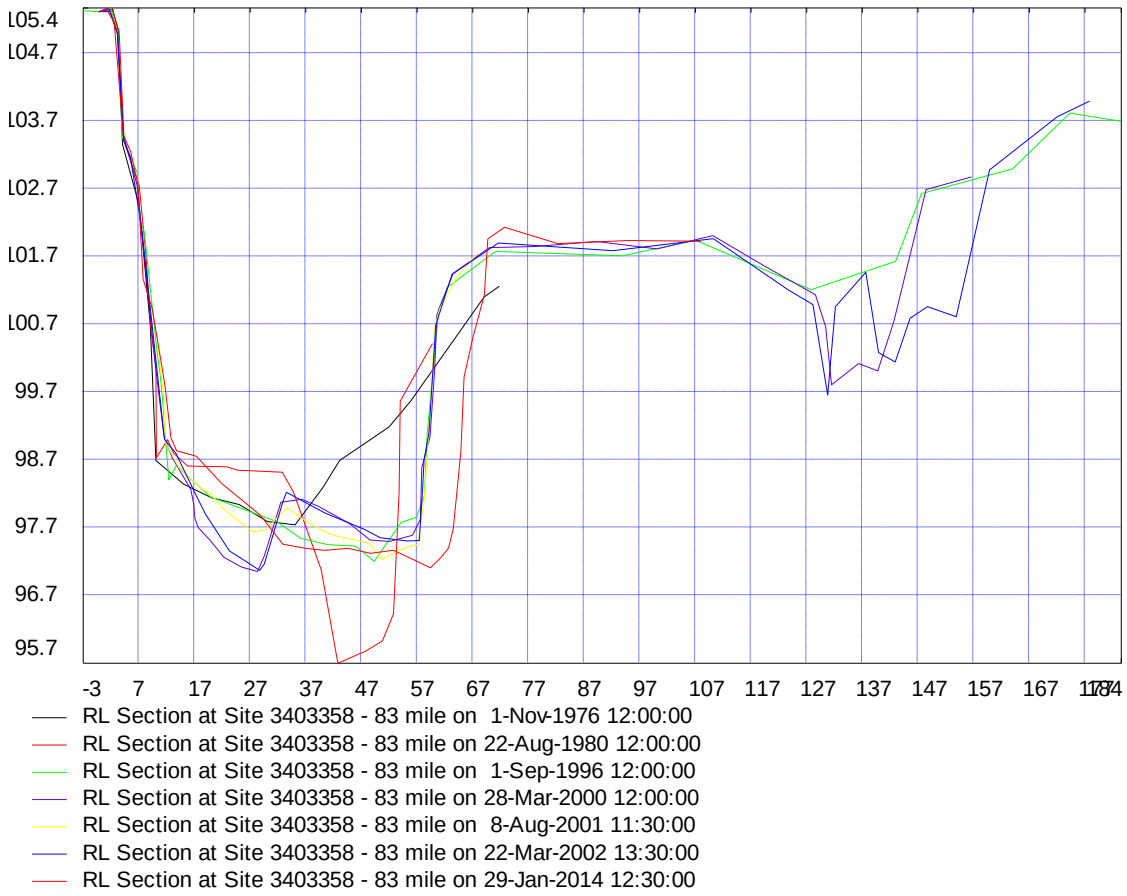
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57
67
77
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97
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117
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137
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167
174
RL Section at Site 3403358 - 83 mile on 1-Nov-1976 12:00:00
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RL Section at Site 3403358 - 83 mile on 1-Sep-1996 12:00:00
RL Section at Site 3403358 - 83 mile on 28-Mar-2000 12:00:00
RL Section at Site 3403358 - 83 mile on 8-Aug-2001 11:30:00
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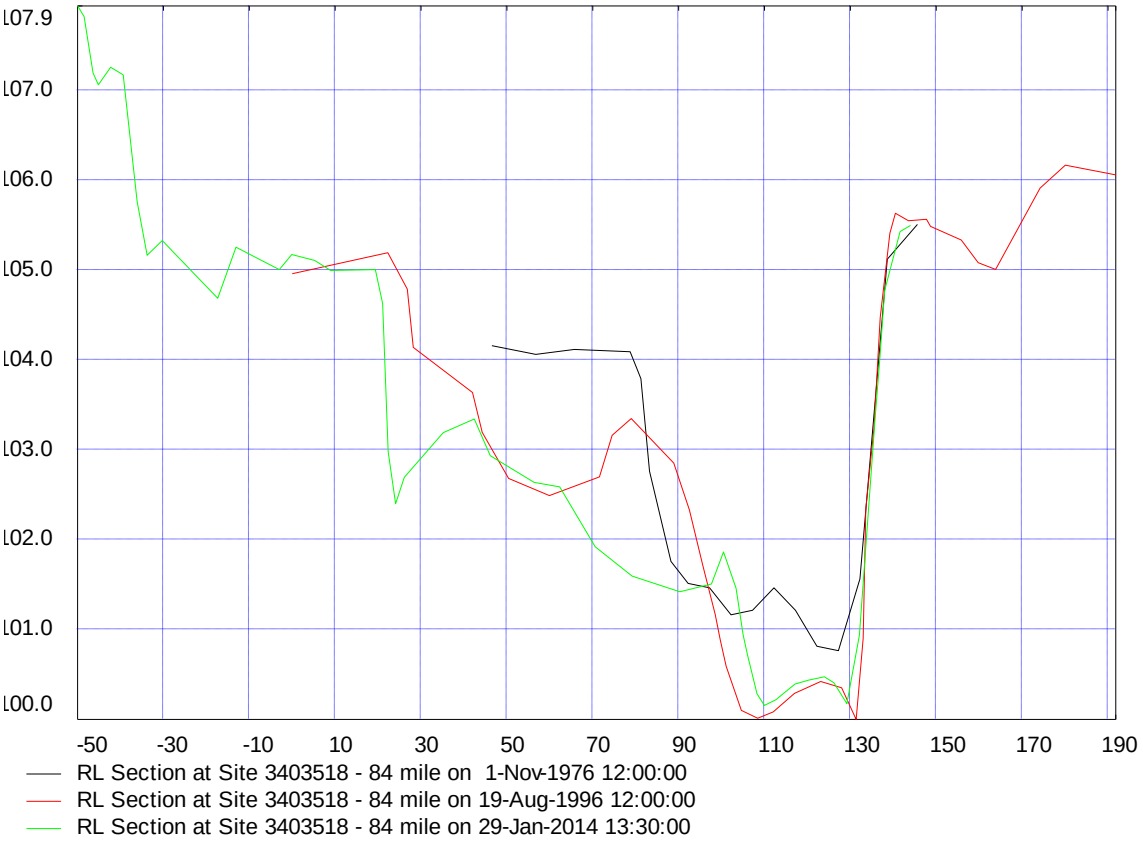
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101.0
100.0
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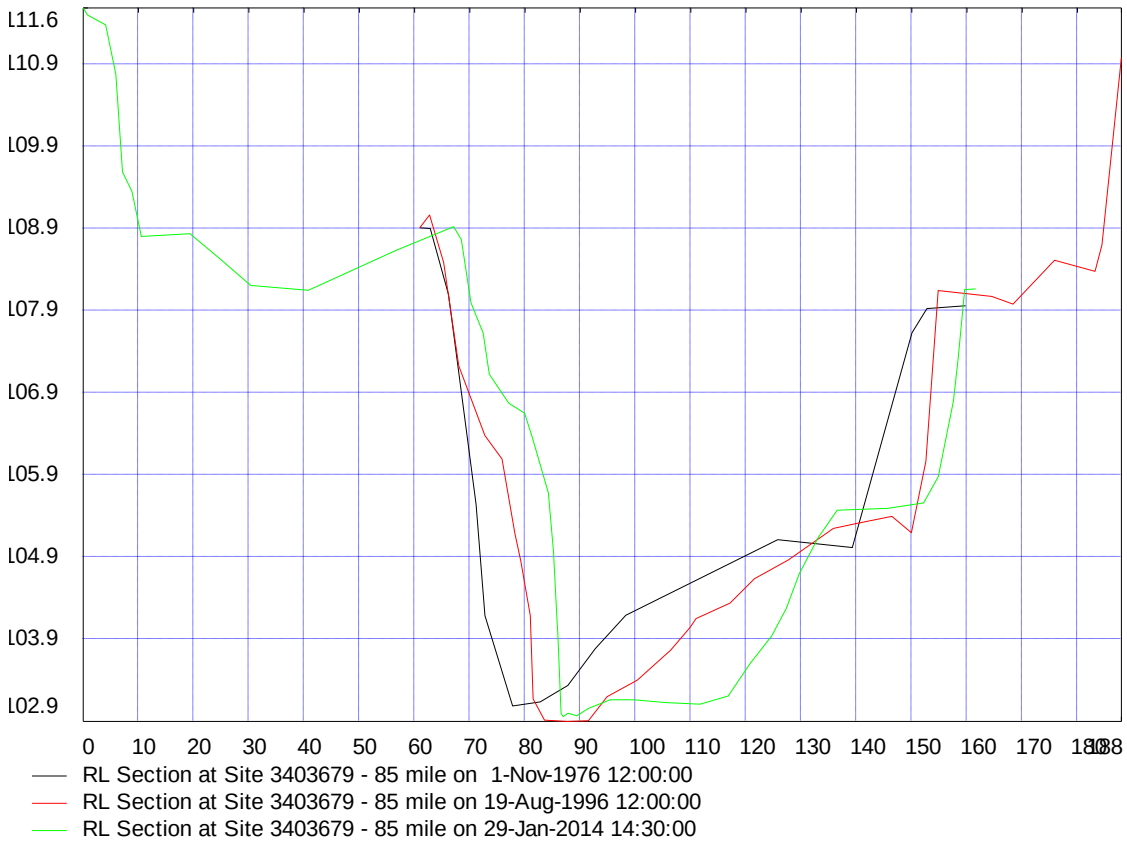
-30
-10
10
30
50
70
90
110
130
150
170
190
RL Section at Site 3403518 - 84 mile on 1-Nov-1976 12:00:00
RL Section at Site 3403518 - 84 mile on 19-Aug-1996 12:00:00
RL Section at Site 3403518 - 84 mile on 29-Jan-2014 13:30:00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L08.9
L07.9
L06.9
L05.9
L04.9
L03.9
L02.9
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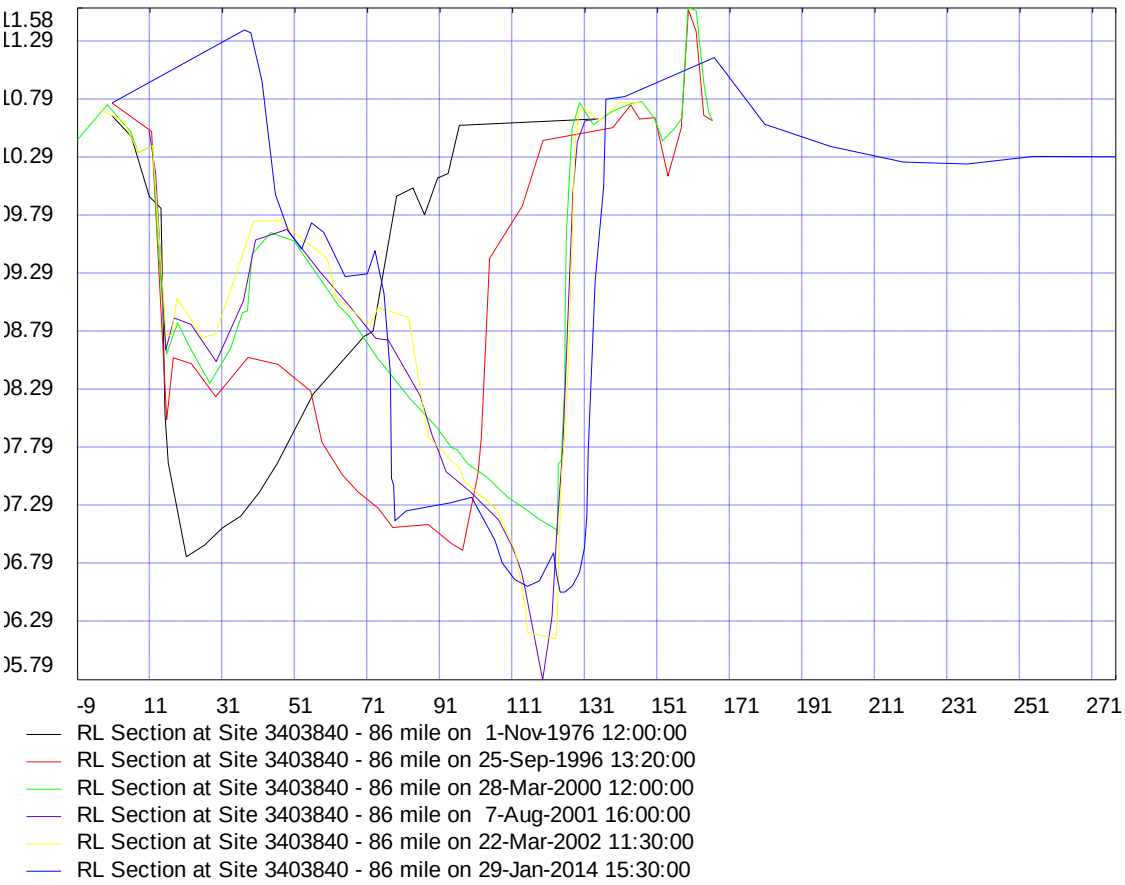
RL Section at Site 3403679 - 85 mile on 1-Nov-1976 12:00:00
RL Section at Site 3403679 - 85 mile on 19-Aug-1996 12:00:00
RL Section at Site 3403679 - 85 mile on 29-Jan-2014 14:30:00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09.29
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07.79
07.29
06.79
06.29
05.79
-9
11
31
51
71
91
111
131
