Mangatainoka Gravel Resource Study

October 2023

horizons
REGIONAL COUNCIL

Author
Bernadette Pancho
Graduate Design Engineer

Acknowledgements to
Jesse Adams
Craig Bleakley
Luke Fullard
Julia Jung
Michaela Rose
Nelly Skelton
Andrew Steffert
Ella Whale

Front Cover Photo by Nelly Skelton
(Mangatainoka 2023 Aerial Photo
at Pahiatua near the water treatment plant)

ISBN: 9781991061386
Report No: 2023/EXT/1821

CONTACT 24 hr freephone 0508 800 80 Help@horizons.govt.nz www.horizons.govt.nz

SERVICE CENTRES	Kairanga Cnr Rongotea and Kairanga-Bunnythorpe Roads Palmerston North Marton 19 Hammon Street Taumarunui 34 Maata Street	REGIONAL HOUSES	Palmerston North 11-15 Victoria Avenue Whanganui 181 Guyton Street	DEPOTS Taihape 243 Wairanu Road Taihape Woodville 116 Vogel Street

POSTAL ADDRESS Horizons Regional Council, Private Bag 11025, Manawatū Mail Centre, Palmerston North 4442 F 06-952 2929

EXECUTIVE SUMMARY

This study examines the gravel resources of the Mangatainoka River based on an analysis of fluvial cross section surveys. The study area covers the length of the Mangatainoka River, from its confluence with the Tiraumea River to the headwaters located approximately 500 metres upstream of Wilsons Road, Putara ("the study area"). The purpose of this analysis is to identify any trends of aggradation or degradation that may be occurring to the gravel resource of the river.

This study predates and assesses the available past data from the year 1978 to 2022, which excludes the effects of Cyclone Gabrielle last 16 February 2023 and the April 2023 flooding event in the Mangatainoka catchment.

Analysis of five cross section surveys carried out during 1978, 1991, 2001, 2015, and 2022 ("the study period") have identified the following:

- There is an overall fluctuating trend in the mean bed elevation over the course of the study period.
- From Bridge Road bridge to Rail bridge, the middle reach of the study area gravel has accumulated at a rate of 10,050 m^3 for the period of 1978 to 1991 or 770m^3 per annum. In 1991-2002, the middle reaches have degraded at a rate of 703,200 m^3 or 63,927m^3 loss per annum.
- In the upper reach of the study area, the general trend for the assessment periods is static change in gravel volume. It is likely that the relatively steep channel and bluffs prevent gravel build-up at the bed and beaches in this location.
- In the lower reaches, the general trend for all four assessment periods is that of a gravel volume loss.
- The gravel loss volumes exceed the volume of gravel gains; therefore, this study concludes that the gravel resources of the Mangatainoka River have degraded over the study period.
- In the period of 2015 to 2022, channel degradation was found to be 460,875 m^3 much lesser compared to the previous period 2001-2015, which yielded a total of 26,025 m^3 amounting to 3,700 m^3 per annum of degradation.
- Reported extracted volume values for the years 2015 to 2022 totalled 105,717 m^3; 15,100 m^3 per annum.
- The 2017 and 2023 gravel studies revealed comparable trends of degradation; from 1978 to 1991, the catchment has continued to record a degrading trend; both studies recorded an aggradation in the middle reach between 2001 and 2015 for the catchment. The offsets used in the previous study were lost and have been recalculated. The calculated volumes between the gravel studies differ due to the use of different offsets. The resulting trends of the 2017 and 2023 study yielded comparable results.
- The study confirms the overall resulting catchment trend of degradation with the Mangatainoka Gravel Study done in 2017.
- Based on gravel extraction records, the average annual gravel extraction rate has been calculated at 13,100 m^3 The One Plan long term average annual allocable volume for the Mangatainoka River is 15,000 m^3. Considering the absence of any degradation/aggradation trends present during the study period, the One Plan limit for the Mangatainoka is appropriate to minimise any negative effects associated with gravel extraction. It is recommended that gravel extraction is focused on the high beaches located in the aggrading reaches that are beyond the re-working zone.
- There is scope to increase the rate of extraction of two or three times over the long-term average, for a short period of time. The extraction should be carried out in the aggradation zone in a manner that reduces channel distortions at bends and along reaches and targets the long-term storage areas beyond the re-working action of the river.
- The gravel loss volumes exceed the volume of gravel gains; therefore, this study concludes that the gravel resources of the Mangatainoka River have degraded over the study period.

Overall trend of the gravel resources of the Mangatainoka River study area have degraded over the study period, while they have been slowly replenishing in the recent years the allocable volume is appropriate.

- The study further recommends a resurvey in the year 2025. Additionally, it is recommended that a more recent LiDAR (Light Detection and Ranging) be flown to enable Difference of DEMs or DoD analysis. The DoD would enable a spatial representation (morphology) of the gravel volume and change of gravel volume along the river based on two DEMs (Digital Elevation Model) of different years.

TABLE OF CONTENTS

Mangatainoka River Gravel Study

1.0 Introduction

1.1 Aim

The aim of this report is to identify any trends of gravel aggradation or degradation that may be occurring to the gravel resource of the Mangatainoka River, and to determine if the restriction in gravel extraction volumes has halted channel degradation identified in the late 1970s. The report aims to determine if the long term average annual allocable volume of gravel listed in Table 17.1 of the One Plan is appropriate for river sustainably gravel extraction volumes.

1.2 Study Area

The Mangatainoka River has a single channel and flows along a relatively broad valley that is infilled with fluvial sediments derived from the Tararua Ranges. The river sits on the underlying baserock and moves the gravel material of the channel and flood plain by an erosion and deposition movement of the channel within the entrenchment. Substantial bed degradation is prevented by the underlying baserock, and the channel shape and bed levels vary in accordance with the meander movements of the channel. The Mangatainoka River catchment is now largely converted from forest to pasture and has undergone extensive channel change as a result (Williams, 2002).

During the 1960s and 1970s the catchment experienced a phase of infrastructure development. Much of the gravels used during this expansion were sourced from the Mangatainoka River. By the late 1970s it became apparent that the extraction of gravels was causing channel degradation. Since this time, gravel extraction has been restricted to retard channel degradation. The annual average extraction rate has been set at 15,000 m^3 per annum in the One Plan.

This study examines the gravel resources in the Mangatainoka River, based on an analysis of river ("fluvial") cross section survey data. The Mangatainoka River cross section study area ranges from its confluence with the Tiraumea River (near Ngawapurua) to a point in the headwaters located approximately 500 metres upstream of Wilsons Road, Putara (see below for location map).

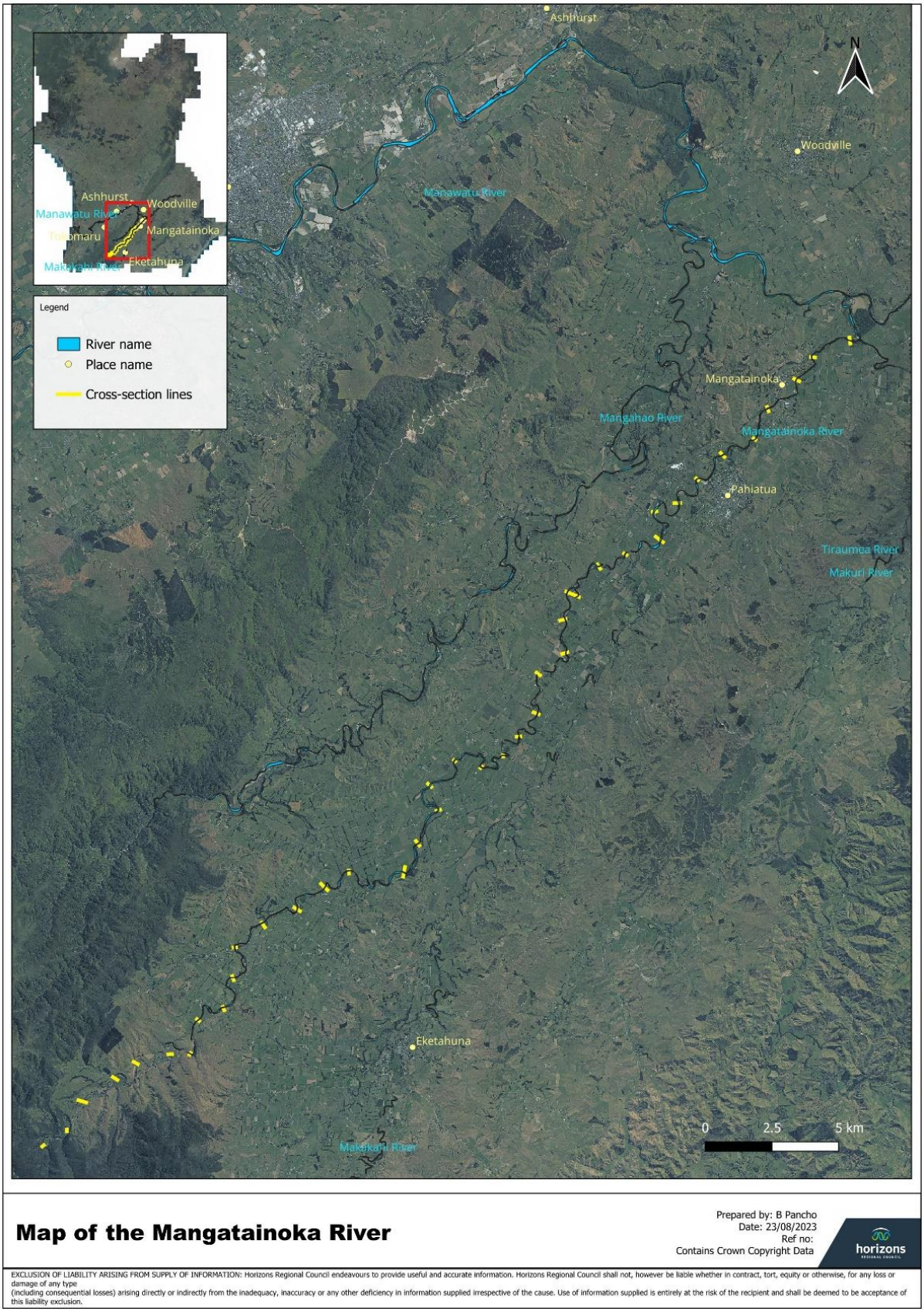


Figure 1: Map of Mangatainoka River and cross section locations

The surveyed cross sections are located 1.5 kilometres apart. This study analyses five cross sectional surveys undertaken in 1978/1977, 1991, 2001/2002, 2015, and 2022 examining the changes in the cross sectional areas over time.

The previous gravel resource study completed in 2017 analysed four cross sectional surveys in 1978, 1991, 2001 and 2015. The surveys were filed to the Wellington 1953 datum; all surveys have been corrected to the current datum NZVD 2016.

Due to the inability to replicate the 2017 data, the analysis has been recalculated for comparability. The offsets of certain cross sections with missing data were extended to allow Hilltop Hydro to calculate the mean bed level and area under the section. This resulted in different calculated volumes where an inflated degradation has been depicted in the calculation. The trends of both studies are comparable.

Period of study	2017 Volume of gravel degradation (m^3/yr)	2023 Volume of gravel degradation (m^3/yr)
1978-1991	24,000 m^3	38,500 m^3
1991-2001	65,700 m^3	132,360 m^3
2001-2015	11,000 m^3	34,700 m^3
2015-2022		3,700 m^3

Table 1.1 Summary of gravel degradation from 1978 to 2022

1.3 2017 Gravel Study

The 2017 Gravel study concluded the following:

- The Mangatainoka River mean bed elevation has both increased and decreased in elevation over the study period.
- No consistent degradation or aggradation has occurred in a reach of the study area, and that channel degradation identified in the late 1970s has been arrested.
- Overall, the assessment of the change in gravel volume and cumulative changes to the gravel volume under the active channel, indicates that the gravel resource is aggrading in the middle reaches of the study area, and degrading in the lower reach of the study area.
- The gravel loss volumes exceed the gravel volume gains, therefore overall, the gravel resource has degraded over the study period with aggradation occurring in the middle reaches.
    - The net per annum change in gravel volume for the period 1978 to 1991 has been calculated at a loss of 24,000 m^3.
    - The net per annum change in gravel volume for the period 1991 to 2001 has been calculated at a loss of 65,700 m^3.
    - The net per annum change in gravel volume for the period 2001 to 2015 has been calculated at a loss of 11,000 m^3.

2.0 Analysis of Cross Section Survey Data

To determine the change in the gravel resource of the Mangatainoka River, the gravel volume under the active channel was calculated using Hilltop Hydro and Microsoft Excel. The active channel is defined as the area that includes the wetted channel and the gravel beaches located above normal water levels. The mean bed level was assessed in this study which considers the boundaries of the wetted channel. The One Plan defines active bed as the bed of a river that is intermittently flowing and where the bed is predominantly unvegetated and comprises sand, gravel, boulders, or

similar material. Figure 2 below illustrates the channel cross section areas of analysis for a gravel-cross section.

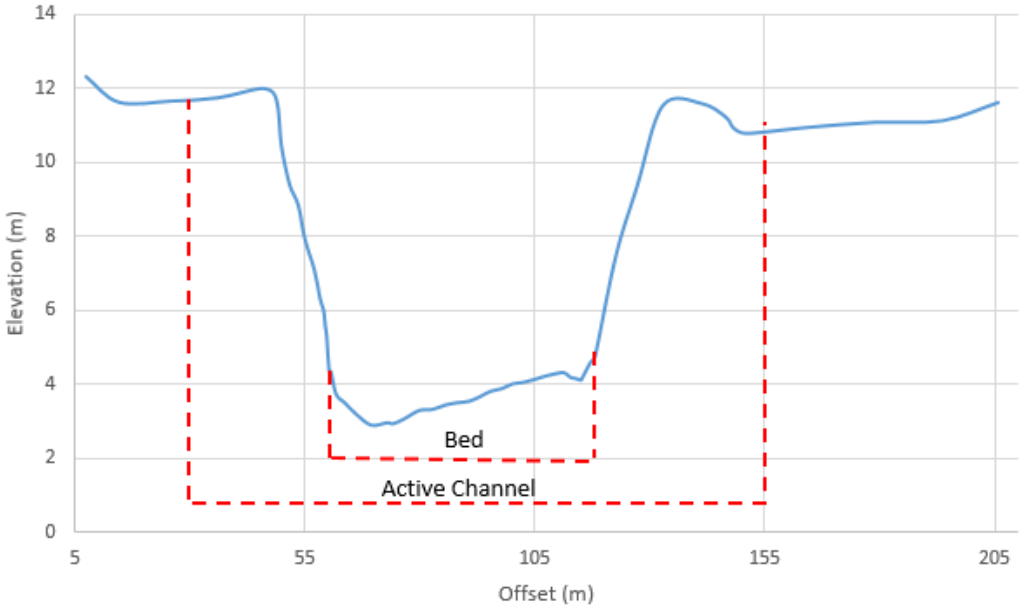


Figure 2: Conceptual channel cross section for a gravel section

Cross sections were over-plotted and analysed in Hilltop Manager (see Appendix F) to determine the extents of the active channel at each cross section location. In cases where visual inspection was not feasible, historical aerial images using ArcMap were examined to determine cross section extents. Hilltop Hydro was used to calculate gravel volume and the mean bed level. The cross sectional surveys, defined offsets, and datum used can be found in the Appendices (A to F of this report).

2.1 Analysis of the Gravel Resources under the Active Channel

Each period of the individual cross sections was analysed using Hilltop whereby the study period: 1978/1977, 1991, 2001/2002, 2015, and 2022 was plotted using the over plot function on Hilltop Manager. Considering the extent to where the active channel is for all the years, the left and right offsets were established in Appendix A. The datum for the purposes of this analysis was set as 0. The area under the section of each year was obtained using the "Section over Time" feature of Reach function in Hilltop Hydro.

The volume was then calculated using the following formula:

Change in volume = V 2015 – V 2022

Vx = (S2 – S1) x ((A2 + A1)/2)

Where:

- V 2015 is the calculated volume from 2015 sections
- V 2022 is the calculated volume from 2022 sections
- Vx is the volume of the year of interest
- S1 is the downstream section distance from the confluence with the Tiraumea
- S2 is the upstream section distance from the confluence with the Tiraumea
- A1 is the area under the bed at the downstream section
- A2 is the area under the bed at the upstream section

The mean average area under the bed for consecutive cross sections is taken, measured and multiplied by the distance between the two sections to derive a volumetric change for the length of the river.

2.1.1 Results of Gravel Volume Change

Calculated results of the area and volume change can be found in Appendix A.

Figure 3 shows all the periods plotted together showing the trends in the change in gravel volume. It is observed that the gravel resources have aggraded and degraded in volume over the four assessment periods from 1978 to 2022. The results of this study have determined an overall trend of degradation through the catchment from 1978-2022.