151
171
191
211
231
251
271
RL Section at Site 3403840 - 86 mile on 1-Nov-1976 12:00:00
RL Section at Site 3403840 - 86 mile on 25-Sep-1996 13:20:00
RL Section at Site 3403840 - 86 mile on 28-Mar-2000 12:00:00
RL Section at Site 3403840 - 86 mile on 7-Aug-2001 16:00:00
RL Section at Site 3403840 - 86 mile on 22-Mar-2002 11:30:00
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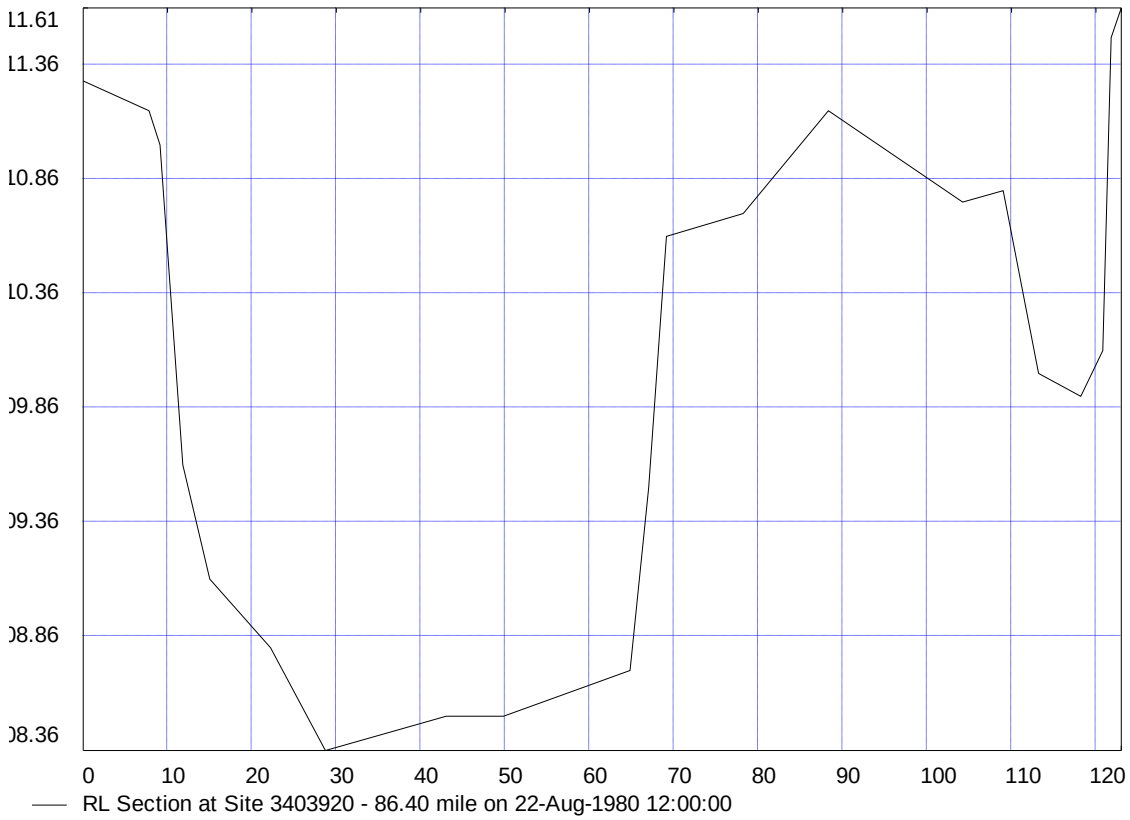
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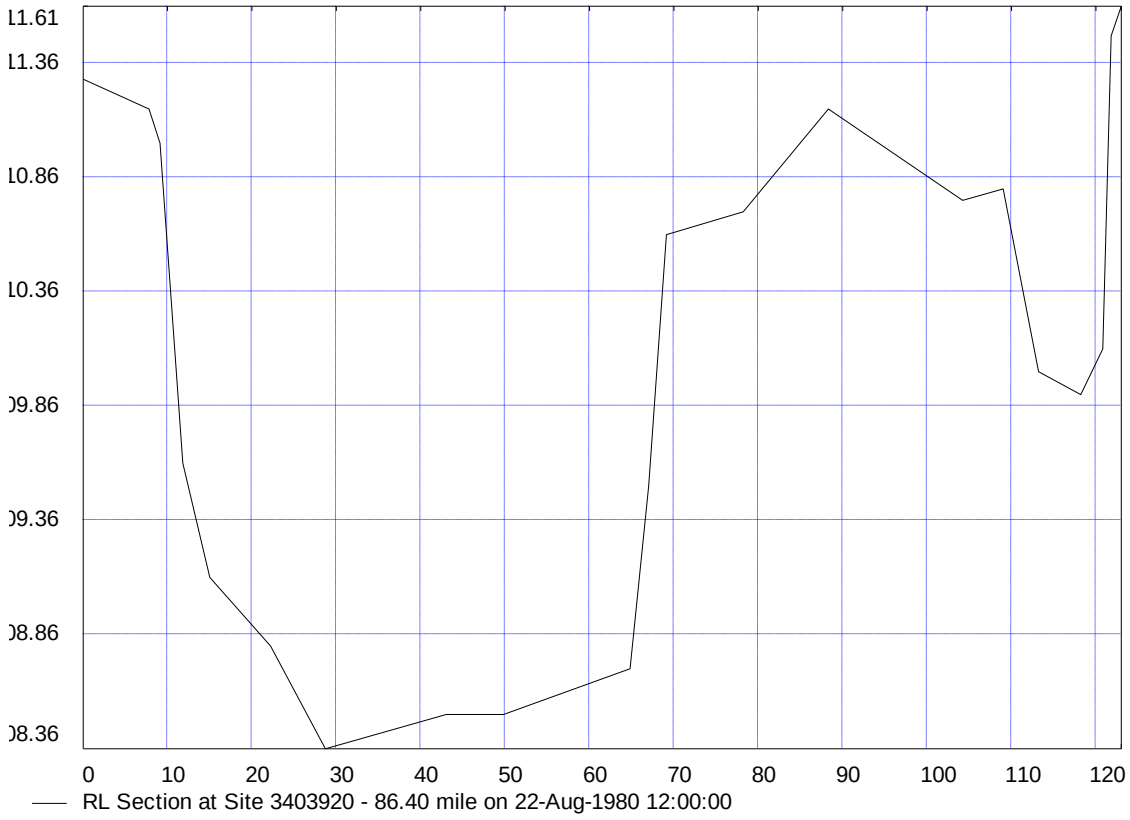
09.86
09.36
08.86
08.36
0
10
20
30
40
50
60
70
80
90
100
110
120
RL Section at Site 3403920 - 86.40 mile on 22-Aug-1980 12:00:00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09.36
08.86
08.36
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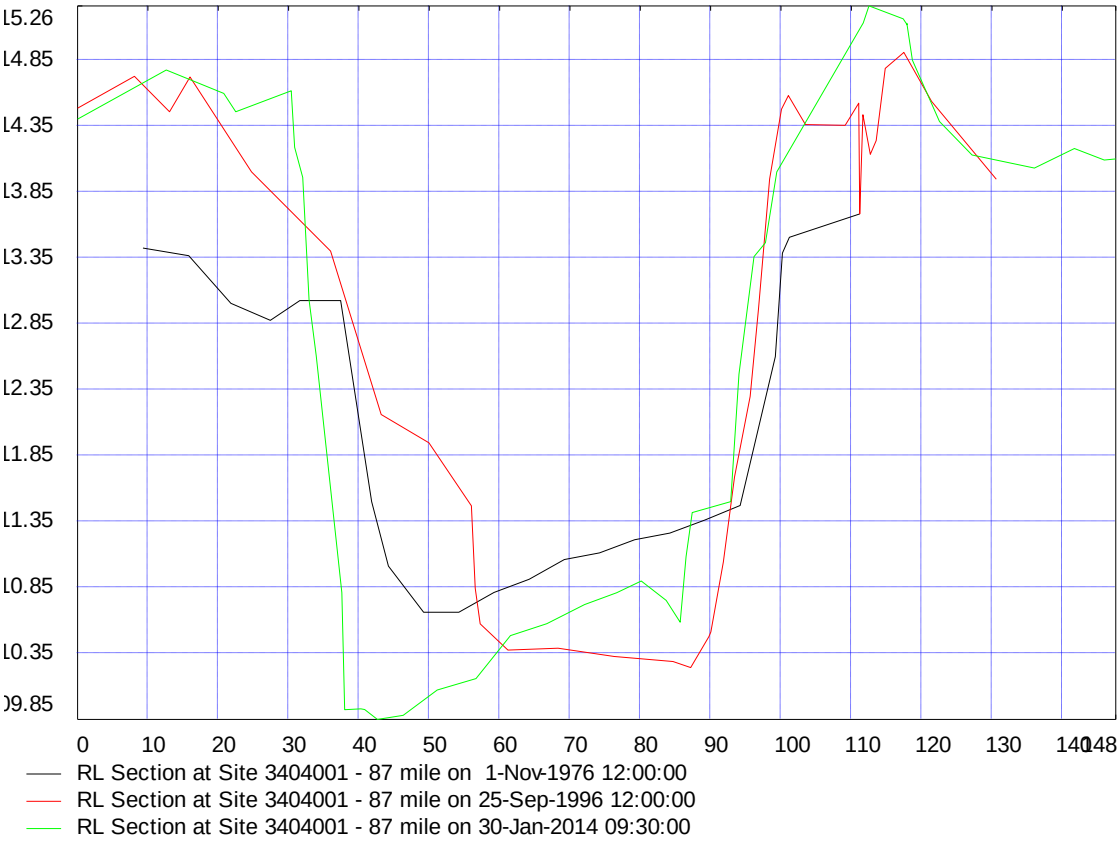
40
50
60
70
80
90
100
110
120
RL Section at Site 3403920 - 86.40 mile on 22-Aug-1980 12:00:00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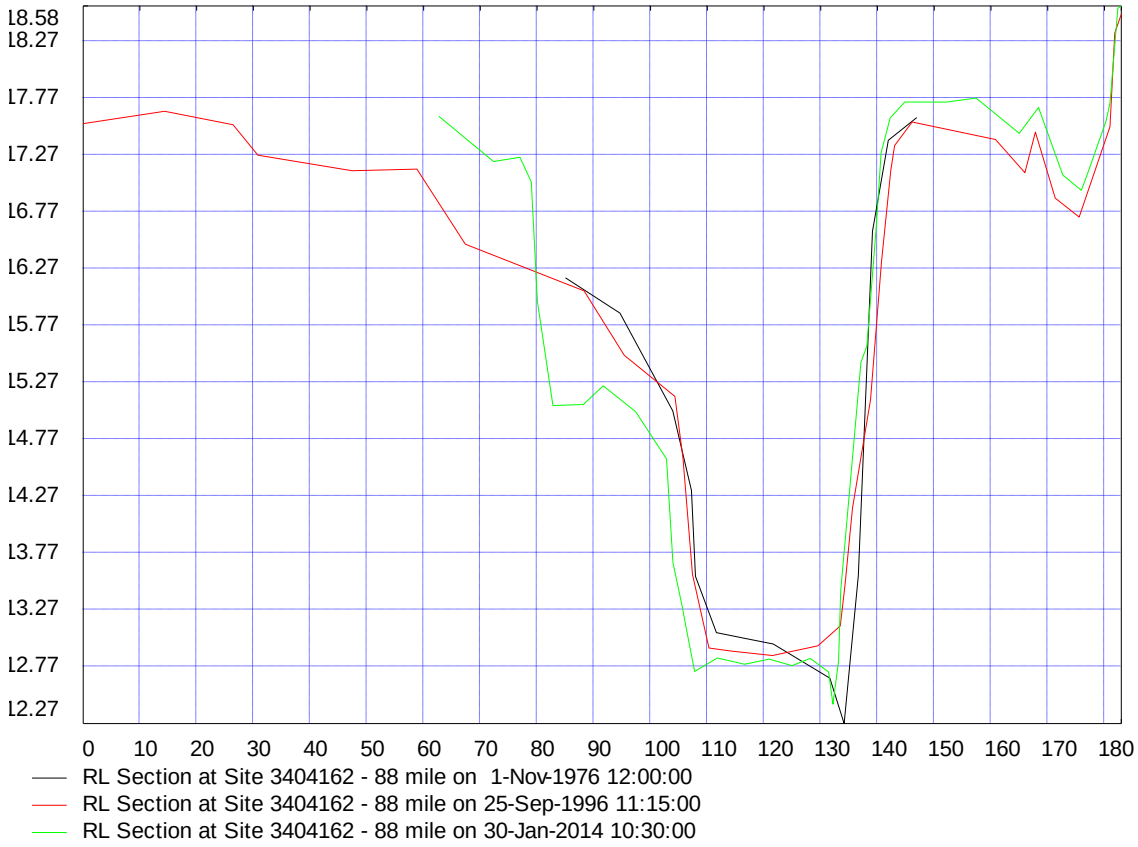
L4.35
L3.85
L3.35
L2.85
L2.35
L1.85
L1.35
L0.85
L0.35
09.85
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140148
RL Section at Site 3404001 - 87 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404001 - 87 mile on 25-Sep-1996 12:00:00
RL Section at Site 3404001 - 87 mile on 30-Jan-2014 09:30:00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l7.77
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l6.77
l6.27
l5.77
l5.27
l4.77
l4.27
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l3.27
l2.77
l2.27
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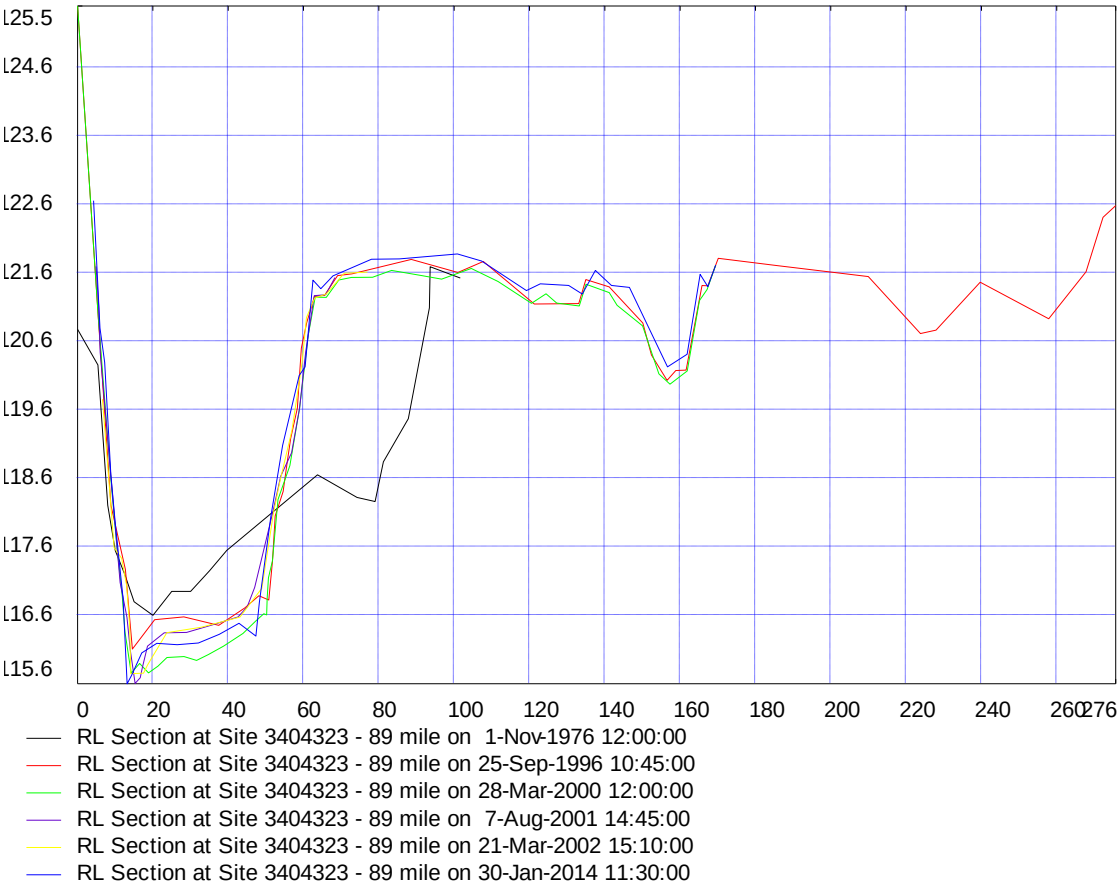
RL Section at Site 3404162 - 88 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404162 - 88 mile on 25-Sep-1996 11:15:00
RL Section at Site 3404162 - 88 mile on 30-Jan-2014 10:30:00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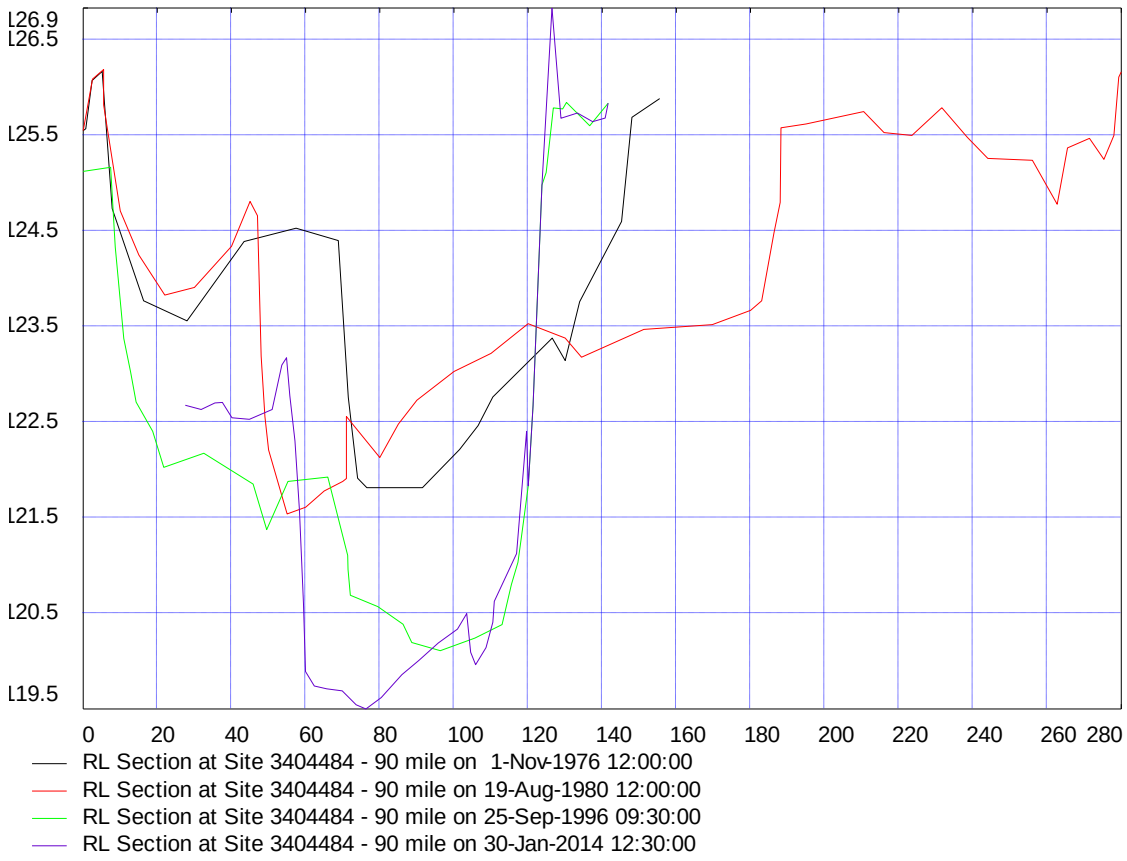
122.6
121.6
120.6
119.6
118.6
117.6
116.6
115.6
0
20
40
60
80
100
120
140
160
180
200
220
240
260
276
RL Section at Site 3404323 - 89 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404323 - 89 mile on 25-Sep-1996 10:45:00
RL Section at Site 3404323 - 89 mile on 28-Mar-2000 12:00:00
RL Section at Site 3404323 - 89 mile on 7-Aug-2001 14:45:00
RL Section at Site 3404323 - 89 mile on 21-Mar-2002 15:10:00
RL Section at Site 3404323 - 89 mile on 30-Jan-2014 11:30:00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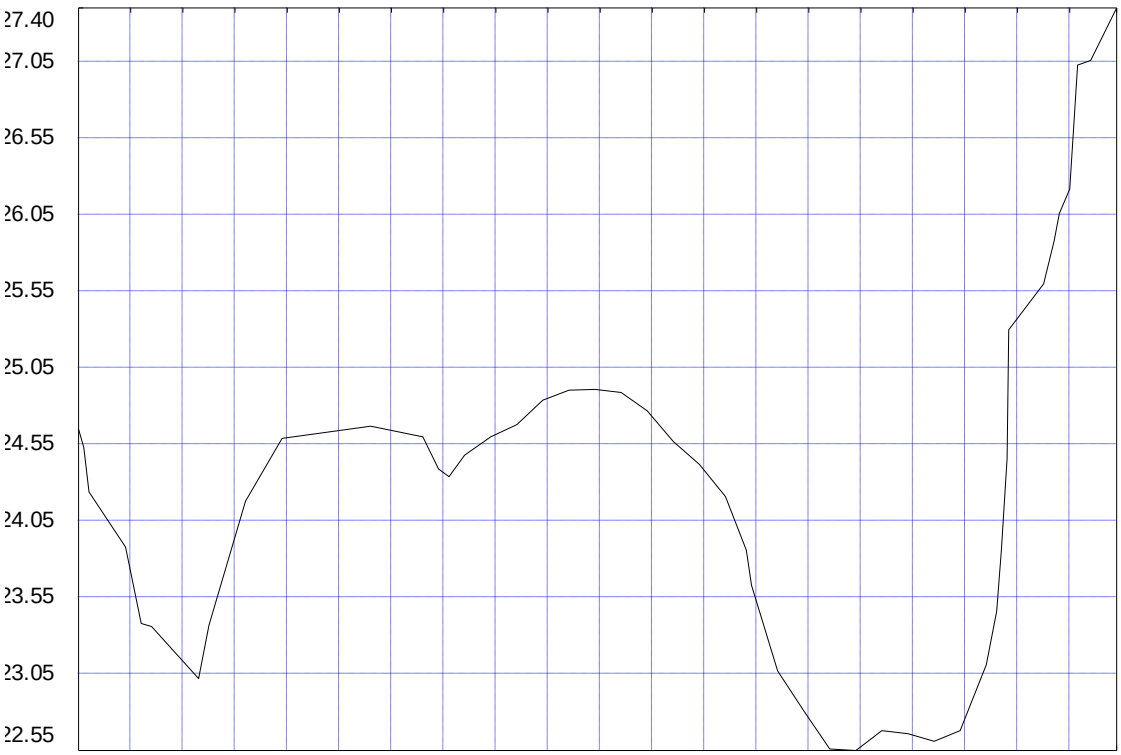
L26.5
L25.5
L24.5
L23.5
L22.5
L21.5
L20.5
L19.5
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
RL Section at Site 3404484 - 90 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404484 - 90 mile on 19-Aug-1980 12:00:00
RL Section at Site 3404484 - 90 mile on 25-Sep-1996 09:30:00
RL Section at Site 3404484 - 90 mile on 30-Jan-2014 12:30:00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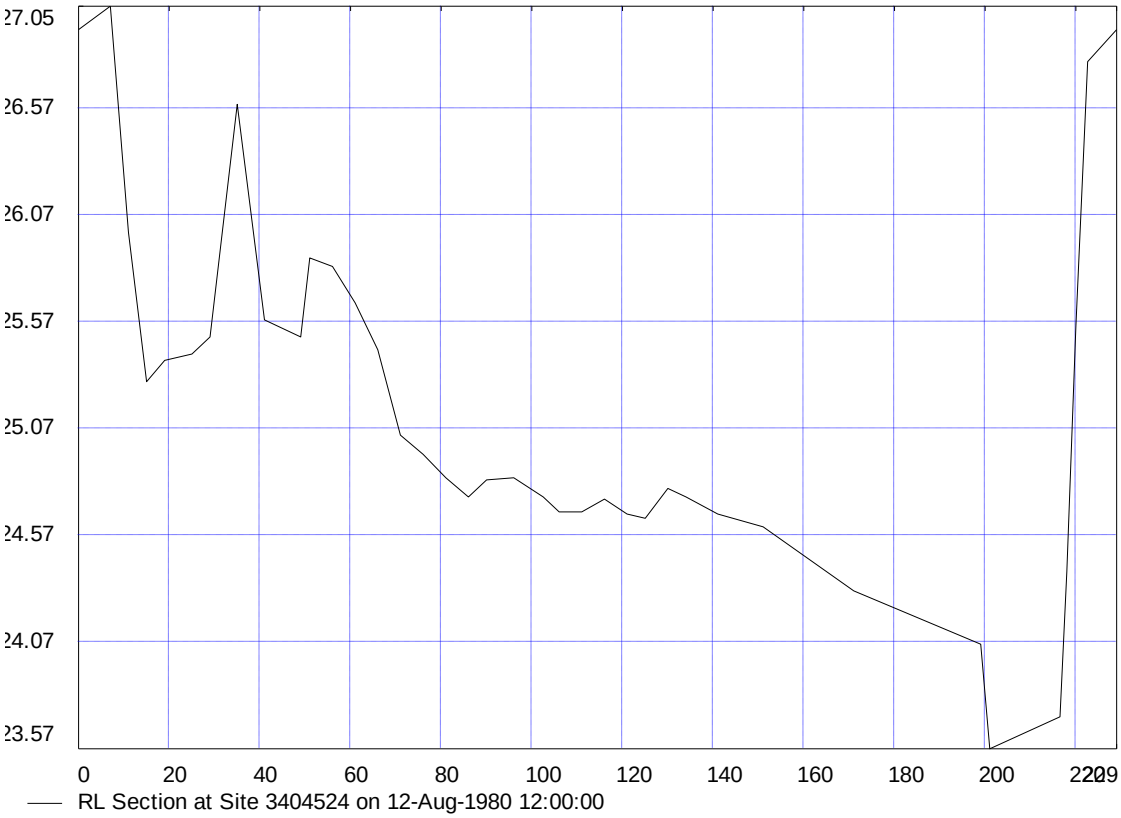
26.55
26.05
25.55
25.05
24.55
24.05
23.55
23.05
22.55
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 199
RL Section at Site 3404504 on 12-Aug-1980 12:00:00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24.57
24.07
23.57
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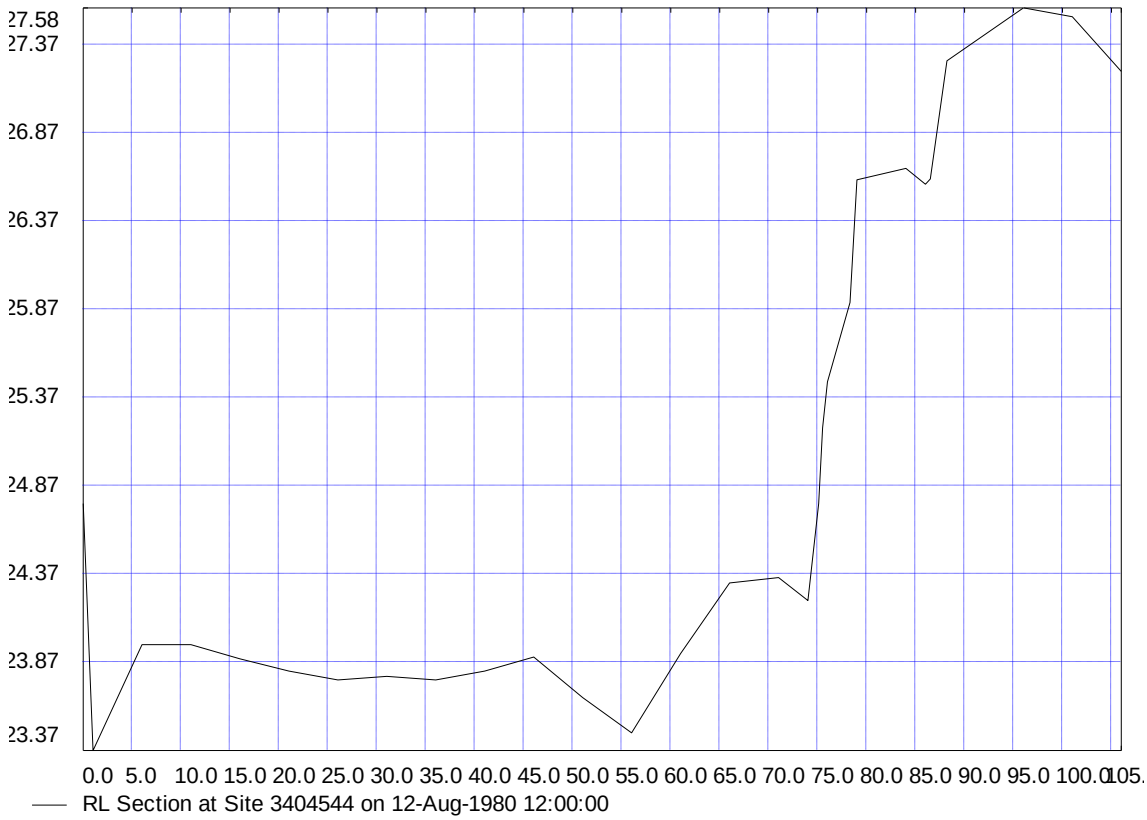
RL Section at Site 3404524 on 12-Aug-1980 12:00:00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23.37