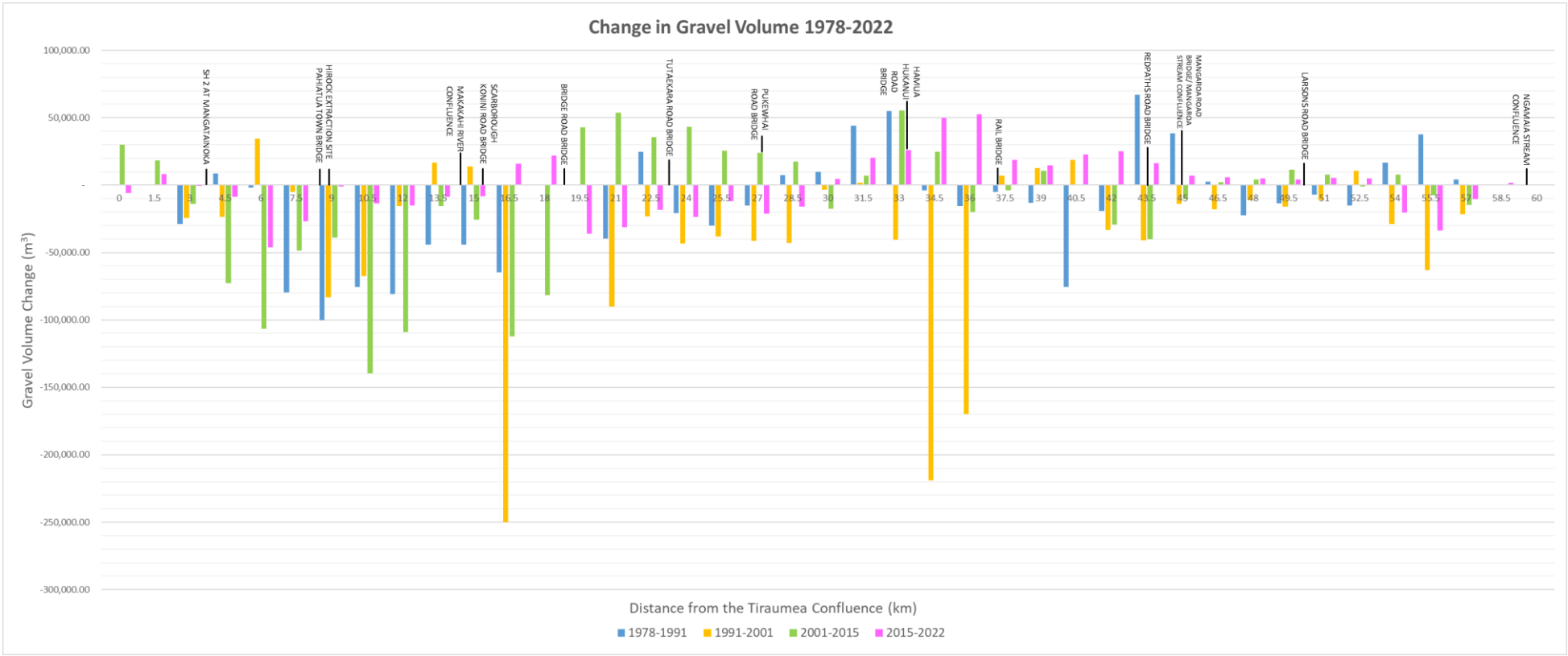


Figure 3: Gravel volume change 1978-2022

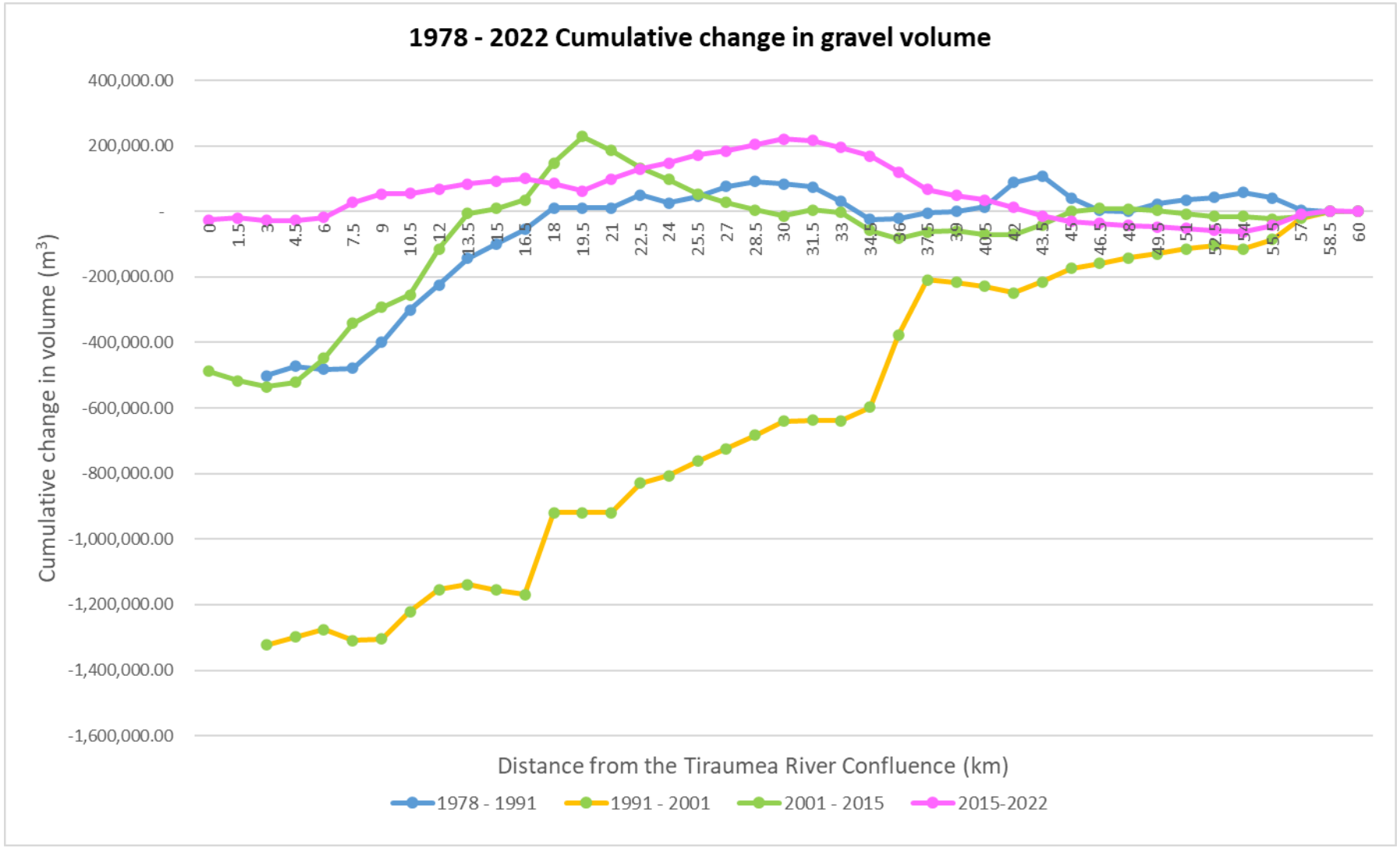


Figure 4: Cumulative change in volume (m^3) 1978-2022

Figure 4 in the previous page shows the cumulative change in volume (m^3) for the periods of 1978 to 2022. Periods 1978-1991 and 2001-2015 can be seen to have similar gravel volume trends. The cumulative volume change of gravel for 1991-2001 is degrading. For the most recent period of 2015-2022, the trend is stable with minimal changes to both aggradation and degradation. The lower reaches have been aggrading since previous surveys in 2015.

For the specific period of 1978-1991 shown in Figure 5 below, there was an overall degrading net gravel volume of 501,375 m^3, which is about 38,500 m^3 per annum of gravel degradation.

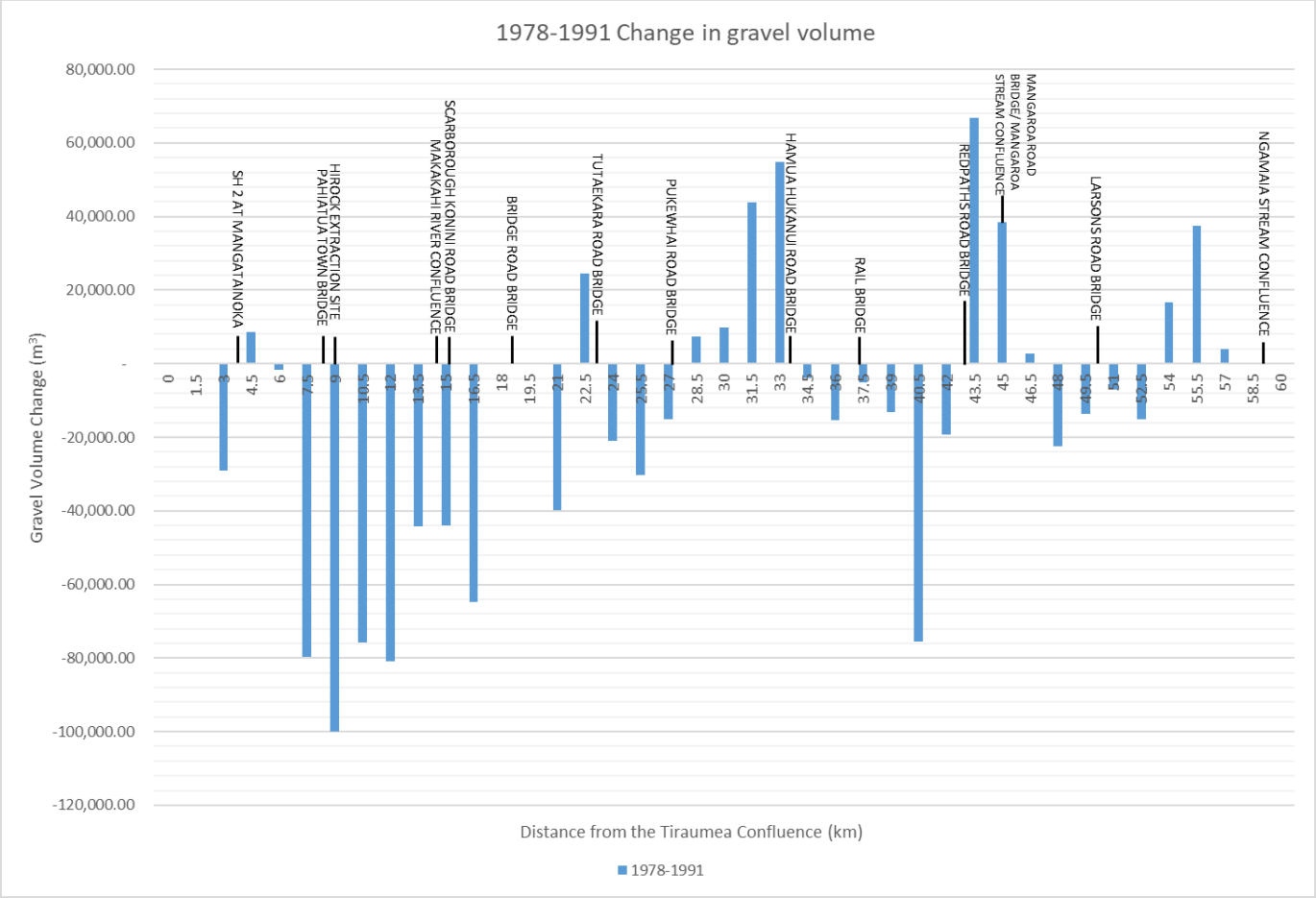


Figure 5: Gravel volume change 1978-1991

Figure 6 below shows that a gravel volume degradation pattern is dominant across the entire reach of the Mangatainoka River study area for the period of 1991-2001. A total net loss of 1,323,600 m^3 has occurred amounting to approximately 132,360 m^3 of gravel degradation per year.

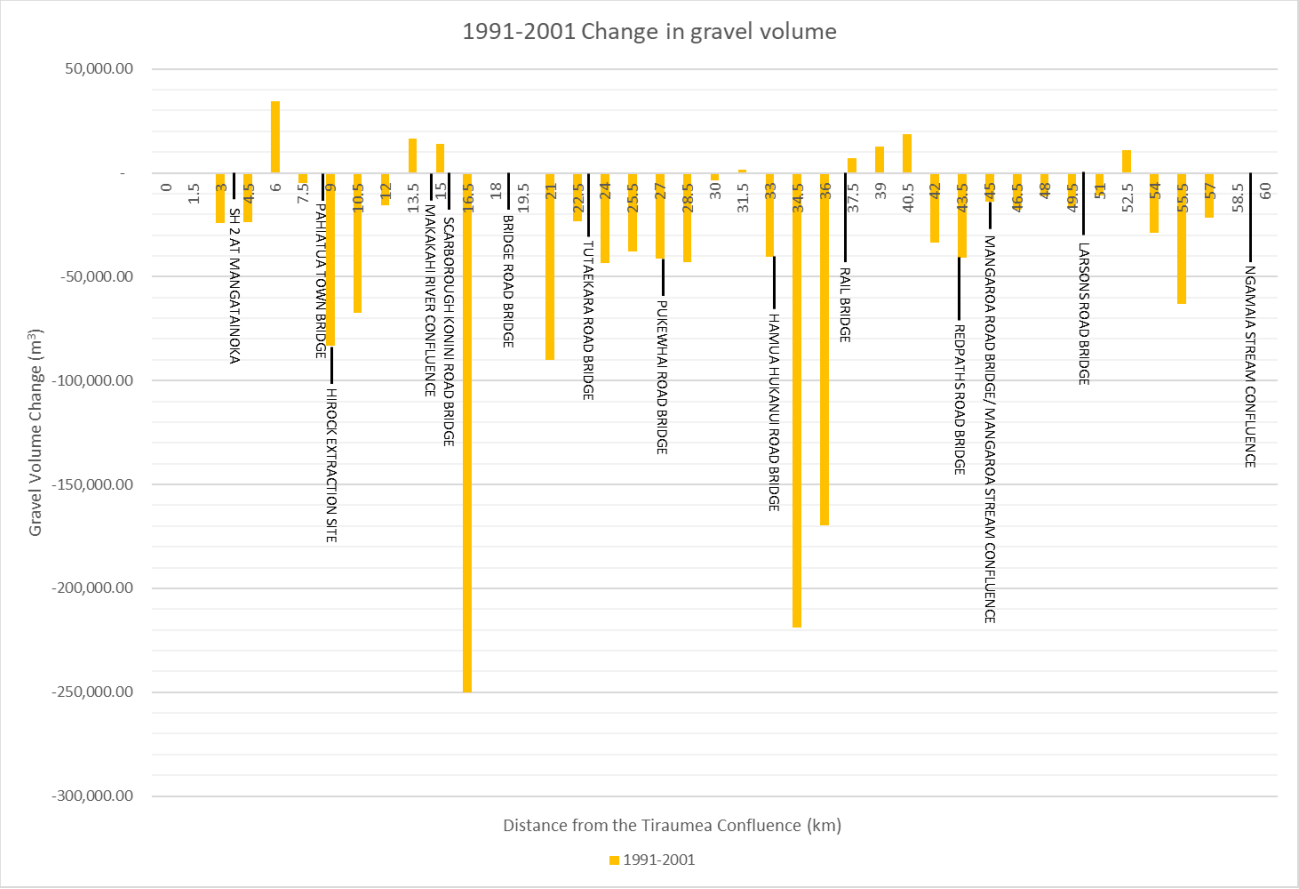


Figure 6: Gravel volume change 1991-2001

In the middle reach of the study area, gravel has accumulated degradation was recorded in the upper reach as in Figure 7. A total net loss of 486,900 m^3 gravel volume was found to have occurred for the year 2001-2015, which is about 34,700 m^3 per annum of gravel degradation (see Figure 7). According to records, a total of 218,064 m^3 of gravel has been extracted from 2001 to 2015 which is around 15,500 m^3 per annum.

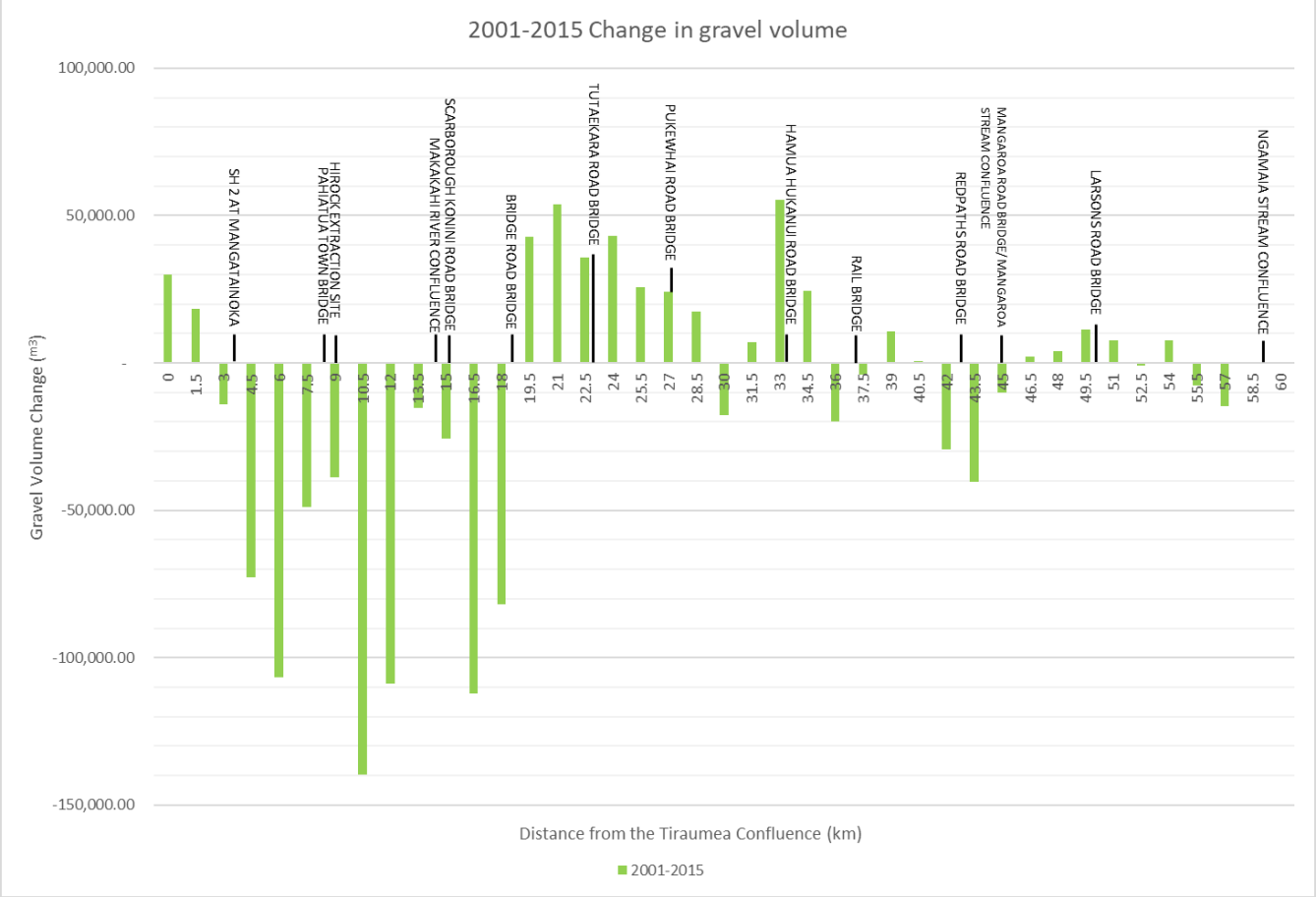


Figure 7: Gravel volume change 2001-2015

For the last period 2015-2022 shown below in Figure 8, an aggrading trend is recorded in the middle to the lower reaches (i.e. XS 30 to XS 52.5) while a degrading trend is recorded in the upper to the middle reaches. Gravel degradation was reduced compared to the previous periods, a total of 26,025 m^3 equating to about 3,700 m^3 per annum of degradation. This indicates that the river's gravel resources have been slowly recovering. According to records, the gravel extracted from the years 2015 to 2022 amounted to 105,717 m^3 which is about 15,102.43 m^3 per annum.