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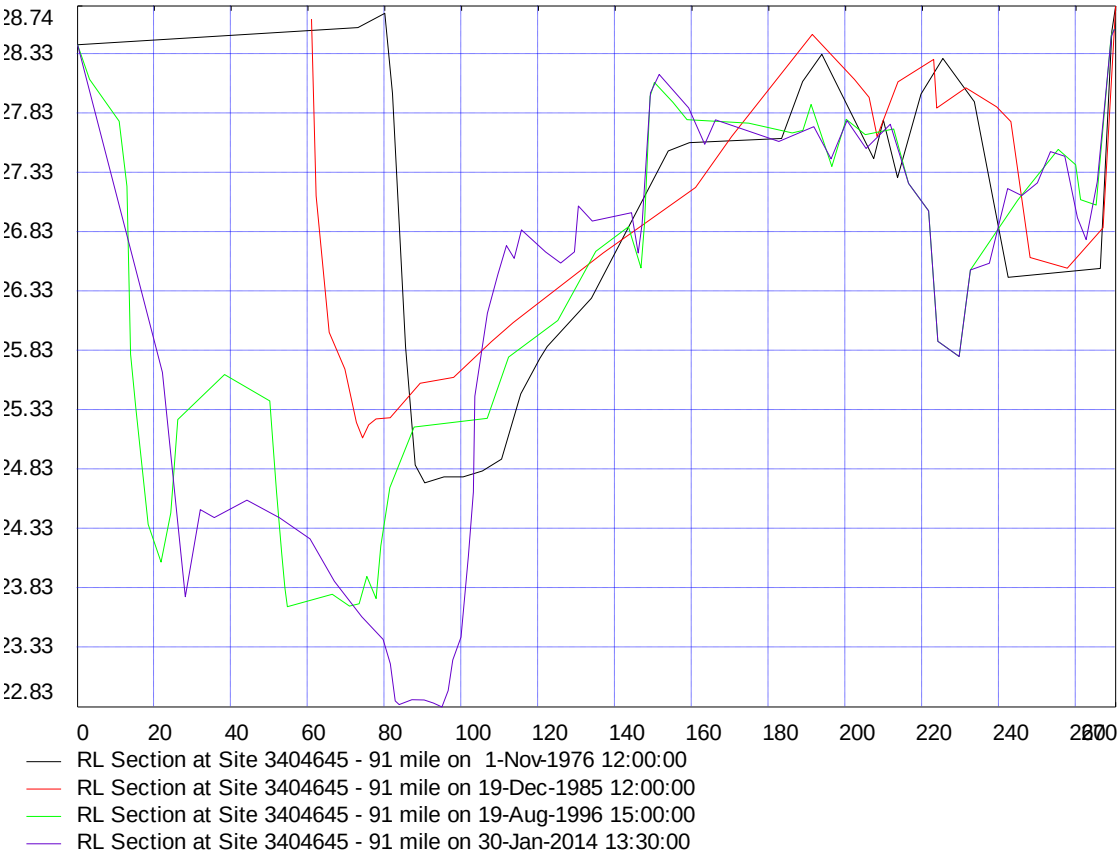
RL Section at Site 3404544 on 12-Aug-1980 12:00:00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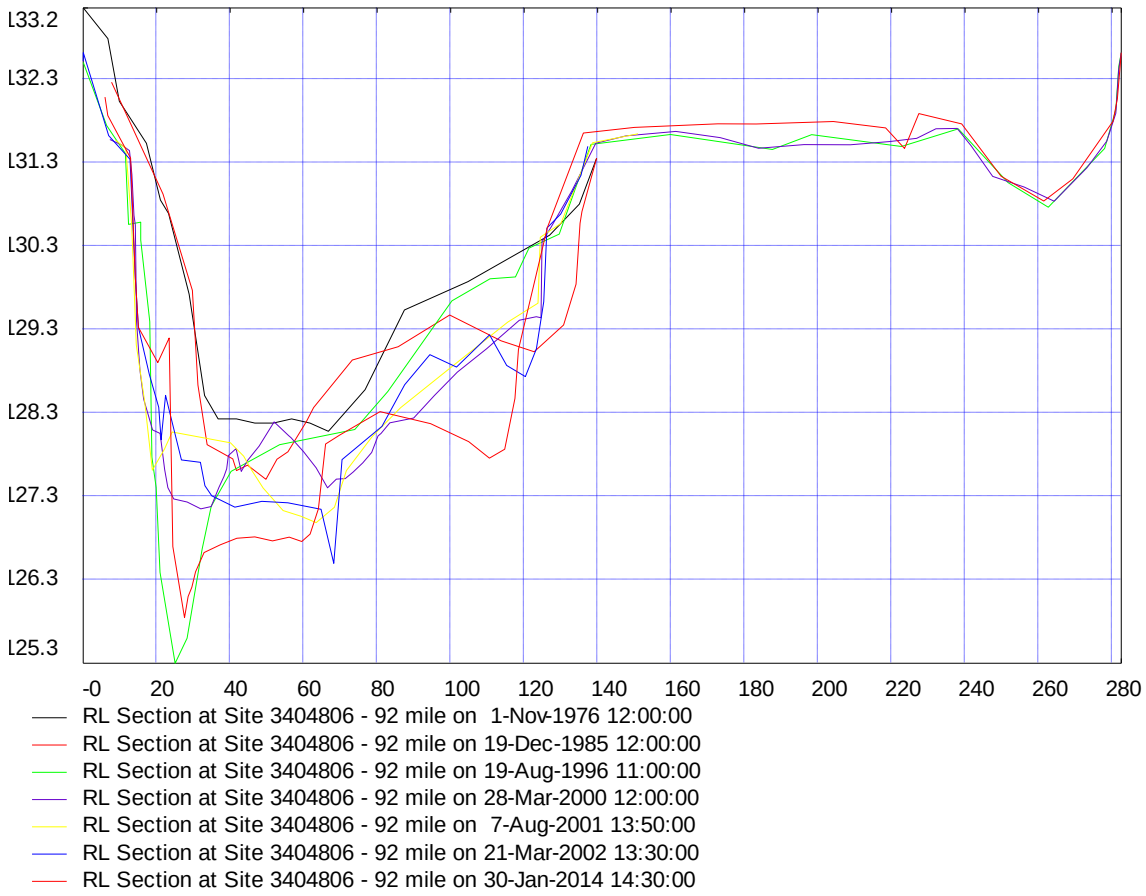
26.33
25.83
25.33
24.83
24.33
23.83
23.33
22.83
0
20
40
60
80
100
120
140
160
180
200
220
240
260
RL Section at Site 3404645 - 91 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404645 - 91 mile on 19-Dec-1985 12:00:00
RL Section at Site 3404645 - 91 mile on 19-Aug-1996 15:00:00
RL Section at Site 3404645 - 91 mile on 30-Jan-2014 13:30:00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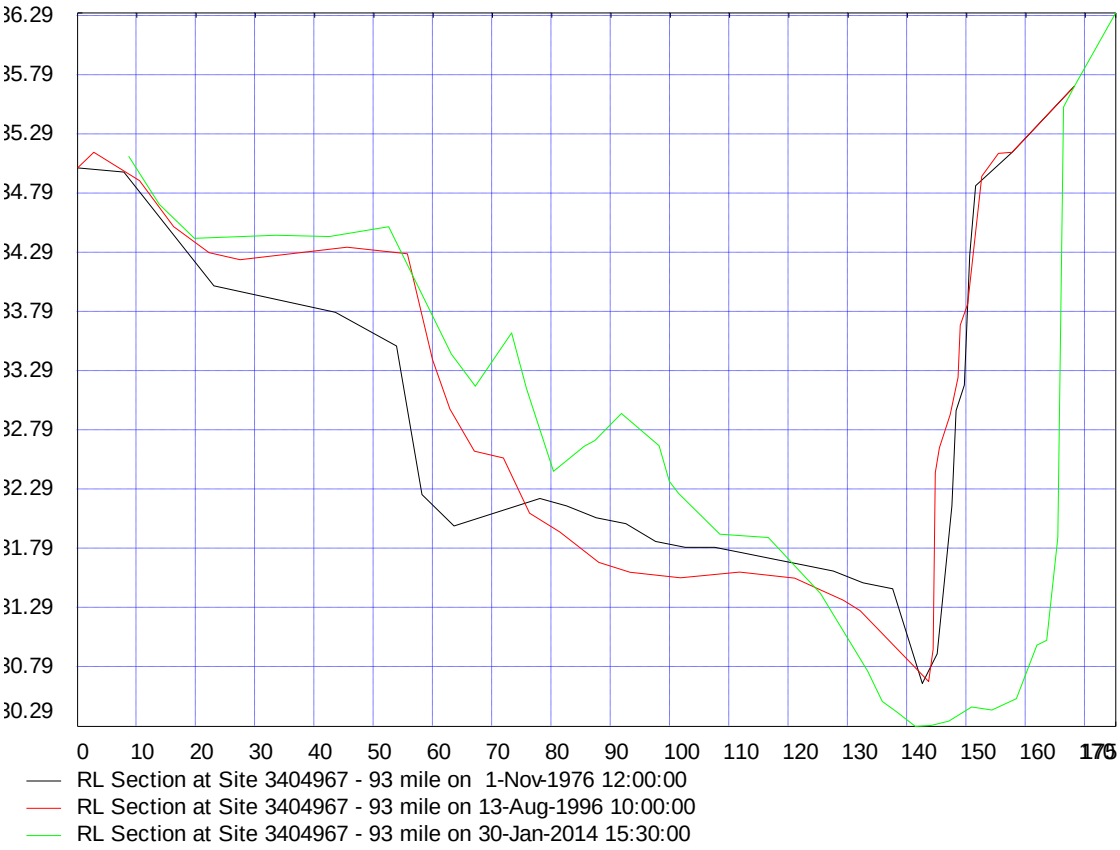
l32.3
l31.3
l30.3
l29.3
l28.3
l27.3
l26.3
l25.3
-0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
RL Section at Site 3404806 - 92 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404806 - 92 mile on 19-Dec-1985 12:00:00
RL Section at Site 3404806 - 92 mile on 19-Aug-1996 11:00:00
RL Section at Site 3404806 - 92 mile on 28-Mar-2000 12:00:00
RL Section at Site 3404806 - 92 mile on 7-Aug-2001 13:50:00
RL Section at Site 3404806 - 92 mile on 21-Mar-2002 13:30:00
RL Section at Site 3404806 - 92 mile on 30-Jan-2014 14:30:00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33.29
32.79
32.29
31.79
31.29
30.79
30.29
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
175
RL Section at Site 3404967 - 93 mile on 1-Nov-1976 12:00:00
RL Section at Site 3404967 - 93 mile on 13-Aug-1996 10:00:00
RL Section at Site 3404967 - 93 mile on 30-Jan-2014 15:30:00

Appendix D Gravel Extraction Records

Upper Manawatu River - Volume of Gravel Extracted Between Mile Marks (m^3)

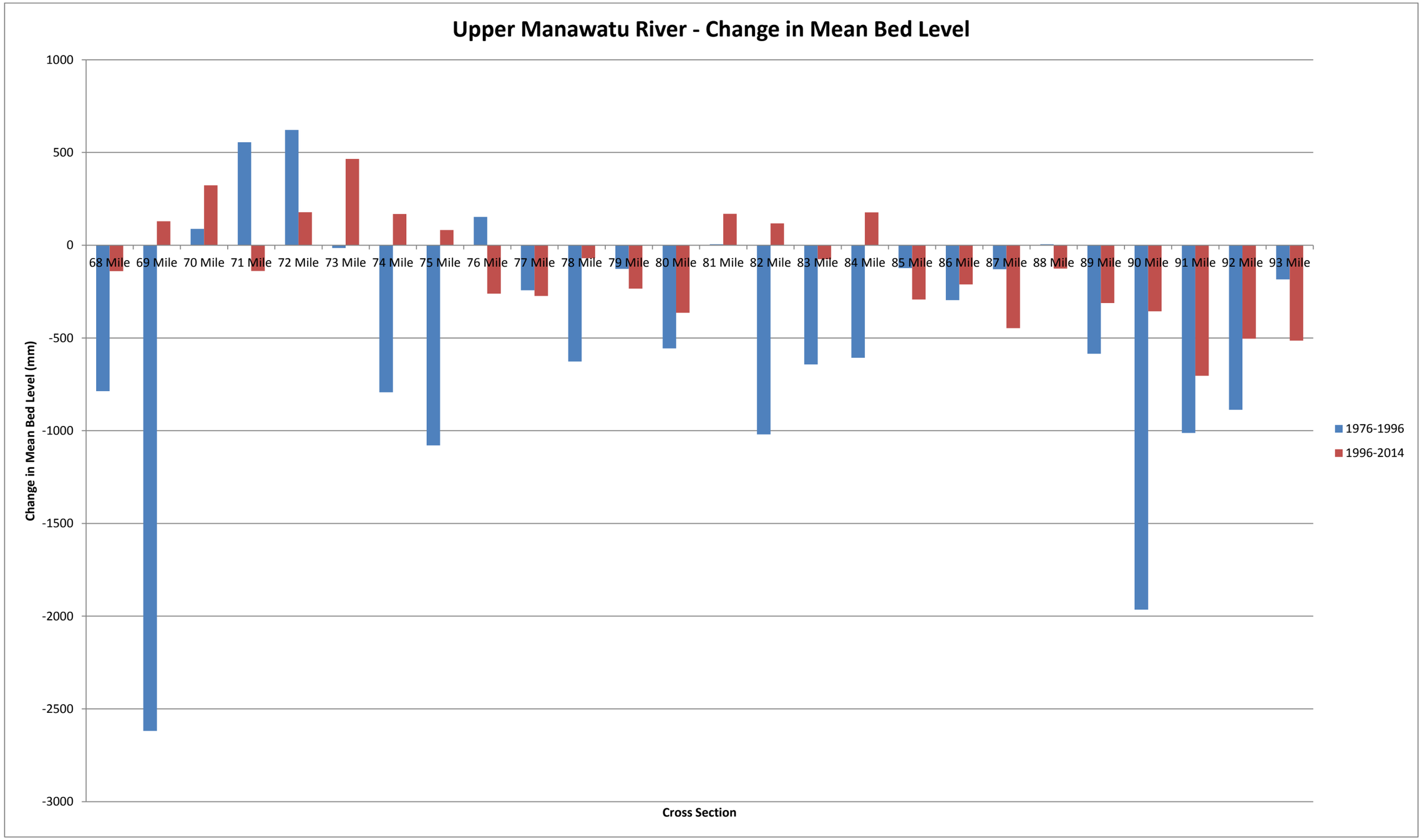
	68-69	69-70	70-71	71-72	72-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90	90-91	91-92	92-93
Oct 96 - Dec 97	0	1970	0	0	0	0	0	2301	1611	410	0	0	0	0	0	66	1450	6500	6500	0	0	0	2463.333	2463.333	17543.33
1998	0	1140	0	0	0	0	0	534	0	0	0	0	0	0	0	2950	0	277.5	277.5	0	0	0	30	30	1384
1999	0	0	0	0	0	0	0	332	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7673
2000	0	0	0	0	0	0	0	400	0	11250	5750	0	0	0	0	115	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	1750	1750	1750	1750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	225	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	3442.5	3442.5	3442.5	3442.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	1221.5	1221.5	1221.5	1221.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	3750	3750	3750	3750	0	0	0	0	133.2267	964.2602	475.5142	0	0	0	0	258.9278	119.9123	560.4866	560.4866	0	0	0	206.194	206.194	2199.798
2010	6247.25	6247.25	6247.25	6247.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	3750	3750	3750	3750	0	0	0	0	605.4842	4382.338	2161.101	0	0	0	0	1176.767	544.9734	2547.281	2547.281	0	0	0	937.1037	937.1037	9997.568
2012	5000	5000	5000	5000	0	0	0	0	306.105	2215.509	1092.554	0	0	0	0	594.9191	275.5135	1287.788	1287.788	0	0	0	473.7565	473.7565	5054.311
2013	5000	5000	5000	5000	0	0	0	0	468.6954	3392.296	1672.873	0	0	0	0	910.9159	421.855	1971.808	1971.808	0	0	0	725.3966	725.3966	7738.954
Total	**30,161**	**33,271**	**30,161**	**30,486**	**0**	**0**	**0**	**3,567**	**3,125**	**22,614**	**11,152**	**0**	**0**	**0**	**0**	**6,073**	**2,812**	**13,145**	**13,145**	**0**	**0**	**0**	**4,836**	**4,836**	**51,591**