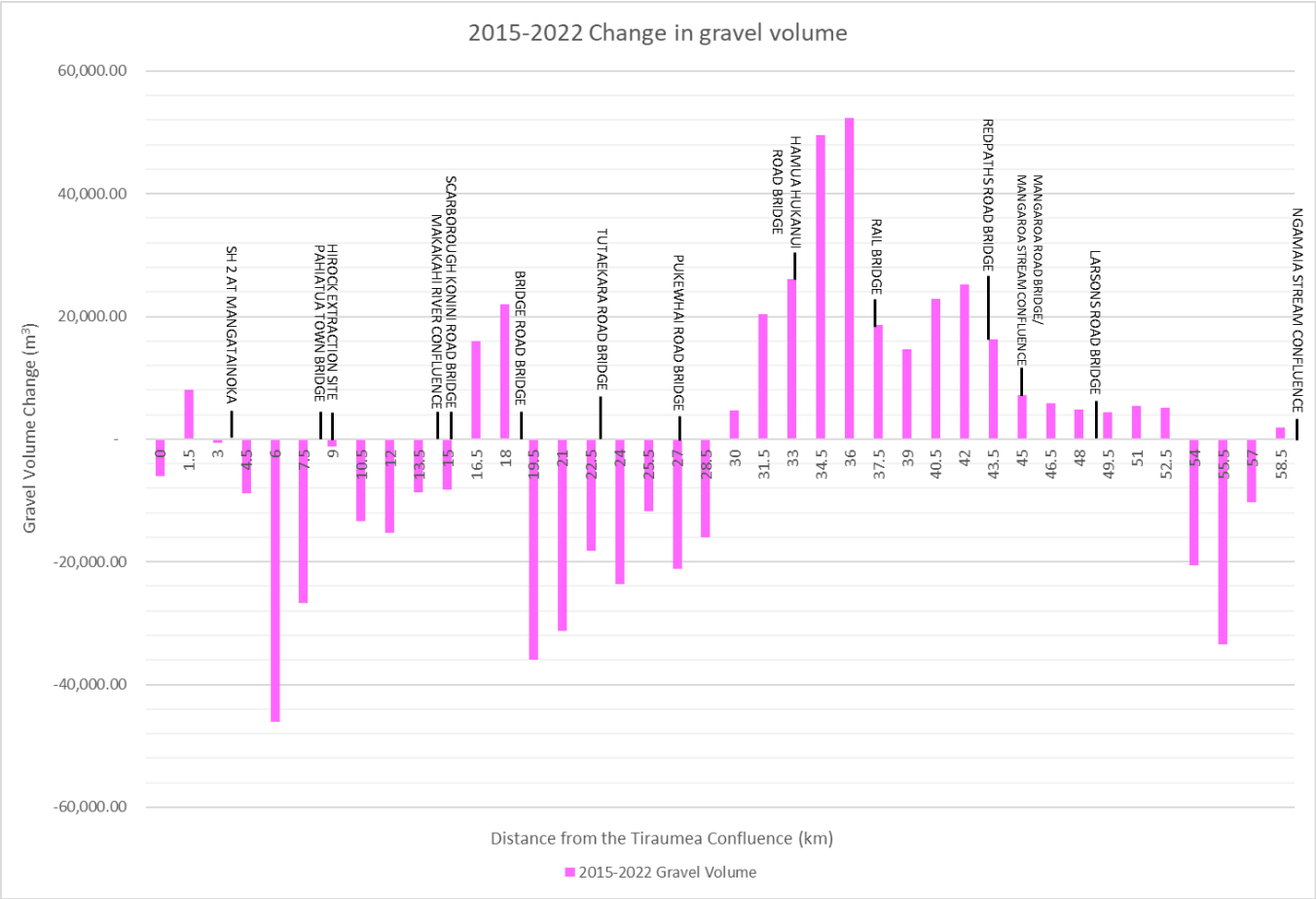


Figure 8: Gravel volume change 2015-2022

Overall, the channel is degrading with periods of localised aggradation in the study area.

This study concludes that the gravel resources in Mangatainoka River have degraded over time within the study period assessment of 1978 to 2015 but have begun to replenish from 2015 to 2022.

2.2 Analysis of the Mangatainoka River Mean Bed Level

Each period of the individual cross sections was analysed using Hilltop whereby the years of interest were over plotted. Inputting the left and right offsets found in Appendix B to E, the mean bed level of each year was obtained using the "Section over Time" feature found under the Reach tab of Hilltop Hydro.

2.2.1 Results of Mean Bed Level

The results for the mean bed level obtained from Hilltop can be found in Appendix B to E.

Figure 9 shows how the mean bed level of the Mangatainoka River has changed across the gravel reach from 1978 to 2022.

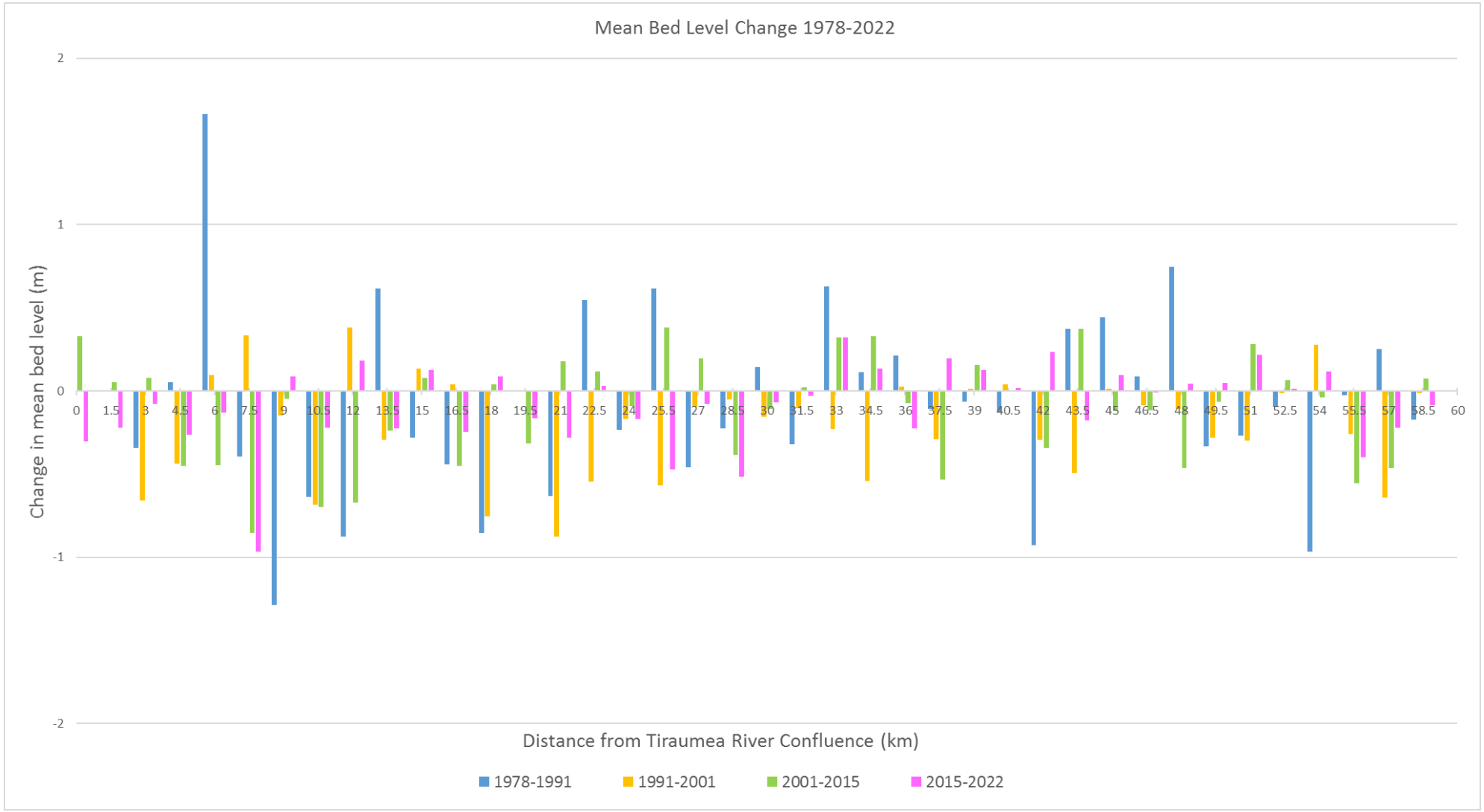


Figure 9: Mean Bed Level Change 1978 - 2022

Figure 10 below shows the change in mean bed level at each cross section location for the year 1978-1991. XS 6 has had appreciable (i.e. greater than one metre change) aggradation while XS 9 has had appreciable degradation.

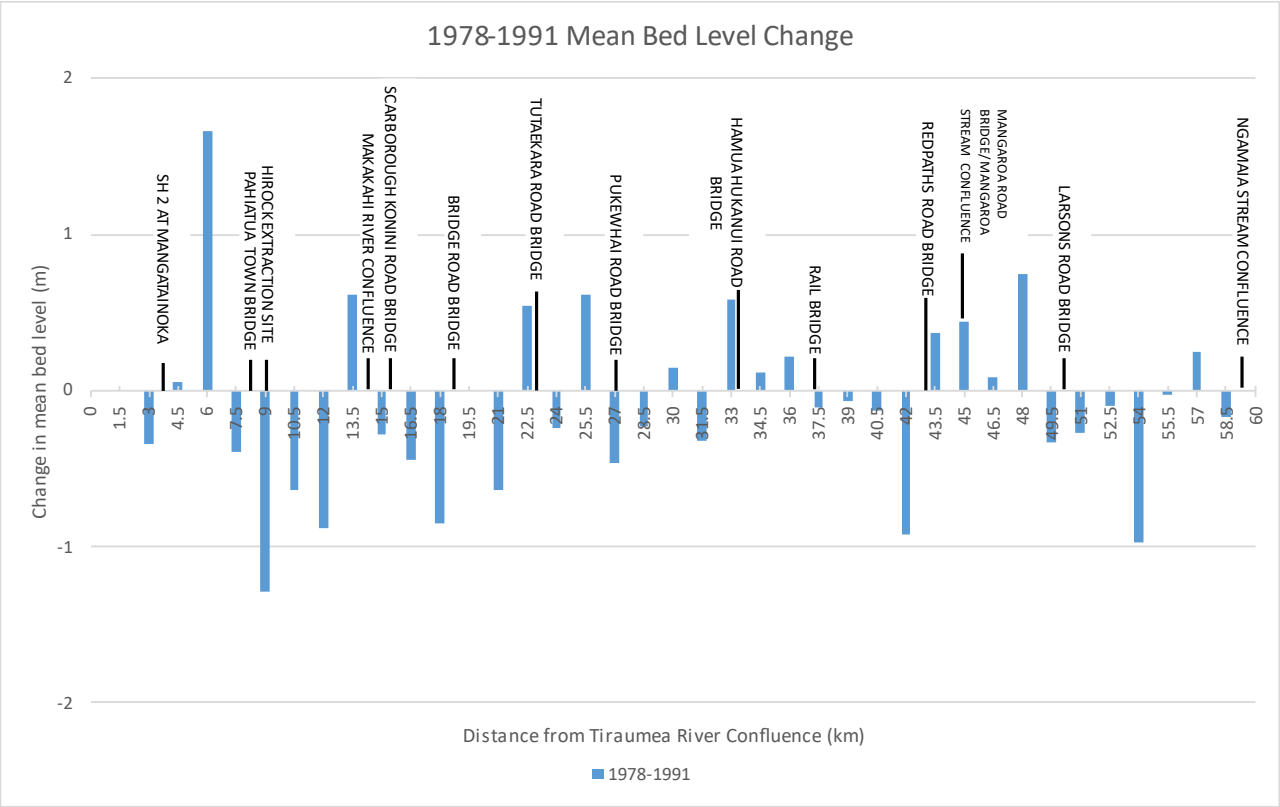


Figure 10: Mean Bed Level Change 1978 – 1991

Figures 11, 12, and 13 on the next pages show that there were no appreciable bed degradation or aggradation on the river's mean bed level from the years 1991 to 2022.