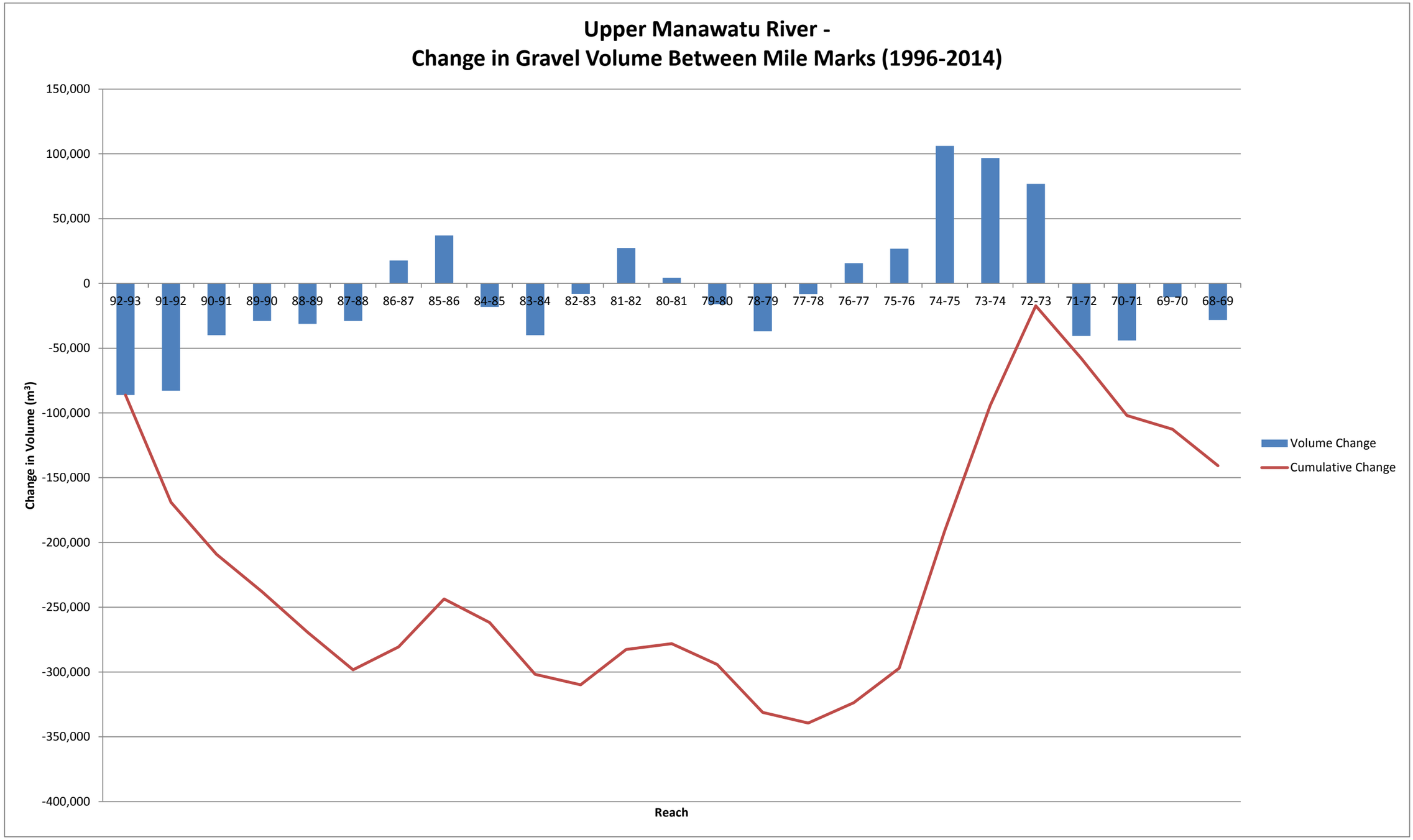
Appendix E Processed Data

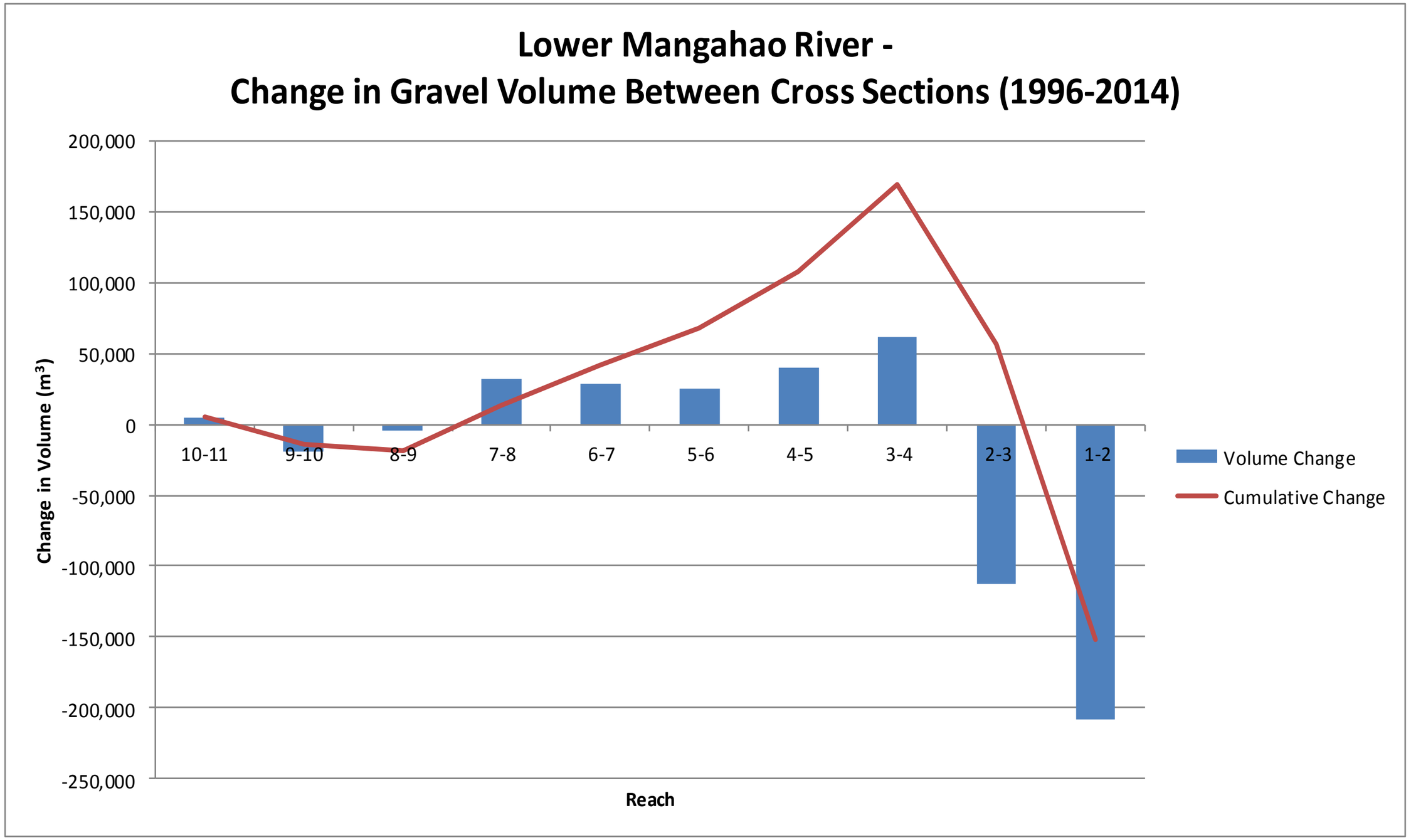
Upper Manawatu River

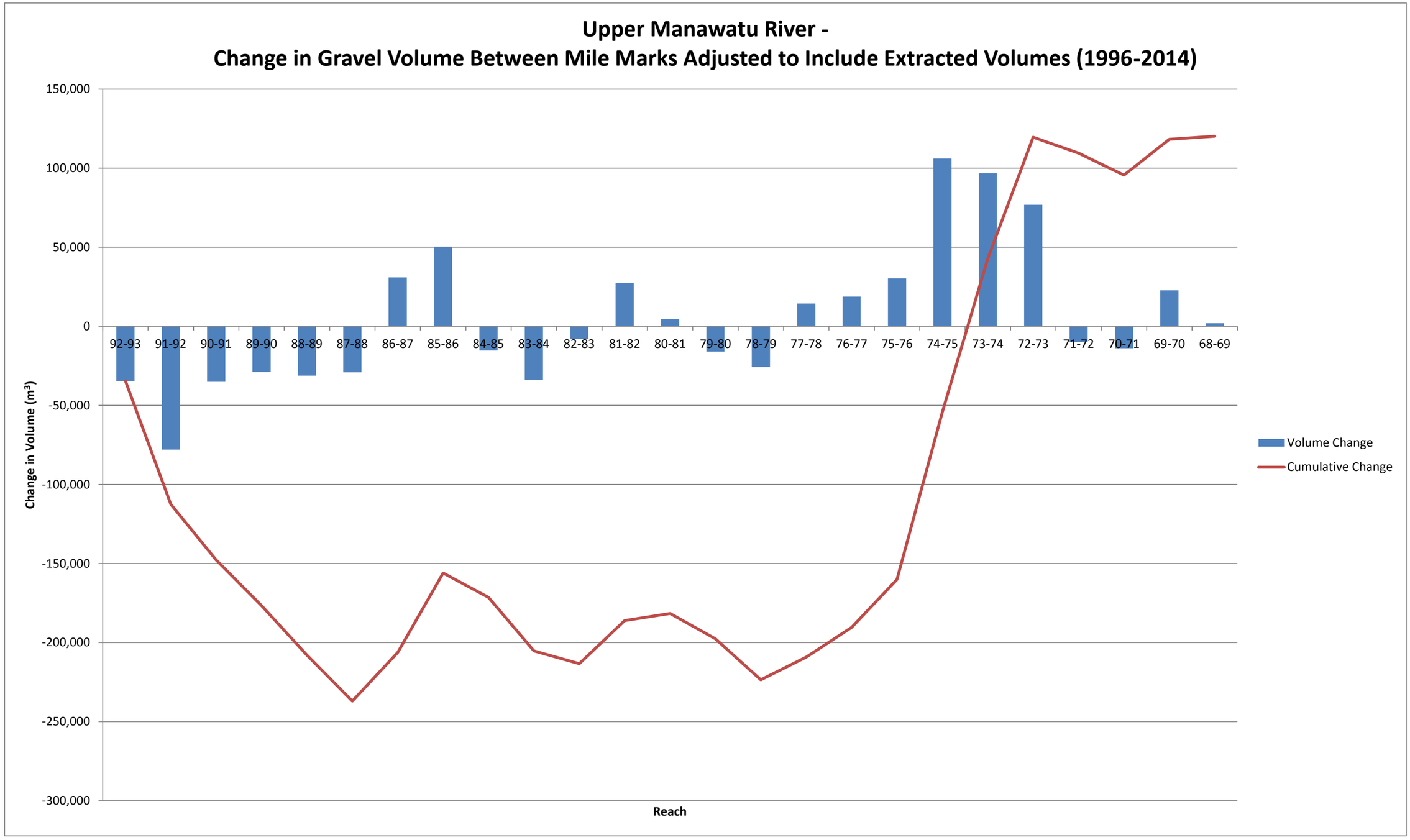
Reach	Volume of gravel in reach (m^3)			Volume Change (m^3)			Volume of Gravel Extracted (m^3)	Volume Change + Extracted Volume (m^3)			Mean bed level in reach (m above Datum)			Change in mean bed level (m)	
	1974	*1996*	*2014*	*1974-1996*	*1996-2014*	*Cumulative (1*	*1996-2014*	*1996-2014*	*Cumulative*		*1974*	*1996*	*2014*	*1974-1996*	*1996-2014*
68-69	19084880	18691680	18663440	-393200	-28240	-140770.5	30,161	1,921	120,204		63.6325	61.9295	61.924	-1.703	-0.0055
69-70	18924262	18522487	18511941	-401775.5	-10545.5	-112530.5	33,271	22,726	118,283		64.9965	63.731	63.957	-1.2655	0.226
70-71	21300703	21383940	21339826	83237	-44114	-101985	30,161	-13,953	95,557		65.742	66.0635	66.1555	0.3215	0.092
71-72	30123020	30304547	30263975	181527.5	-40572	-57871	30,486	-10,086	109,510		68.623	69.2115	69.231	0.5885	0.0195
72-73	19451135	19542583	19619380	91448	76797	-17299	0	76,797	119,596		70.478	70.7815	71.103	0.3035	0.3215
73-74	17766189	17801609	17898451	35420	96841.5	-94096	0	96,842	42,799		72.2375	71.8335	72.15	-0.404	0.3165
74-75	20103668	20134580	20240679	30912	106099	-190937.5	0	106,099	-54,043		74.762	73.826	73.951	-0.936	0.125
75-76	16127692	16111512	16138238	-16180.5	26726	-297036.5	3,567	30,293	-160,142		77.3305	76.8675	76.778	-0.463	-0.0895
76-77	17679571	17472767	17488384	-206804.5	15617	-323762.5	3,125	18,742	-190,435		80.1085	80.0635	79.7965	-0.045	-0.267
77-78	15033295	14860622	14852411	-172672.5	-8211	-339379.5	22,614	14,403	-209,176		83.0555	82.6205	82.449	-0.435	-0.1715
78-79	13261409	13300452	13263422	39042.5	-37030	-331168.5	11,152	-25,878	-223,579		86.208	85.8305	85.6785	-0.3775	-0.152
79-80	14356853	14362569	14346549	5715.5	-16019.5	-294138.5	0	-16,019	-197,701		89.4645	89.1225	88.8235	-0.342	-0.299
80-81	13290550	13280246	13284674	-10304	4427.5	-278119	0	4,428	-181,682		92.137	91.8615	91.764	-0.2755	-0.0975
81-82	13576245	13538329	13565619	-37915.5	27289.5	-282546.5	0	27,290	-186,109		94.708	94.2005	94.344	-0.5075	0.1435
82-83	10956292	10908072	10900022	-48219.5	-8050	-309836	0	-8,050	-213,399		97.271	96.4395	96.461	-0.8315	0.0215
83-84	12781600	12712080	12672080	-69520	-40000	-301786	6,073	-33,927	-205,349		99.852	99.227	99.278	-0.625	0.051
84-85	16429326	16362350	16344157	-66976	-18193	-261786	2,812	-15,381	-171,421		102.802	102.437	102.379	-0.365	-0.058
85-86	19246021	19169224	19206254	-76797	37030	-243593	13,145	50,175	-156,041		105.942	105.7325	105.4805	-0.2095	-0.252
86-87	20066074	20032747	20050457	-33327	17710	-280623	13,145	30,855	-206,216		109.308	109.0955	108.7665	-0.2125	-0.329
87-88	14895398	14922044	14892983	26645.5	-29060.5	-298333	0	-29,061	-237,070		112.047	111.985	111.6985	-0.062	-0.2865
88-89	15241629	15309732	15278498	68103	-31234	-269272.5	0	-31,234	-208,010		115.106	114.816	114.597	-0.29	-0.219
89-90	20851593	20796853	20767873	-54740	-28980	-238038.5	0	-28,980	-176,776		119.842	118.567	118.233	-1.275	-0.334
90-91	38994683	38650143	38610135	-344540	-40008.5	-209058.5	4,836	-35,173	-147,796		123.7635	122.275	121.745	-1.4885	-0.53