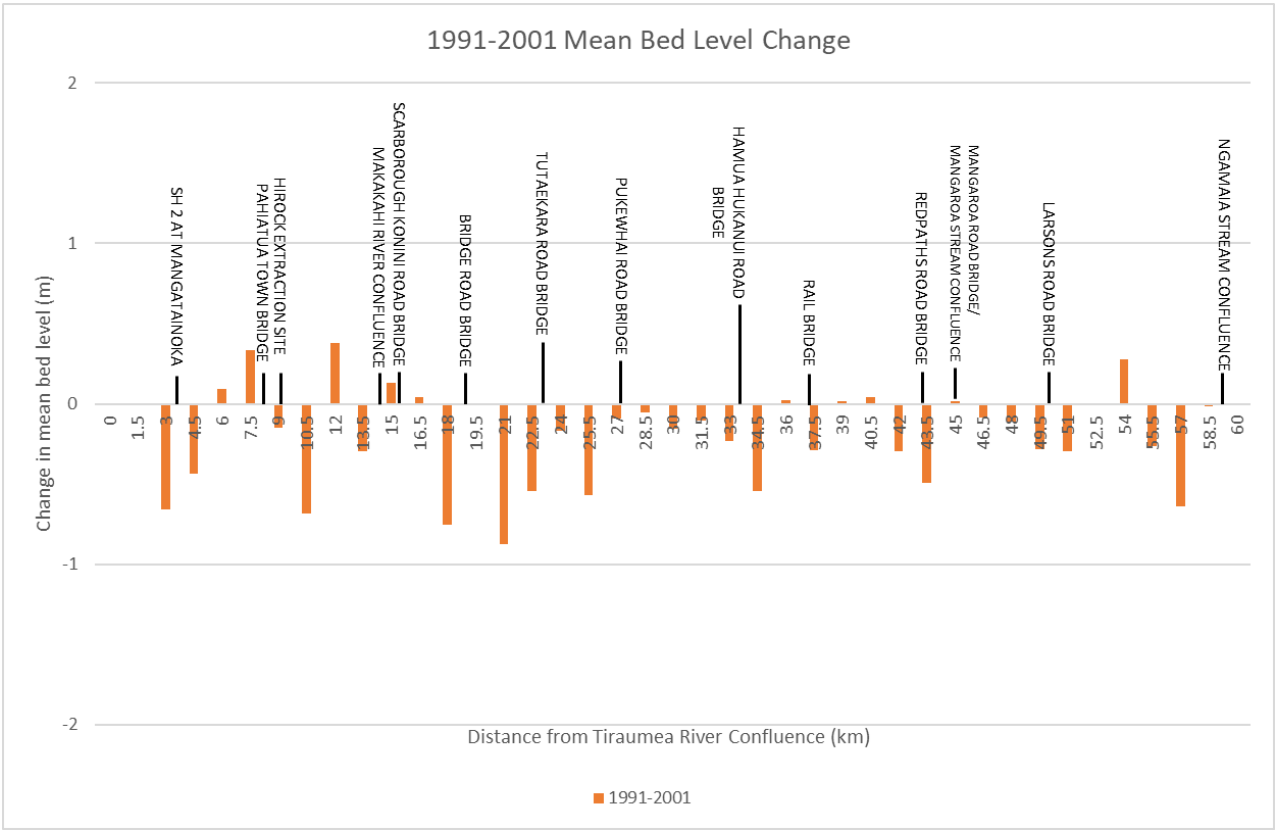


Figure 11: Mean Bed Level Change 1991-2001

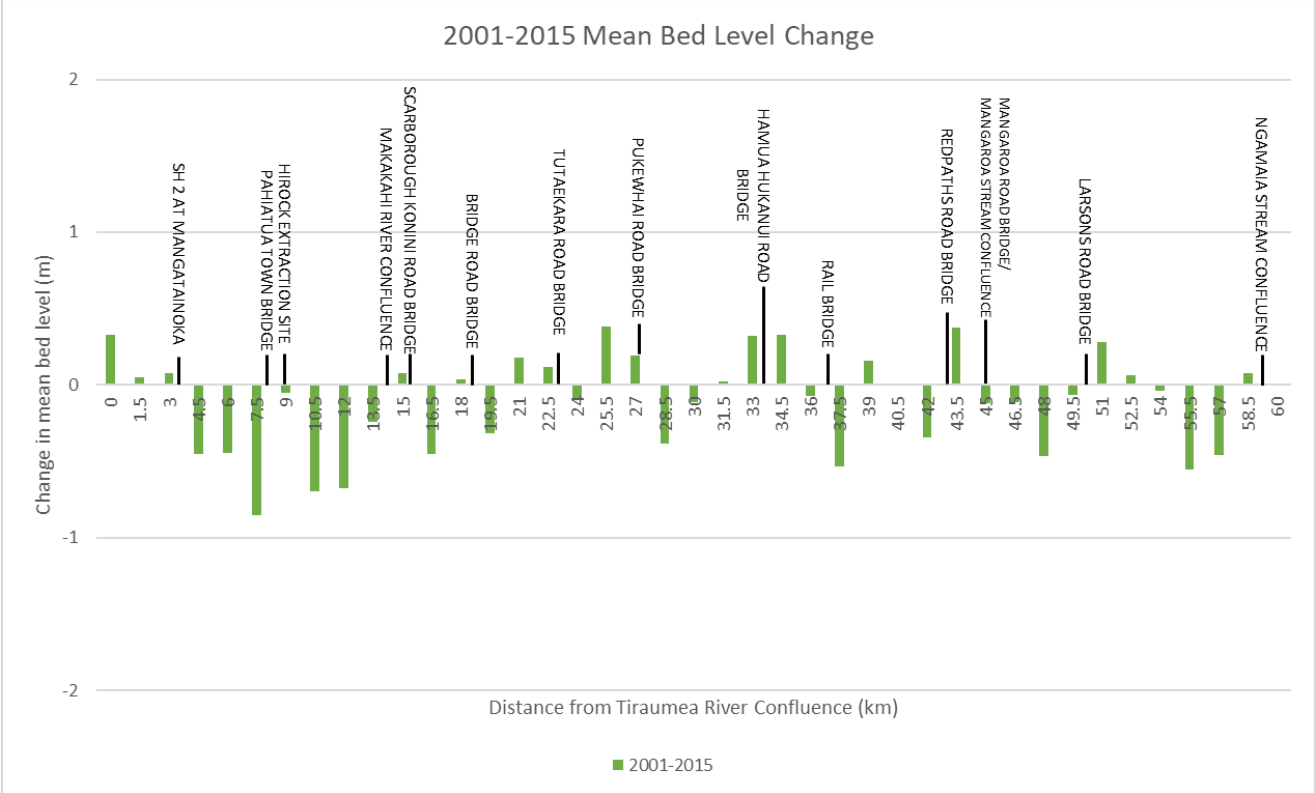


Figure 12: Mean Bed Level Change 2001-2015

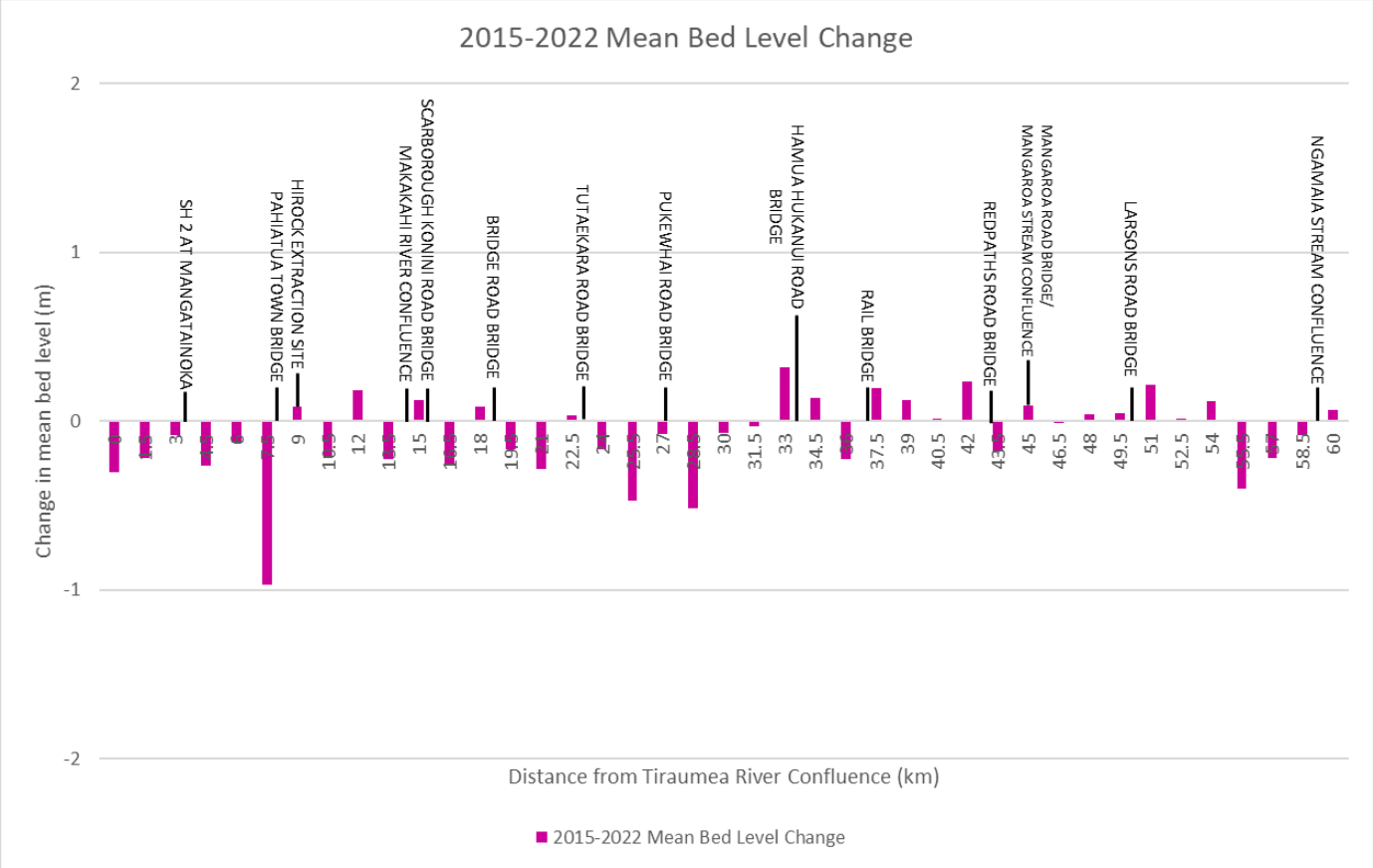


Figure 13: Mean Bed Level Change 2015-2022

The mean bed level has not degraded or aggraded by an appreciable volume during the present (2015-2022) assessment period. This indicates that the volume of gravel extracted during this period has not caused any negative impact on the mean bed level.

The figures show that the mean bed elevation has decreased and increased throughout the study period, with both occurring in individual comparison years, but there remains an overall degrading trend for all the periods from 1978 to 2022 based on the mean bed level.

3.0 Gravel Extraction and One Plan Mangatainoka River Gravel Extraction Allowance

A gravel transport study carried out in the Mangatainoka River during 1997, indicated that the river has an average annual transport capacity of between 15,000 and 30,000 m^3 (Williams, 1997). Table 17.1 of the One Plan states that the Mangatainoka River long term annual average volume of gravel available for extraction is 15,000 m^3.

Horizons Regional Council holds resource consent 106737, which authorises the combined extraction of 14,000 m^3 of gravel per annum from the Mangatainoka River (from its confluence with the Tiraumea River to the Larsens Road Bridge) and the Makakahi River (from its confluence with the Mangatainoka River to Bourkes Road), for river management purposes. As of July 2023, there is a single resource consent ATH-2013014970.00 which authorises the extraction of gravels from the Mangatainoka and Makakahi River.

Gravel extraction records provided to Horizons Regional Council by resource consent holders have reported that 250,634 m^3 of gravel has been extracted from the Mangatainoka River from January 1995 to June 2015 which is approximately 12,500 m^3 per annum (Standen, 2017). The volume of

gravel extraction reported from 1 July 2015 to 31 June 2023 was 118,590 m^3 which amounts to about 14,800 m^3 per annum. A total of 369,224 m^3 of gravel has been extracted from 1995 to 2023, which equates to an average extraction rate of 13,100 m^3 per annum. The reported extraction volume from 1 July 2022 until 30 June 2023 was 14,214 m^3 which is 214 m^3 above consent and One Plan allocable volume of 14,000 m^3. Table 3.1 shows the summary of gravel volume extracted from 1994 to 2023.

Year	Volume extracted (m^3)
1994	280
1995	290
1996	570
1997	3800
1998	9180
1999	15750
2000	16000
2001	11000
2002	53100
2003	
2004	
2005	
2006	
2007	24180
2008	22600
2009	14405
2010	18152
2011	19673
2012	7900
2013	10434
2014	20000
2015	16620
2016	16350
2017	15120
2018	10119
2019	17173
2020	10486
2021	7290
2022	12559
2023 (Jan-Jun)	14214

Table 3.1: Summary of gravel volume extracted (m^3) in the Mangatainoka River from 1994 to 2023

4.0 Actual status of the river

This report excludes the effects of Cyclone Gabrielle in February 2023 and the April 2023 which have resulted in significant aggradation observed in the study area.

On 8 August 2023, a site visit on various locations of the Mangatainoka River was conducted (see Figure 14 for the map of the locations visited and Appendix G for actual site photos), revealing that areas of gravel beaches have been replenishing gravels quickly after a decent amount of rain as in Makuri Street (see Figure G22) and Halls Road (see Figure G11). The 2015-2022 change in volume (see Figure 8) showed degrading cross sections but the cumulative change in volume suggests improvement or increase for the aforementioned cross sections.

Evidence of steep and large piles of gravel can be seen at various locations, including Te Hawera Road (see Figure G7), Tutaekara Road (see Figure G16), Makuri Street (see Figure G22), Nireaha Hukanui Road (see Figure G3), Mangaroa Road (see Figure G1), and Pukewhai Road (see Figure G9). Vegetation has started to form on the gravel beaches (see Figure G17), and a gravel extraction site operated by Hirock showed a large area of gravel beaches. Hirock staff reported that gravel extraction was done before the April flood, and that after the flood, the gravels came back to the beach.

Logan Mchardy's property (see Figure G19) had a large chunk of land devoured by the river due to the April flood event and Cyclone Gabrielle. Observing the aerial and actual photos for the sites, sediments are generally deposited on meandering parts of the river, particularly on inside bends, forming gravel beaches (i.e. Figure G6, G9, G11, and G13). Erosion and scouring are more likely to occur in outer bends of the river (i.e. Figure G1 and G18). Straight river sections are less likely to deposit sediments, making gravel beaches unlikely to develop (i.e. Figure G4, G5, and G20).

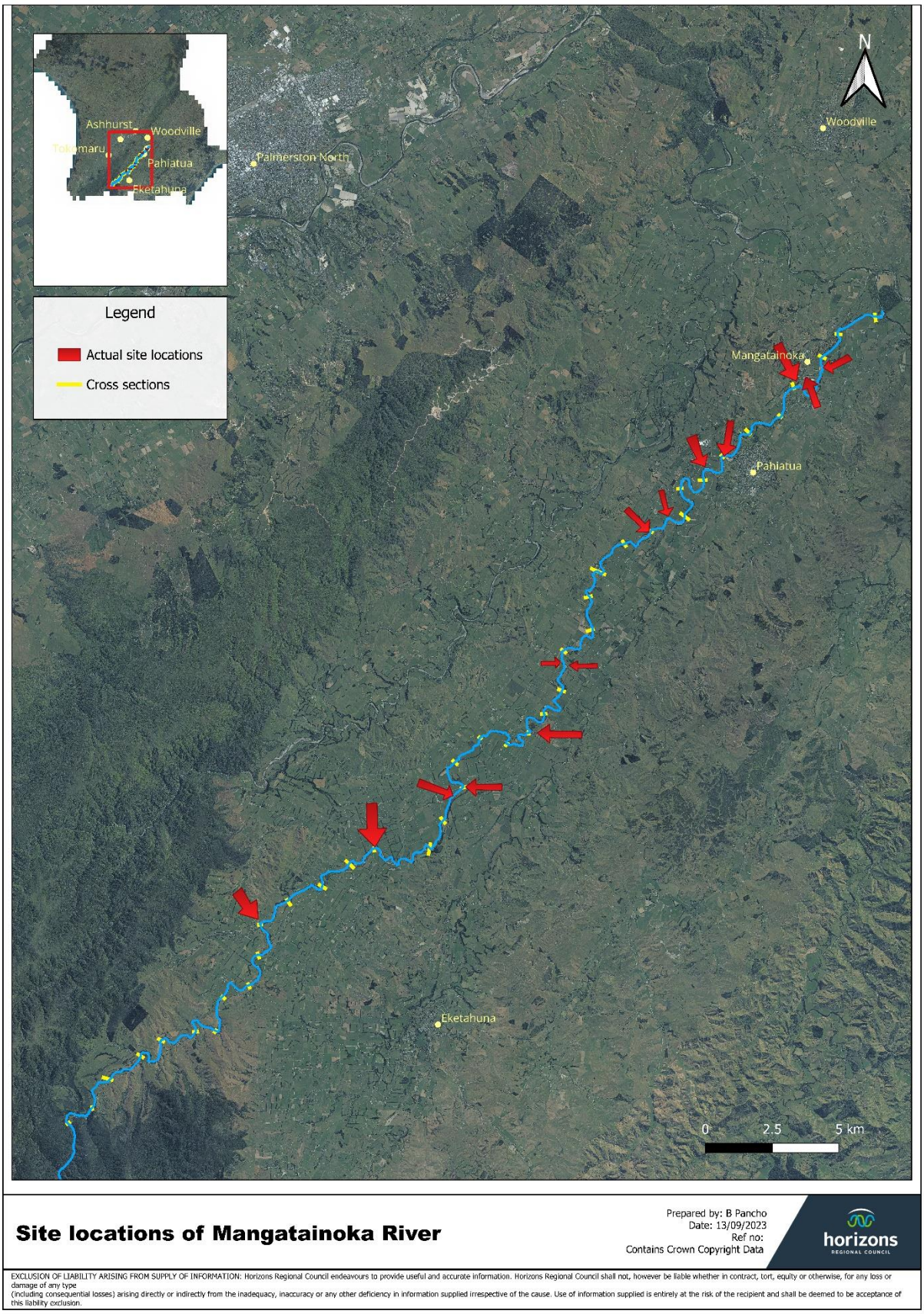


Figure 14: Locations of sites visited in the Mangatainoka River

5.0 Conclusion and Recommendations

The main findings of this study show that the Mangatainoka River mean bed elevation have both increased and decreased over the study period.

The change in gravel volume under the active channel indicates that a gravel sink has occurred in the middle reach of the study area during the period of 1991-2001. During 1978-1991, 2001-2015, and 2015-2022, a combination of a static gravel volume change, and a loss of gravel volume occurred in this same reach.

- For period 1978 to 1991, the annual gravel volume degradation was 38,500 m^3
- For period 1991 to 2001, the annual gravel volume degradation was 132,360 m^3
- For period 2001 to 2015, the annual gravel volume degradation was 34,700 m^3
- For period 2015 to 2022, the annual gravel volume degradation was 3,700 m^3

- The results in the study have produced comparable trends of those reported in the 2017 study for the study area and period.
- Overall, the assessment of the change in gravel volume and cumulative changes to the gravel volume under the active channel, indicates that the gravel resource is aggrading in the middle reaches of the study area, and has recently (2015-2022) begun aggrading in the lower reach of the study area. The gravel loss volumes exceed the gravel volume gains, therefore overall the gravel resource has degraded over the study period with aggradation occurring in the middle reaches.
- Overall, the gravel volume losses overwhelmed the gravel volume gains according to the four assessment periods, measuring 4700 m^3 annual volume degradation from 1978 to 2022. The gravel resources in Mangatainoka River have degraded over time within the study period assessment of 1978 to 2015 but has started to replenish from 2015 to 2022.
- The extraction should be carried out in a manner that reduces channel distortions at bend along reaches and target long term storage areas beyond the re-working action of the river in the middle reaches of the study area.

- It is recommended that gravel extraction in the middle and lower reaches should target the higher beach areas that are beyond the re-working action of the river, which would not affect river dynamics. Gravel extraction from the actively re-worked channel area should be kept as low as possible to ensure minimal compensating responses from the river, to obtain its required transport load.

- The One Plan long-term annual gravel allocation of 15,000 m^3 set for the Mangatainoka River is appropriate to minimise any negative impacts associated with gravel extraction as the cross sectional analysis has shown that mean bed levels have not degraded over the study period and that bed degradation identified in the late 1970s has not continued.

- This report does not consider the effects of Cyclone Gabrielle (February 2023) and the April 2023 flood event which have occurred following the period of analysis.

- It is recommended that the Mangatainoka River is re-surveyed in 2025 to account for the effects of Cyclone Gabrielle.

- It is further recommended that the use of a most up-to-date LiDAR (Light Detection and Ranging) and Difference of Digital elevation models (DoD) analysis be incorporated in addition to the cross sectional analysis. The DoD analysis provides a spatial assessment of the morphological bedform (shape) response of the channel, if and where the channel is aggrading or degrading. Two digital elevation models (DEMs) will be compared and provide a spatial variability in elevation and a volume of gravel change. This will provide a greater context and measurement of spatial morphologic response and volume change of gravel in the catchment.

6.0 References

Standen, S. (2017). Mangatainoka River Gravel Resource Study 2017.

Williams, G. J. (1997). Mangatainoka River – Sediment Transport & Gravel Extraction for River Management Purposes

Williams, G. J. (2002). Mangatainoka River Gravel Resources. Analysis and Comment on the Availability of Gravel and its management

7.0 Appendices

Appendix A: 1978-2022 Gravel Volume Change Data

Distance from Tiraumea Confluence	Cross-section	Left Offset	Right Offset	Datum=0	Area under section 1978/1977 (m^2)	Area under section 1991 (m^2)	Area under section 2001/2002 (m^2)	Area under section 2015 (m^2)	Area under section 2022 (m^2)	Volume 1978 (m^3)	Volume 1991 (m^3)	Change in volume (1991-1978) m^3	Volume 2001 (m^3)	Change in volume (2001-1991) m^3	Volume 2015 (m^3)	Change in volume (2015-2001) m^3	Volume 2022 (m^3)	Change in volume (2022-2015) m^3
0	0000	30	177	0	12,178.20		12,160.80	12,191.80	12,173.60	15,172,575.00	-		15,133,800.00		15,163,650.00	29,850.00	15,157,650.00	- 6,000.00
1.5	1500	0	93	0	8,051.90		8,017.60	8,026.40	8,036.60	16,202,550.00			16,143,150.00		16,161,600.00	18,450.00	16,169,625.00	8,025.00
3	3000	50	200	0	13,551.50	13,508.70	13,506.60	13,522.40	13,522.90	16,754,025.00	16,725,000.00	- 29,025.00	16,700,625.00	- 24,375.00	16,686,525.00	- 14,100.00	16,685,850.00	- 675.00
4.5	4500	23	116	0	8,787.20	8,791.30	8,760.90	8,726.30	8,724.90	12,857,925.00	12,866,550.00	8,625.00	12,842,850.00	- 23,700.00	12,770,175.00	- 72,675.00	12,761,400.00	- 8,775.00
6	6000	10	95.8	0	8,356.70	8,364.10	8,362.90	8,300.60	8,290.30	17,820,150.00	17,818,425.00	- 1,725.00	17,852,775.00	34,350.00	17,746,200.00	- 106,575.00	17,700,150.00	- 46,050.00
7.5	7500	50	200	0	15,403.50	15,393.80	15,440.80	15,361.00	15,309.90	19,947,450.00	19,867,875.00	- 79,575.00	19,862,925.00	- 4,950.00	19,814,175.00	- 48,750.00	19,787,475.00	- 26,700.00
9	9000	10	114	0	11,193.10	11,096.70	11,043.10	11,057.90	11,073.40	19,041,525.00	18,941,550.00	- 99,975.00	18,858,150.00	- 83,400.00	18,819,300.00	- 38,850.00	18,818,175.00	- 1,125.00
10.5	10500	1	126.2	0	14,195.60	14,158.70	14,101.10	14,034.50	14,017.50	25,482,750.00	25,407,000.00	- 75,750.00	25,339,575.00	- 67,425.00	25,199,775.00	- 139,800.00	25,186,350.00	- 13,425.00
12	12000	4.5	172	0	19,781.40	19,717.30	19,685.00	19,565.20	19,564.30	34,857,375.00	34,776,525.00	- 80,850.00	34,761,000.00	- 15,525.00	34,652,100.00	- 108,900.00	34,636,800.00	- 15,300.00
13.5	13500	-4	216	0	26,695.10	26,651.40	26,663.00	26,637.60	26,618.10	28,270,800.00	28,226,550.00	- 44,250.00	28,243,050.00	16,500.00	28,227,675.00	- 15,375.00	28,219,050.00	- 8,625.00
15	15000	0	88	0	10,999.30	10,984.00	10,994.40	10,999.30	11,007.30	19,934,475.00	19,890,450.00	- 44,025.00	19,904,475.00	14,025.00	19,878,675.00	- 25,800.00	19,870,425.00	- 8,250.00
16.5	16500	40	160	0	15,580.00	15,536.60	15,544.90	15,505.60	15,486.60	58,700,025.00	58,635,150.00	- 64,875.00	58,385,250.00	- 249,900.00	58,273,200.00	- 112,050.00	58,289,100.00	15,900.00
18	18000	16.5	480	0	62,686.70	62,643.60	62,302.10	62,192.00	62,232.20	66,455,700.00			66,137,775.00		66,056,025.00	- 81,750.00	66,078,000.00	21,975.00
19.5	19500	40	227	0	25,920.90		25,881.60	25,882.70	25,871.80	34,123,875.00			33,956,475.00		33,999,225.00	42,750.00	33,963,225.00	- 36,000.00
21	21000	99	235	0	19,577.60	19,491.20	19,393.70	19,449.60	19,412.50	26,955,300.00	26,915,400.00	- 39,900.00	26,825,175.00	- 90,225.00	26,879,025.00	53,850.00	26,847,750.00	- 31,275.00
22.5	22500	10	120	0	16,362.80	16,396.00	16,373.20	16,389.10	16,384.50	25,058,700.00	25,083,300.00	24,600.00	25,059,900.00	- 23,400.00	25,095,675.00	35,775.00	25,077,450.00	- 18,225.00
24	24000	90	200	0	17,048.80	17,048.40	17,040.00	17,071.80	17,052.10	26,727,900.00	26,706,975.00	- 20,925.00	26,663,700.00	- 43,275.00	26,706,900.00	43,200.00	26,683,275.00	- 23,625.00
25.5	25500	25	140	0	18,588.40	18,560.90	18,511.60	18,537.40	18,525.60	19,551,000.00	19,520,775.00	- 30,225.00	19,482,825.00	- 37,950.00	19,508,475.00	25,650.00	19,496,700.00	- 11,775.00
27	27000	0.8	45.8	0	7,479.60	7,466.80	7,465.50	7,473.90	7,470.00	14,603,175.00	14,588,025.00	- 15,150.00	14,546,625.00	- 41,400.00	14,570,700.00	24,075.00	14,549,625.00	- 21,075.00
28.5	28500	5	75	0	11,991.30	11,983.90	11,930.00	11,953.70	11,929.50	16,663,275.00	16,670,550.00	7,275.00	16,627,425.00	- 43,125.00	16,644,975.00	17,550.00	16,628,925.00	- 16,050.00
30	30000	2.5	61	0	10,226.40	10,243.50	10,239.90	10,239.60	10,242.40	19,107,975.00	19,117,800.00	9,825.00	19,114,275.00	- 3,525.00	19,096,500.00	- 17,775.00	19,101,225.00	4,725.00
31.5	31500	9	94.2	0	15,250.90	15,246.90	15,245.80	15,222.40	15,225.90	25,147,500.00	25,191,375.00	43,875.00	25,192,950.00	1,575.00	25,199,925.00	6,975.00	25,220,325.00	20,400.00
33	33000	26	126	0	18,279.10	18,341.60	18,344.80	18,377.50	18,401.20	30,621,975.00	30,676,875.00	54,900.00	30,636,525.00	- 40,350.00	30,691,875.00	55,350.00	30,717,975.00	26,100.00
34.5	34500	60	180	0	22,550.20	22,560.90	22,503.90	22,545.00	22,556.10	53,479,575.00	53,475,825.00	- 3,750.00	53,256,900.00	- 218,925.00	53,281,500.00	24,600.00	53,331,000.00	49,500.00
36	36000	18	271	0	48,755.90	48,740.20	48,505.30	48,497.00	48,551.90	48,419,925.00	48,404,550.00	- 15,375.00	48,234,825.00	- 169,725.00	48,214,875.00	- 19,950.00	48,267,225.00	52,350.00
37.5	37500	-23.5	57	0	15,804.00	15,799.20	15,807.80	15,789.50	15,804.40	23,234,925.00	23,229,825.00	- 5,100.00	23,236,950.00	7,125.00	23,232,900.00	- 4,050.00	23,251,575.00	18,675.00
39	39000	10	85	0	15,175.90	15,173.90	15,174.80	15,187.70	15,197.70	31,249,725.00	31,236,525.00	- 13,200.00	31,249,275.00	12,750.00	31,260,075.00	10,800.00	31,274,775.00	14,700.00
40.5	40500	100	228	0	26,490.40	26,474.80	26,490.90	26,492.40	26,502.00	35,421,225.00	35,345,625.00	- 75,600.00	35,364,450.00	18,825.00	35,364,975.00	525.00	35,387,850.00	22,875.00
42	42000	131	228	0	20,737.90	20,652.70	20,661.70	20,660.90	20,681.80	39,053,100.00	39,033,825.00	- 19,275.00	39,000,450.00	- 33,375.00	38,971,275.00	- 29,175.00	38,996,550.00	25,275.00
43.5	43500	7.1	150	0	31,332.90	31,392.40	31,338.90	31,300.80	31,313.60	33,171,825.00	33,238,725.00	66,900.00	33,197,775.00	- 40,950.00	33,157,500.00	- 40,275.00	33,173,775.00	16,275.00
45	45000	25	82.5	0	12,896.20	12,925.90	12,924.80	12,909.20	12,918.10	21,016,950.00	21,055,500.00	38,550.00	21,041,400.00	- 14,100.00	21,031,275.00	- 10,125.00	21,038,400.00	7,125.00
46.5	46500	30	95	0	15,126.40	15,148.10	15,130.40	15,132.50	15,133.10	22,180,725.00	22,183,425.00	2,700.00	22,165,500.00	- 17,925.00	22,167,600.00	2,100.00	22,173,450.00	5,850.00
48	48000	3	63	0	14,447.90	14,429.80	14,423.60	14,424.30	14,431.50	20,108,625.00	20,086,275.00	- 22,350.00	20,075,025.00	- 11,250.00	20,079,150.00	4,125.00	20,083,950.00	4,800.00
49.5	49500	30	80	0	12,363.60	12,351.90	12,343.10	12,347.90	12,347.10	17,573,925.00	17,560,350.00	- 13,575.00	17,544,450.00	- 15,900.00	17,555,700.00	11,250.00	17,560,050.00	4,350.00
51	51000	21.5	65	0	11,068.30	11,061.90	11,049.50	11,059.70	11,066.30	16,890,375.00	16,883,325.00	- 7,050.00	16,872,225.00	- 11,100.00	16,880,025.00	7,800.00	16,885,500.00	5,475.00
52.5	52500	46	90	0	11,452.20	11,449.20	11,446.80	11,447.00	11,447.70	20,808,750.00	20,793,525.00	- 15,225.00	20,804,250.00	10,725.00	20,803,200.00	- 1,050.00	20,808,300.00	5,100.00
54	54000	50	110	0	16,292.80	16,275.50	16,292.20	16,290.60	16,296.70	41,884,350.00	41,901,000.00	16,650.00	41,872,125.00	- 28,875.00	41,879,925.00	7,800.00	41,859,375.00	- 20,550.00
55.5	55500	52	192	0	39,553.00	39,592.50	39,537.30	39,549.30	39,515.80	42,988,350.00	43,025,775.00	37,425.00	42,962,700.00	- 63,075.00	42,955,050.00	- 7,650.00	42,921,525.00	- 33,525.00
57	57000	165	225	0	17,764.80	17,775.20	17,746.30	17,724.10	17,712.90	20,970,525.00	20,974,575.00	4,050.00	20,952,825.00	- 21,750.00	20,938,125.00	- 14,700.00	20,927,775.00	- 10,350.00
58.5	58500	12	45	0	10,195.90	10,190.90	10,190.80	10,193.40	10,190.80			-		-	19,086,525.00		19,088,400.00	1,875.00
60	60000	4	50	0				15,255.30	15,260.40									

Appendix B: 1978-1991 Mean Bed Level Data

Distance from Tiraumea	Cross-section	Left Offset	Right Offset	Mean bed level 1978	Mean bed level 1991	Mean bed level change (1991-1978)
0	0000					
1.5	1500					
3	3000	73	205	90.209	89.866	-0.343
4.5	4500	41	97	93.351	93.405	0.054
6	6000	57.5	91	95.533	97.198	1.665
7.5	7500	128	195	102.106	101.711	-0.395
9	9000	25	91	106.686	105.398	-1.288
10.5	10500	21.5	85	112.041	111.405	-0.636
12	12000	106	169	117.317	116.44	-0.877
13.5	13500	9	33	119.838	120.452	0.614
15	15000	9.5	55	124.118	123.837	-0.281
16.5	16500	58	108	128.662	128.221	-0.441
18	18000	413.5	460	133.167	132.313	-0.854
19.5	19500				X	
21	21000	133	226	143.536	142.901	-0.635
22.5	22500	25	104	147.94	148.487	0.547
24	24000	126	186.5	154.264	154.028	-0.236
25.5	25500	58	85	159.515	160.129	0.614
27	27000	8.5	39.2	165.417	164.957	-0.46
28.5	28500	37.5	62	169.506	169.281	-0.225
30	30000	24.7	54.5	173.499	173.643	0.144
31.5	31500	48	87	178.142	177.822	-0.32
33	33000	80	113.8	181.349	181.976	0.627
34.5	34500	124	183	187.07	187.184	0.114
36	36000	41	104	190.897	191.111	0.214
37.5	37500	-3	53	195.718	195.611	-0.107
39	39000	21	76.5	201.599	201.533	-0.066
40.5	40500	89	229	207.057	206.926	-0.131
42	42000	134.5	228	213.818	212.892	-0.926
43.5	43500	7.5	137.5	219.241	219.615	0.374
45	45000	7	90	224.89	225.333	0.443
46.5	46500	37	112	232.813	232.901	0.088
48	48000	10	29	239.82	240.564	0.744
49.5	49500	40	71	246.493	246.16	-0.333
51	51000	29	61.5	253.555	253.287	-0.268
52.5	52500	50	83.5	259.833	259.736	-0.097
54	54000	64	83	270.384	269.415	-0.969
55.5	55500	28.5	159.3	282.811	282.783	-0.028
57	57000	169	211.5	295.595	295.847	0.252
58.5	58500	14.7	39	308.635	308.461	-0.174
60	60000					

Appendix C: 1991-2001 Mean Bed Level Data

Distance from Tiraumea Confluence	Cross-section	Left Offset	Right Offset	Mean bed level 1991	Mean bed level 2001	Mean bed level change (2001-1991)
0	0000					
1.5	1500					
3	3000	72	113	88.459	87.8	-0.659
4.5	4500	41.5	98	93.414	92.978	-0.436
6	6000	22	90.6	96.753	96.848	0.095
7.5	7500	67.5	198	102.535	102.868	0.333
9	9000	28	80	105.204	105.055	-0.149
10.5	10500	18.1	113.2	112.543	111.859	-0.684
12	12000	108	165	116.327	116.708	0.381
13.5	13500	75	176.5	120.807	120.512	-0.295
15	15000	6.45	82.9	124.533	124.667	0.134
16.5	16500	63.5	111.4	128.202	128.241	0.039
18	18000	74.5	459	135.012	134.257	-0.755
19.5	19500					
21	21000	118	228	143.075	142.197	-0.878
22.5	22500	15.4	78.5	148.505	147.958	-0.547
24	24000	126.5	190	154.187	154.016	-0.171
25.5	25500	35.3	126.3	161.165	160.598	-0.567
27	27000	8.5	38.4	164.898	164.804	-0.094
28.5	28500	38.7	72	169.89	169.838	-0.052
30	30000	25	48	173.144	172.989	-0.155
31.5	31500	41	86.5	178.087	177.984	-0.103
33	33000	85	111.5	181.569	181.337	-0.232
34.5	34500	80	163	187.703	187.162	-0.541
36	36000	35.5	87.6	190.836	190.86	0.024
37.5	37500	-6.6	59.5	195.334	195.043	-0.291
39	39000	22.3	73	201.386	201.401	0.015
40.5	40500	107	199	206.61	206.649	0.039
42	42000	174	218	212.552	212.258	-0.294
43.5	43500	2.3	63.1	218.573	218.079	-0.494
45	45000	25.7	77	224.696	224.71	0.014
46.5	46500	35.6	112.2	232.914	232.829	-0.085
48	48000	7.7	61.5	240.321	240.211	-0.11
49.5	49500	37.5	75.6	246.542	246.258	-0.284
51	51000	21	63.2	254.076	253.778	-0.298
52.5	52500	36.8	103.5	260.971	260.96	-0.011
54	54000	60.5	121.5	271.014	271.29	0.276
55.5	55500	26.3	205.3	282.701	282.439	-0.262
57	57000	171.7	214.5	295.903	295.263	-0.64
58.5	58500	13	45	308.789	308.776	-0.013
60	60000					

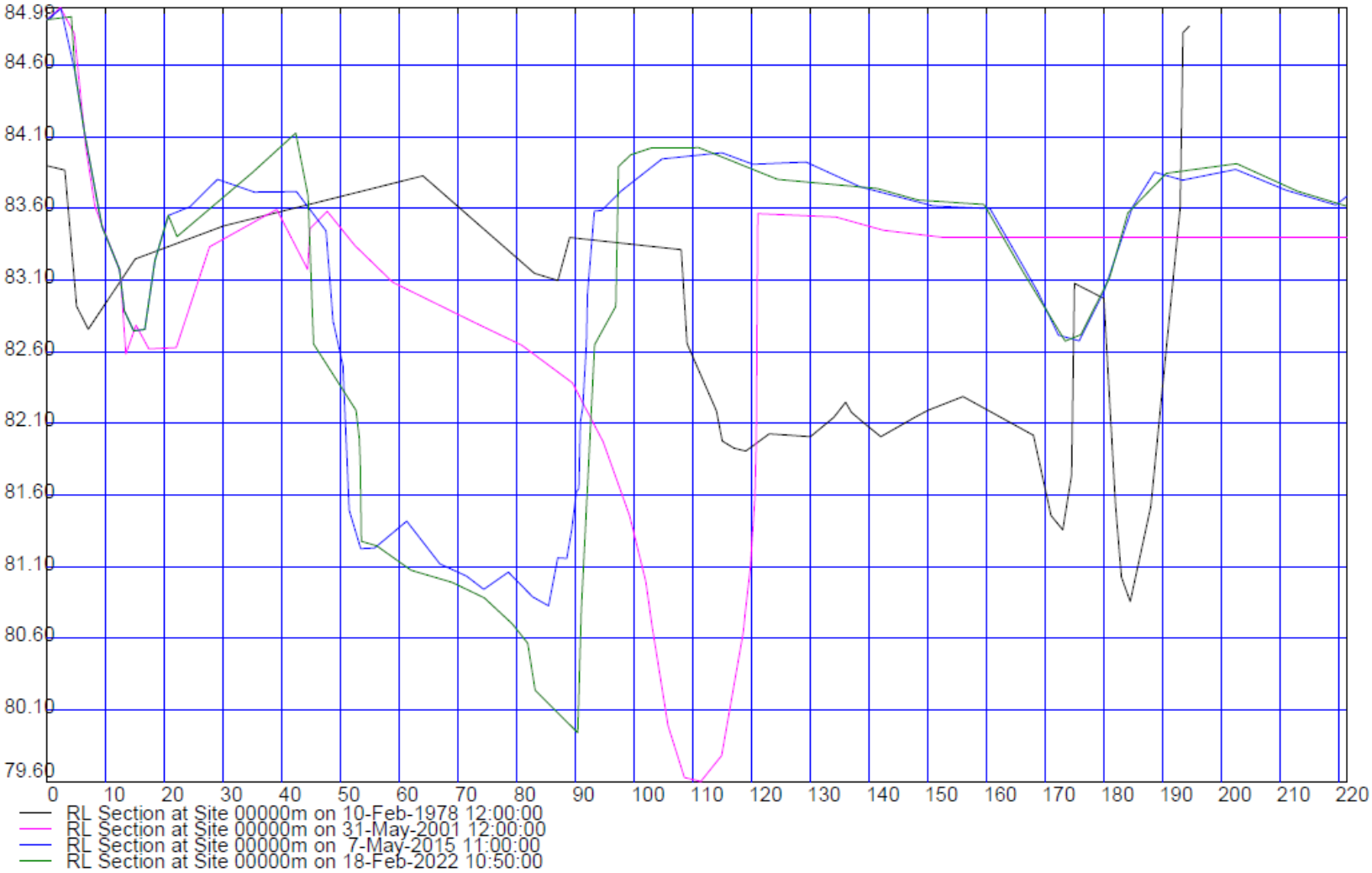
Appendix D: 2001-2015 Mean Bed Level Data