91-92	41083417	40782749	40699915	-300667.5	-82834.5	-169050	4,836	-77,999	-112,623		126.9455	125.996	125.392	-0.9495	-0.604
92-93	30472953	30410002	30323787	-62951	-86215.5	-86215.5	51,591	-34,625	-34,625		130.186	129.6505	129.1415	-0.5355	-0.509

Appendix F Graphs


Upper Manawatu River - Change in Mean Bed Level
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
68 Mile
69 Mile
70 Mile
71 Mile
72 Mile
73 Mile
74 Mile
75 Mile
76 Mile
77 Mile
78 Mile
79 Mile
80 Mile
81 Mile
82 Mile
83 Mile
84 Mile
85 Mile
86 Mile
87 Mile
88 Mile
89 Mile
90 Mile
91 Mile
92 Mile
93 Mile
Change in Mean Bed Level (mm)
Cross Section
1976-1996
1996-2014


Upper Manawatu River -
Change in Gravel Volume Between Mile Marks (1996-2014)
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
-300,000
-350,000
-400,000
Change in Volume (m³)
92-93
91-92
90-91
89-90
88-89
87-88
86-87
85-86
84-85
83-84
82-83
81-82
80-81
79-80
78-79
77-78
76-77
75-76
74-75
73-74
72-73
71-72
70-71
69-70
68-69
Reach
Volume Change
Cumulative Change


Lower Mangahao River -
Change in Gravel Volume Between Cross Sections (1996-2014)
200,000
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
Change in Volume (m³)
10-11
9-10
8-9
7-8
6-7
5-6
4-5
3-4
2-3
1-2
Reach
Volume Change
Cumulative Change


Upper Manawatu River -
Change in Gravel Volume Between Mile Marks Adjusted to Include Extracted Volumes (1996-2014)
150,000
100,000
50,000
0
-50,000
-100,000
-150,000
-200,000
-250,000
-300,000
Change in Volume (m³)
92-93
91-92
90-91
89-90
88-89
87-88
86-87
85-86
84-85
83-84
82-83
81-82
80-81
79-80
78-79
77-78
76-77
75-76
74-75
73-74
72-73
71-72
70-71
69-70
68-69
Reach
Volume Change
Cumulative Change