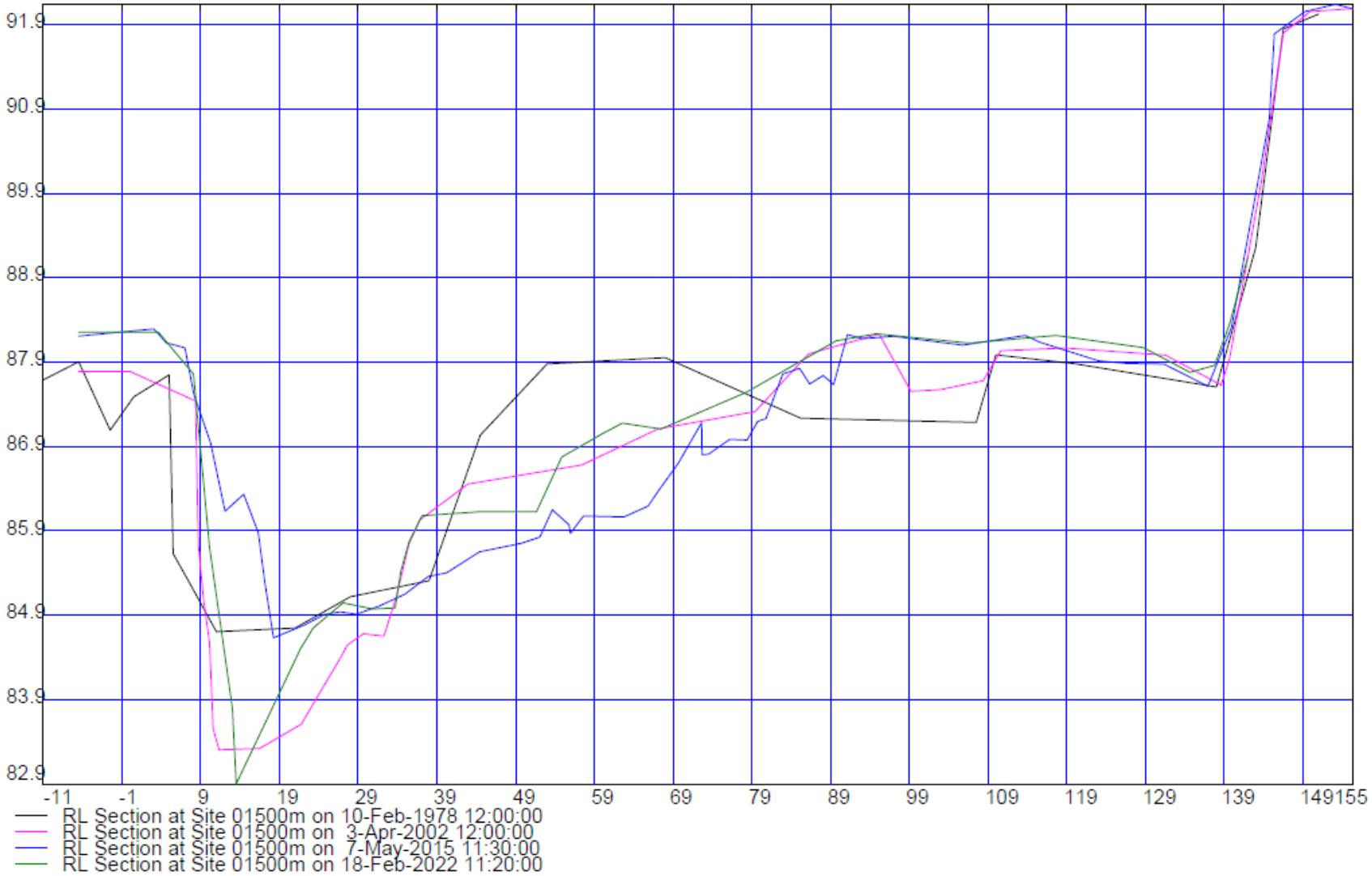
Distance from Tiraumea Confluence	Cross-section	Left Offset	Right Offset	Mean bed level 2001	Mean bed level 2015	Mean bed level change (2015-2001)
0	0000	50	120.8	81.95	82.28	0.33
1.5	1500	8	93	86.08	86.133	0.053
3	3000	67.5	127	88.666	88.742	0.076
4.5	4500	22.2	101	93.803	93.352	-0.451
6	6000	1	89	97.394	96.946	-0.448
7.5	7500	54.3	145.4	102.712	101.859	-0.853
9	9000	24	98	105.159	105.11	-0.049
10.5	10500	27	125.7	112.267	111.569	-0.698
12	12000	7	162	117.435	116.762	-0.673
13.5	13500	73	204	120.907	120.667	-0.24
15	15000	4.5	70	124.359	124.438	0.079
16.5	16500	65	141	129.1	128.651	-0.449
18	18000	24.5	185	133.984	134.022	0.038
19.5	19500	170	223.5	137.452	137.136	-0.316
21	21000	118.2	194	142.212	142.39	0.178
22.5	22500	15.6	80	147.991	148.109	0.118
24	24000	127.6	174	153.483	153.393	-0.09
25.5	25500	56	126.3	160.569	160.949	0.38
27	27000	7	39	164.978	165.171	0.193
28.5	28500	39	68	169.52	169.136	-0.384
30	30000	10.5	49.2	174.388	174.278	-0.11
31.5	31500	25	82.2	178.356	178.378	0.022
33	33000	70	114.5	182.068	182.391	0.323
34.5	34500	75.5	160	187.191	187.519	0.328
36	36000	127	265.5	191.798	191.724	-0.074
37.5	37500	-16.5	28.6	195.594	195.059	-0.535
39	39000	20.85	75.7	201.541	201.696	0.155
40.5	40500	108	209.7	206.753	206.75	-0.003
42	42000	176	218	212.213	211.872	-0.341
43.5	43500	25	63	218.221	218.593	0.372
45	45000	7	84.8	224.805	224.684	-0.121
46.5	46500	35	72.5	232.282	232.166	-0.116
48	48000	7.5	30	240.018	239.554	-0.464
49.5	49500	42.3	71.2	245.971	245.908	-0.063
51	51000	29	65	253.609	253.892	0.283
52.5	52500	65.5	83.4	258.803	258.866	0.063
54	54000	61.5	108	270.986	270.945	-0.041
55.5	55500	74	126.6	282.546	281.989	-0.557
57	57000	168.7	219	295.522	295.06	-0.462
58.5	58500	13.6	43	308.652	308.726	0.074
60	60000					

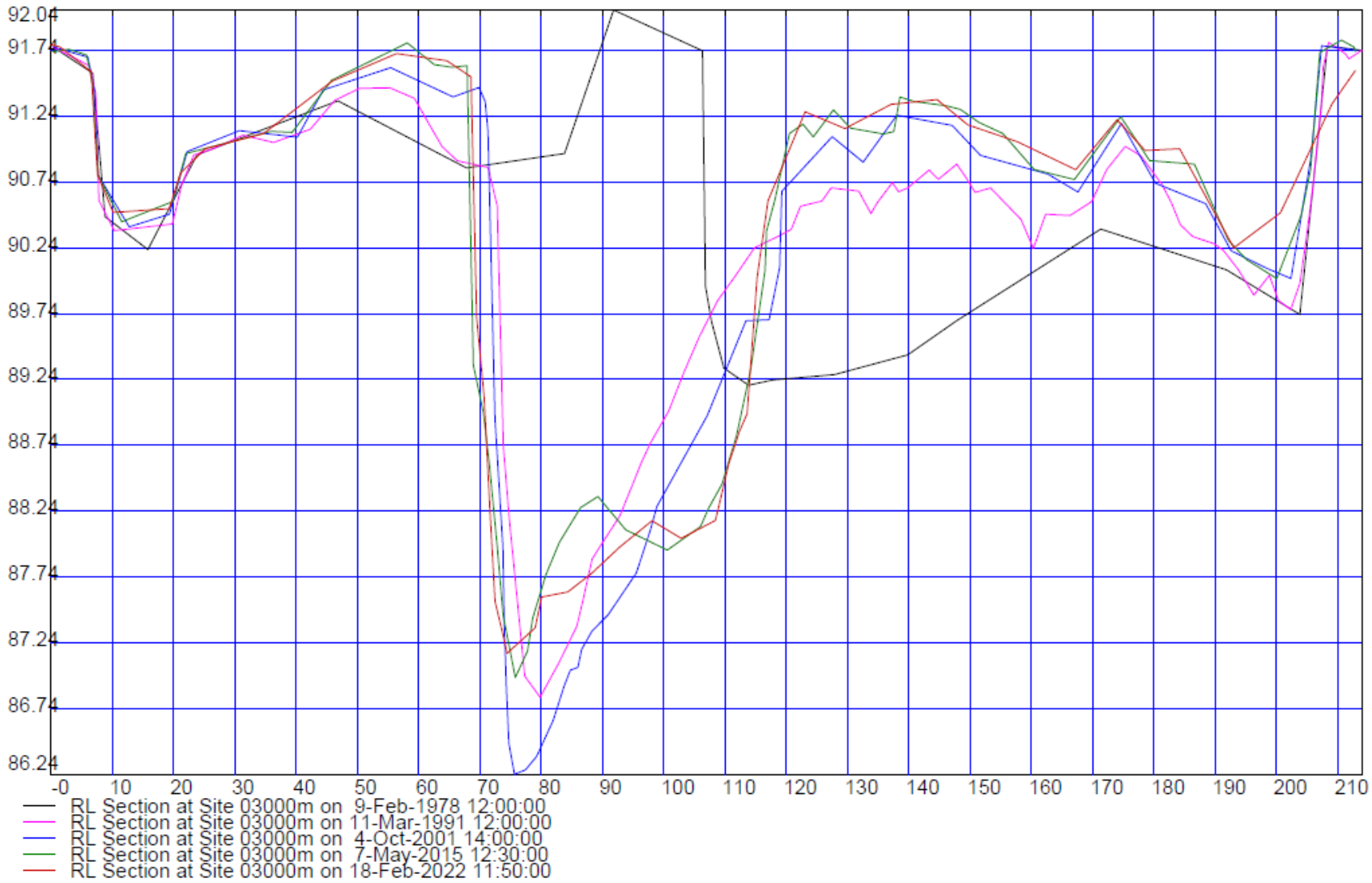
Appendix E: 2015-2022 Mean Bed Level Data

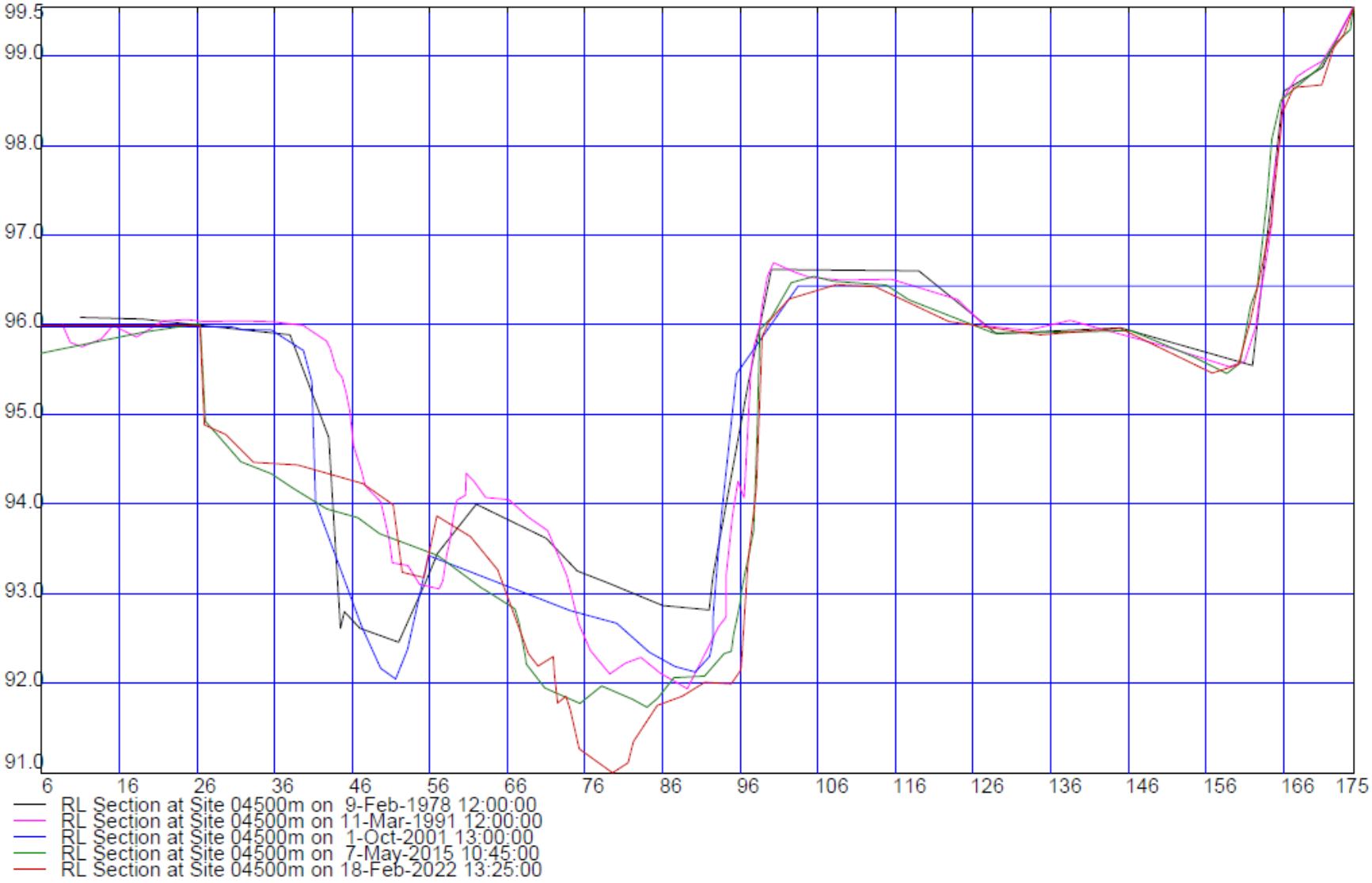
Distance from Tiraumea Confluence	Cross-section	Left Offset	Right Offset	Mean bed level 2015	Mean bed level 2021/2022	Mean bed level change (2022-2015)
0	0000	50	92	81.208	80.904	-0.304
1.5	1500	10.5	53	85.373	85.152	-0.221
3	3000	68	116	88.207	88.127	-0.08
4.5	4500	66	98	92.125	91.86	-0.265
6	6000	16.2	88.4	96.542	96.412	-0.13
7.5	7500	80	129	100.873	99.905	-0.968
9	9000	25.5	59	104.619	104.706	0.087
10.5	10500	58	123	110.99	110.769	-0.221
12	12000	12	79	116.057	116.239	0.182
13.5	13500	121	218	120.42	120.194	-0.226
15	15000	20	62	123.648	123.773	0.125
16.5	16500	70	139	128.504	128.255	-0.249
18	18000	26.5	138	133.714	133.799	0.085
19.5	19500	176	216	136.729	136.563	-0.166
21	21000	143	199	142.137	141.855	-0.282
22.5	22500	14.7	82.5	160.91	160.941	0.031
24	24000	123.2	187.5	154.174	154.005	-0.169
25.5	25500	55.5	96.5	160.506	160.034	-0.472
27	27000	9	35.8	164.724	164.645	-0.079
28.5	28500	35.6	66.5	169.274	168.756	-0.518
30	30000	7.5	38.8	174.152	174.081	-0.071
31.5	31500	25	59	177.893	177.862	-0.031
33	33000	89	118.5	182.155	182.476	0.321
34.5	34500	104	162.1	187.168	187.304	0.136
36	36000	193	250	191.27	191.045	-0.225
37.5	37500	-23	42	195.7	195.896	0.196
39	39000	21.5	80	201.799	201.925	0.126
40.5	40500	160	216.7	206.698	206.714	0.016
42	42000	174.5	224.5	212.243	212.478	0.235
43.5	43500	20	65	218.718	218.541	-0.177
45	45000	5	88	224.838	224.933	0.095
46.5	46500	33.6	78.6	232.371	232.361	-0.01
48	48000	7	57	240.129	240.172	0.043
49.5	49500	33.6	73.6	246.484	246.53	0.046
51	51000	30	60	252.858	253.073	0.215
52.5	52500	54	90	259.856	259.868	0.012
54	54000	60	102	270.84	270.959	0.119
55.5	55500	62.7	120	282.175	281.774	-0.401
57	57000	172	220	295.02	294.798	-0.222
58.5	58500	15	46	308.828	308.743	-0.085
60	60000	7.75	36.3	331.054	331.121	0.067

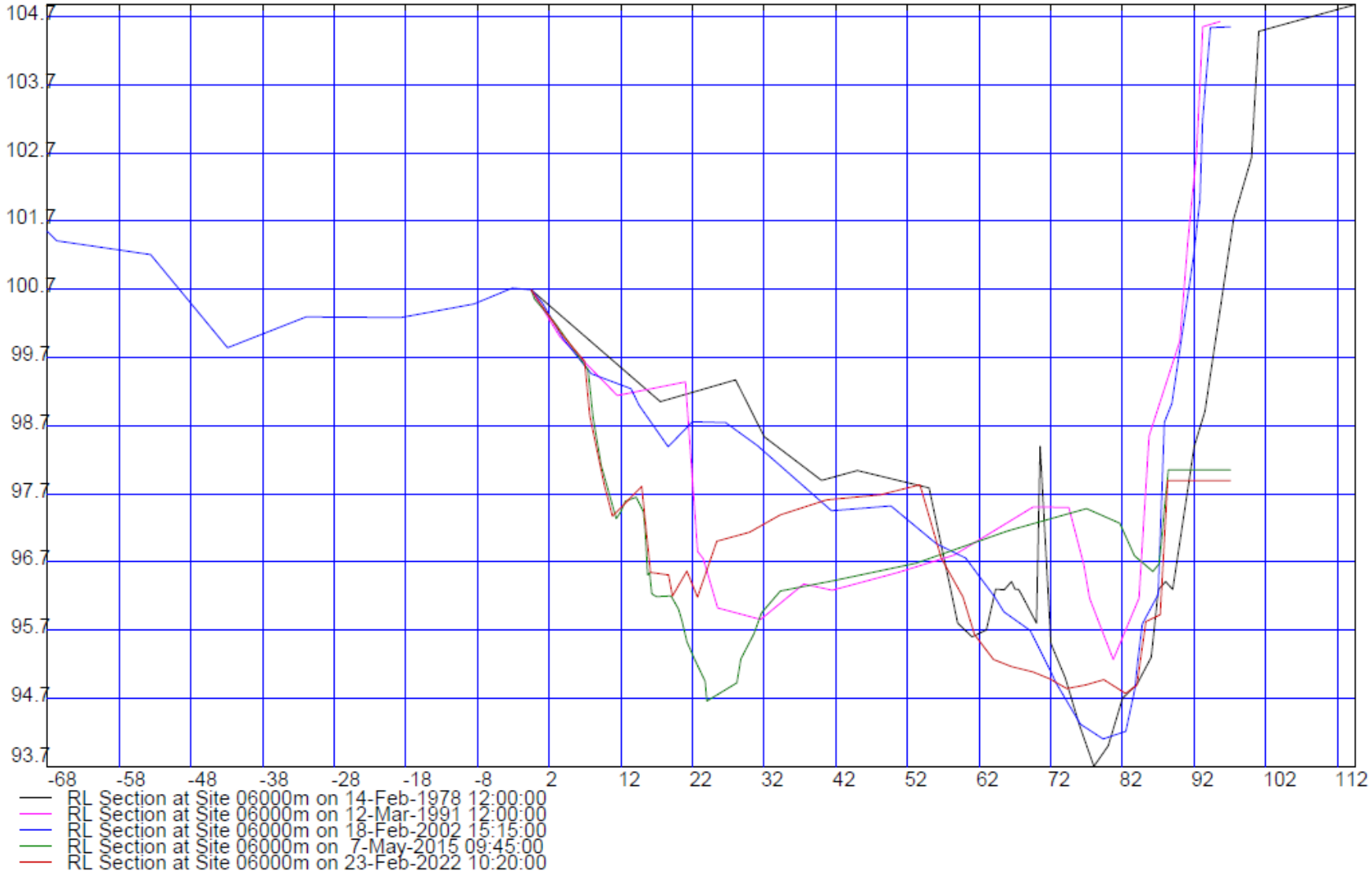
Appendix F: Cross sections

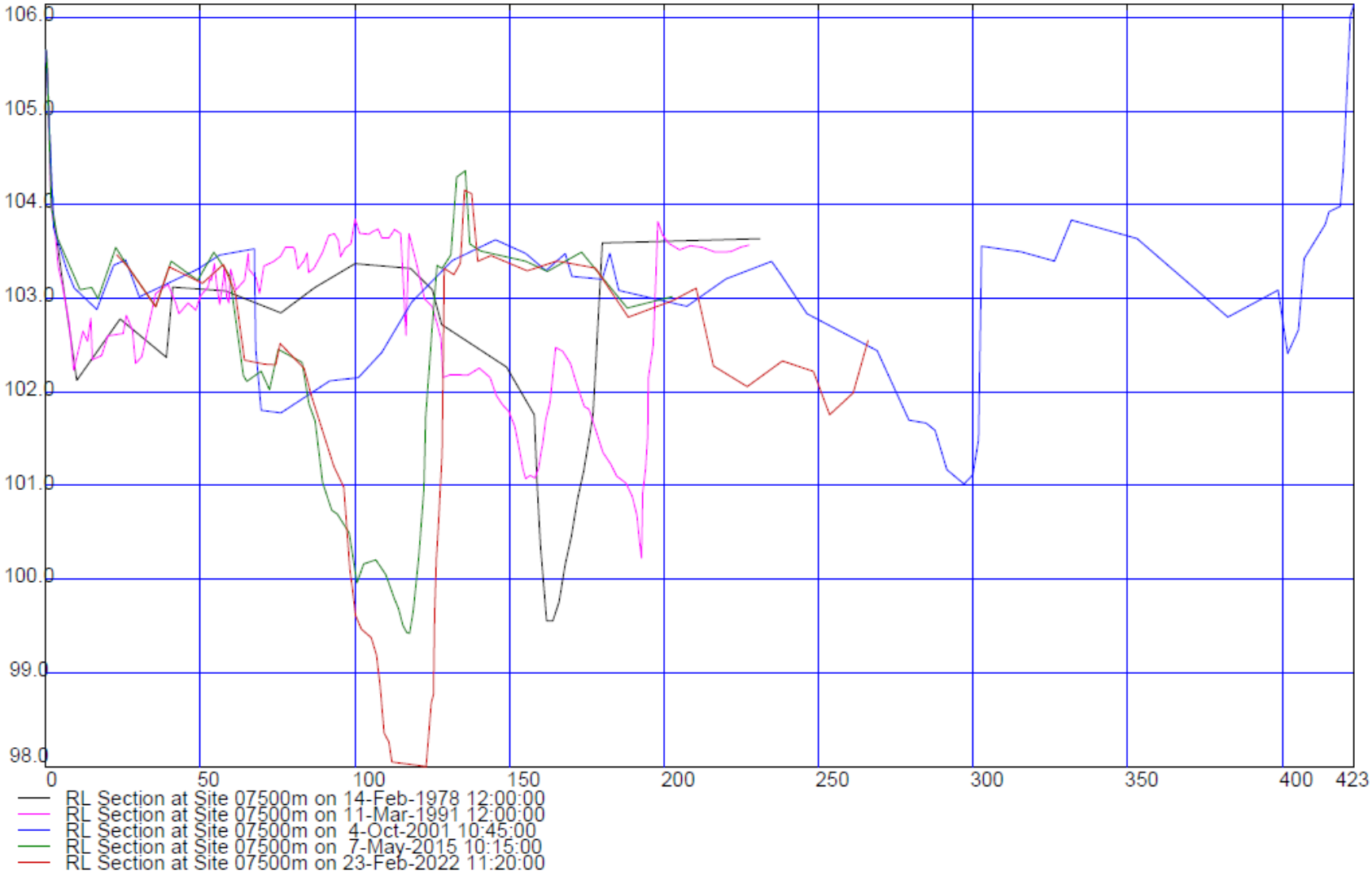


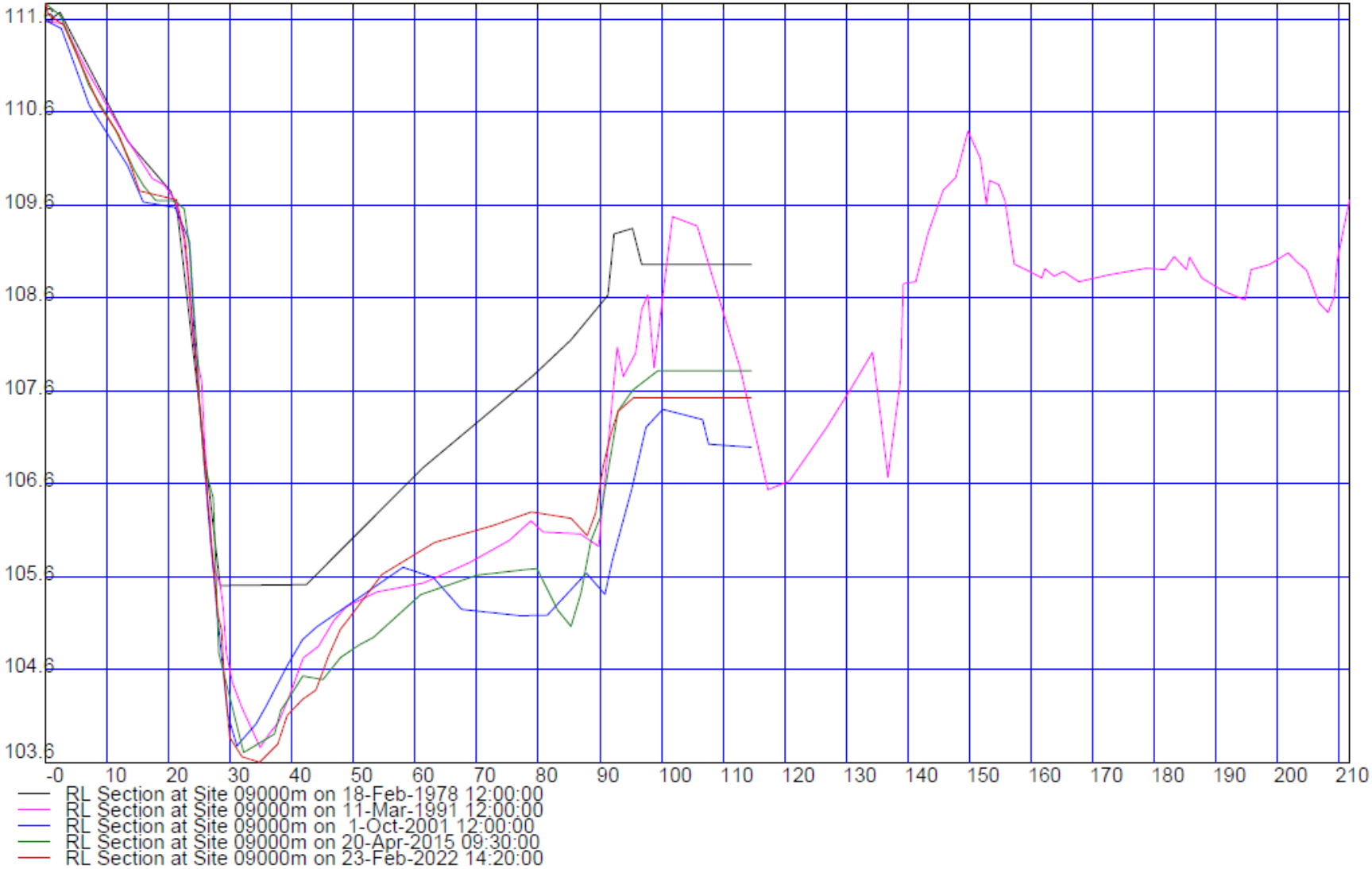

91.9
90.9
89.9
88.9
87.9
86.9
85.9
84.9
83.9
82.9
-11
-1
9
19
29
39
49
59
69
79
89
99
109
119
129
139
149155
RL Section at Site 01500m on 10-Feb-1978 12:00:00
RL Section at Site 01500m on 3-Apr-2002 12:00:00
RL Section at Site 01500m on 7-May-2015 11:30:00
RL Section at Site 01500m on 18-Feb-2022 11:20:00

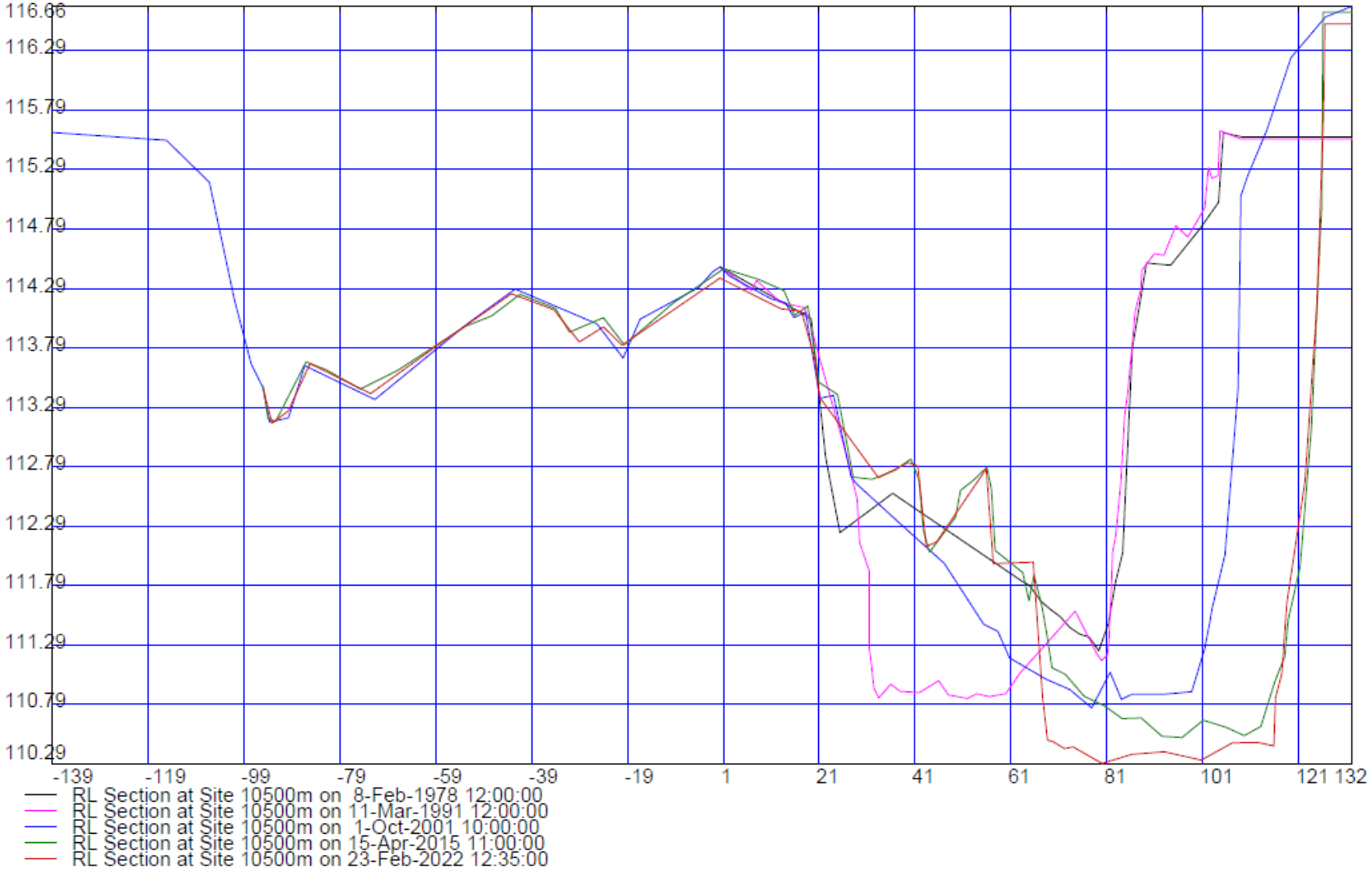

92.04
91.74
91.24
90.74
90.24
89.74
89.24
88.74
88.24
87.74
87.24
86.74
86.24
-0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
RL Section at Site 03000m on 9-Feb-1978 12:00:00
RL Section at Site 03000m on 11-Mar-1991 12:00:00
RL Section at Site 03000m on 4-Oct-2001 14:00:00
RL Section at Site 03000m on 7-May-2015 12:30:00
RL Section at Site 03000m on 18-Feb-2022 11:50:00

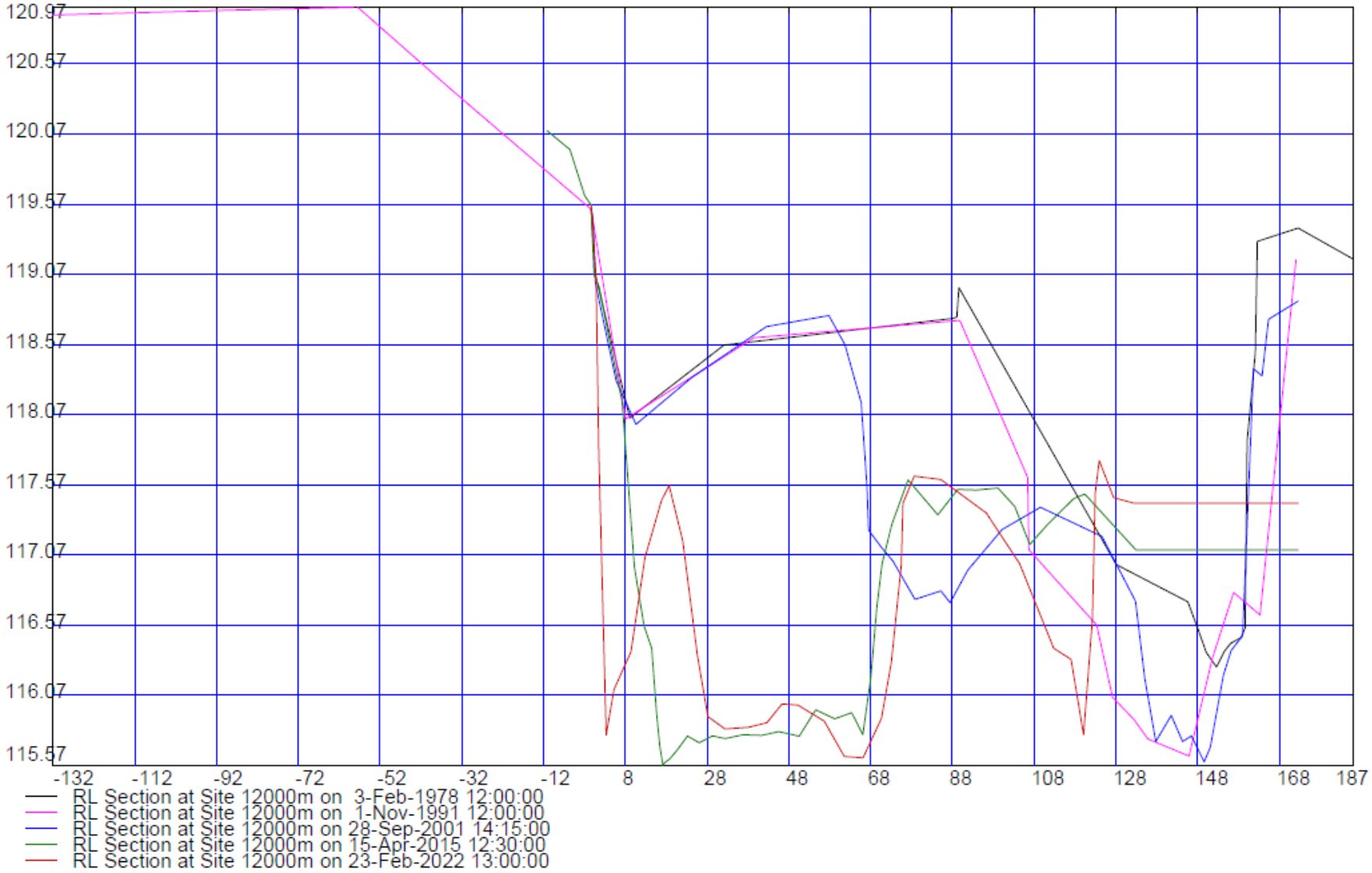

99.5
99.0
98.0
97.0
96.0
95.0
94.0
93.0
92.0
91.0
6
16
26
36
46
56
66
76
86
96
106
116
126
136
146
156
166
175
RL Section at Site 04500m on 9-Feb-1978 12:00:00
RL Section at Site 04500m on 11-Mar-1991 12:00:00
RL Section at Site 04500m on 1-Oct-2001 13:00:00
RL Section at Site 04500m on 7-May-2015 10:45:00
RL Section at Site 04500m on 18-Feb-2022 13:25:00

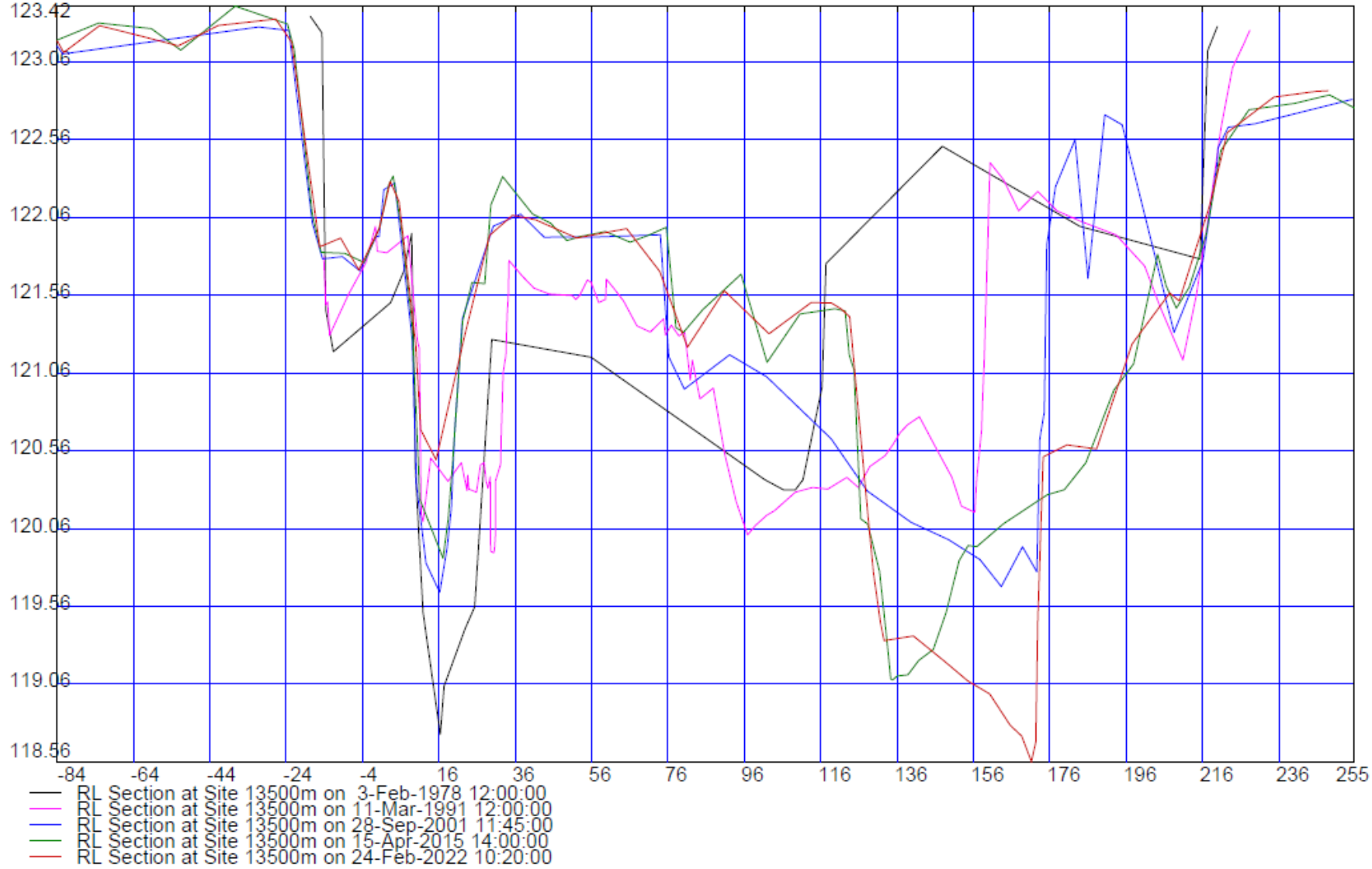

104.7
103.7
102.7
101.7
100.7
99.7
98.7
97.7
96.7
95.7
94.7
93.7
-68
-58
-48
-38
-28
-18
-8
2
12
22
32
42
52
62
72
82
92
102
112
RL Section at Site 06000m on 14-Feb-1978 12:00:00
RL Section at Site 06000m on 12-Mar-1991 12:00:00
RL Section at Site 06000m on 18-Feb-2002 15:15:00
RL Section at Site 06000m on 7-May-2015 09:45:00
RL Section at Site 06000m on 23-Feb-2022 10:20:00

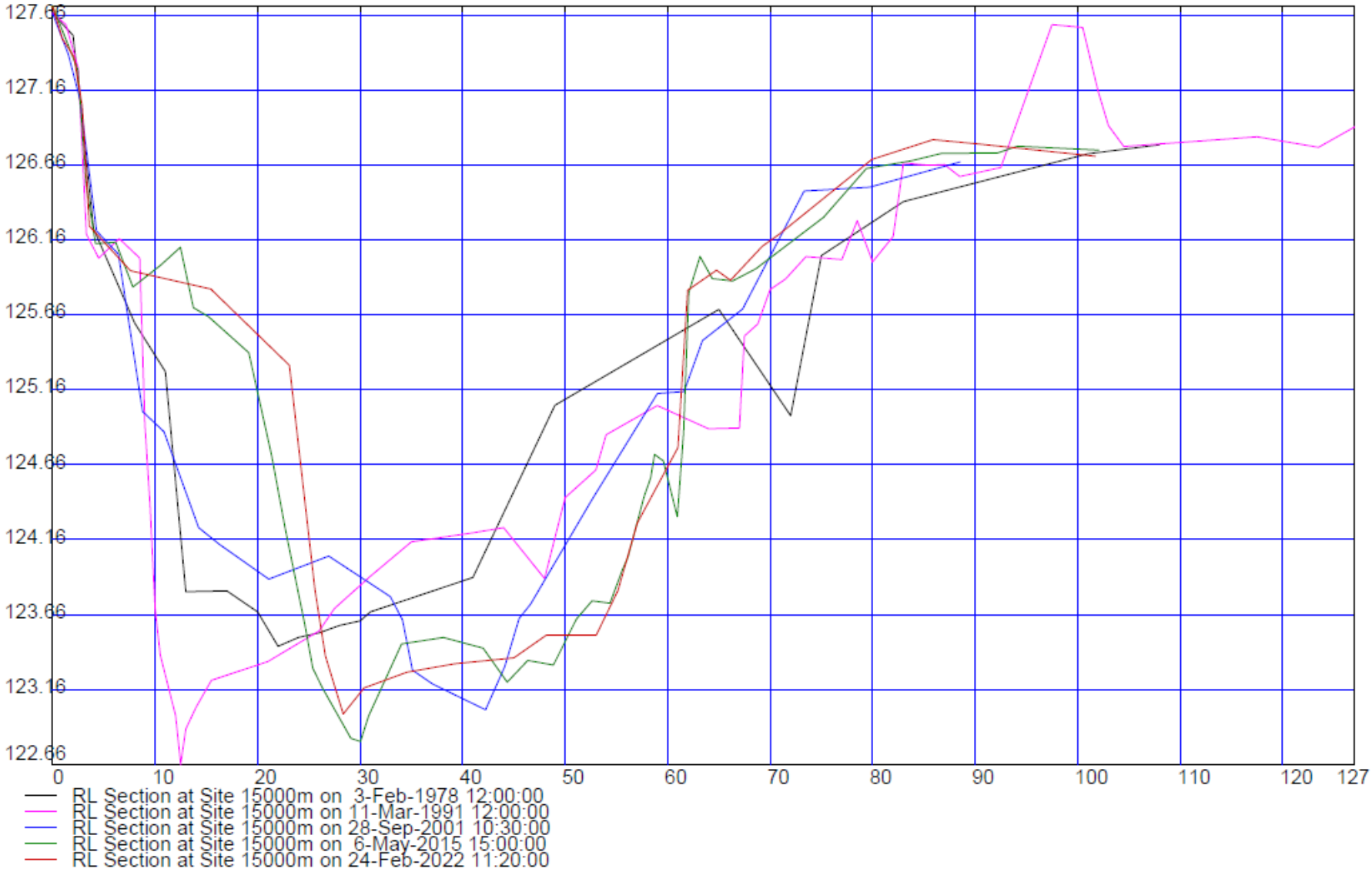

106.0
105.0
104.0
103.0
102.0
101.0
100.0
99.0
98.0
0
50
100
150
200
250
300
350
400
423
RL Section at Site 07500m on 14-Feb-1978 12:00:00
RL Section at Site 07500m on 11-Mar-1991 12:00:00
RL Section at Site 07500m on 4-Oct-2001 10:45:00
RL Section at Site 07500m on 7-May-2015 10:15:00
RL Section at Site 07500m on 23-Feb-2022 11:20:00

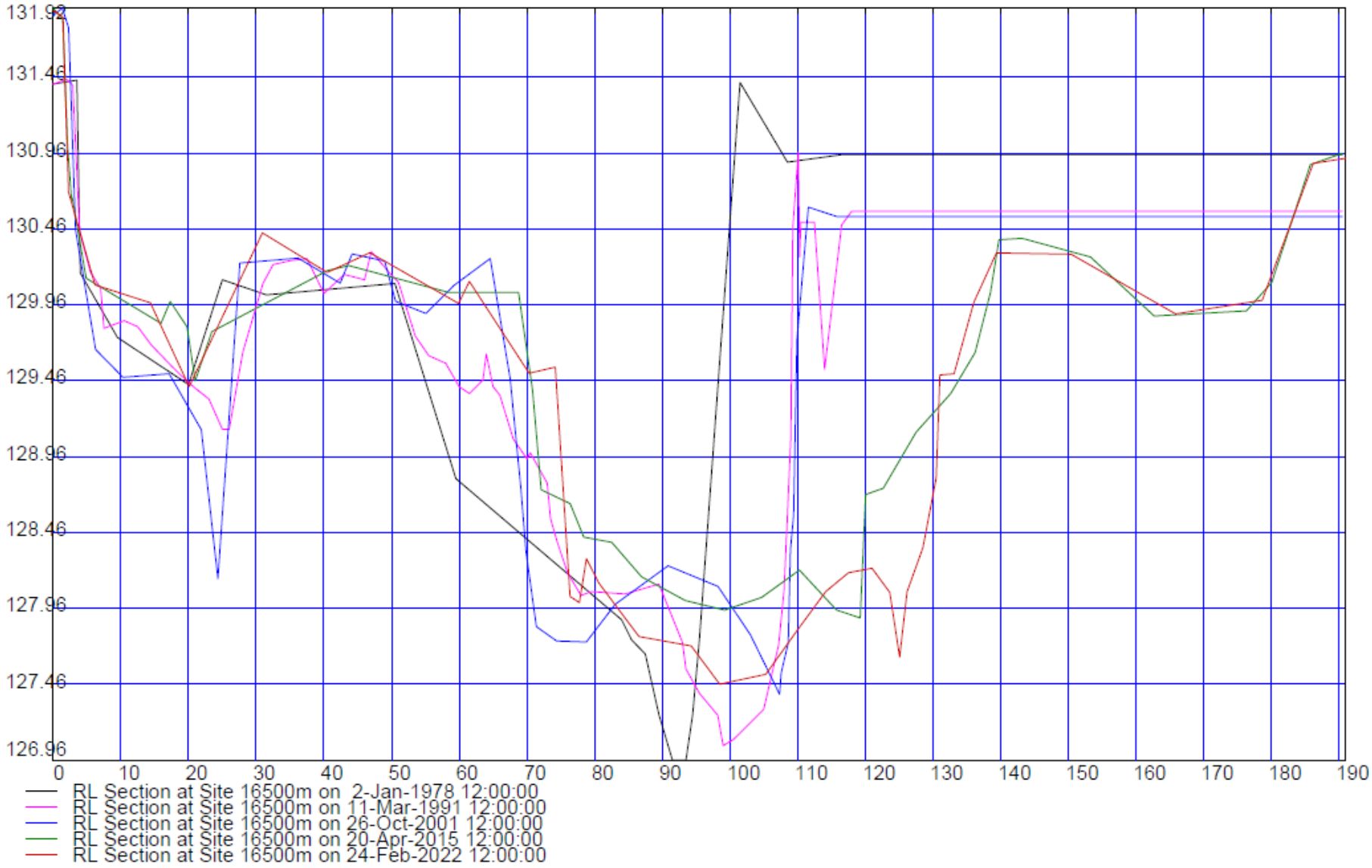

111.6
110.6
109.6
108.6
107.6
106.6
105.6
104.6
103.6
-0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
RL Section at Site 09000m on 18-Feb-1978 12:00:00
RL Section at Site 09000m on 11-Mar-1991 12:00:00
RL Section at Site 09000m on 1-Oct-2001 12:00:00
RL Section at Site 09000m on 20-Apr-2015 09:30:00
RL Section at Site 09000m on 23-Feb-2022 14:20:00

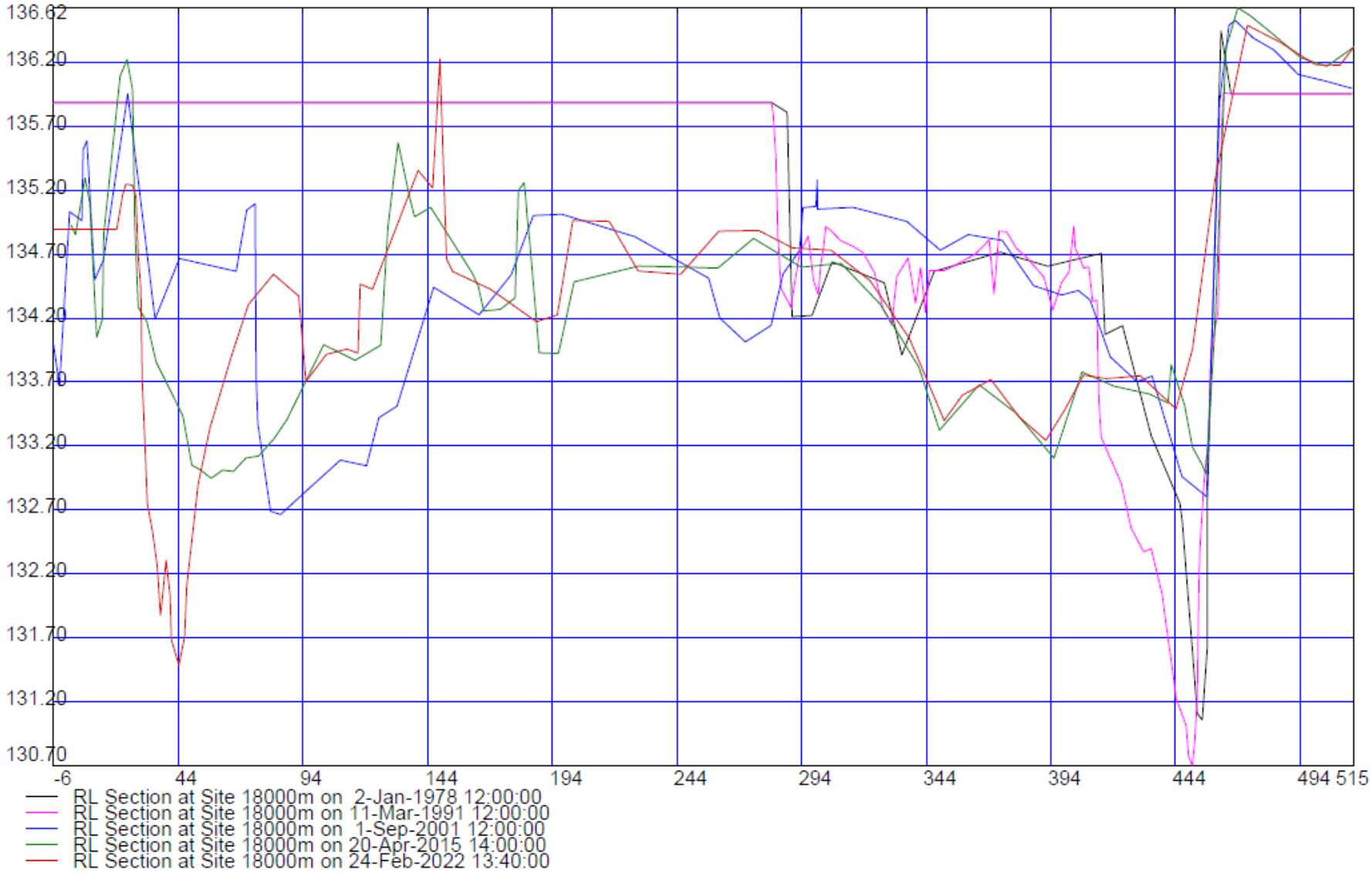

116.66
116.29
115.79
115.29
114.79
114.29
113.79
113.29
112.79
112.29
111.79
111.29
110.79
110.29
-139
-119
-99
-79
-59
-39
-19
1
21
41
61
81
101
121 132
RL Section at Site 10500m on 8-Feb-1978 12:00:00
RL Section at Site 10500m on 11-Mar-1991 12:00:00
RL Section at Site 10500m on 1-Oct-2001 10:00:00
RL Section at Site 10500m on 15-Apr-2015 11:00:00
RL Section at Site 10500m on 23-Feb-2022 12:35:00

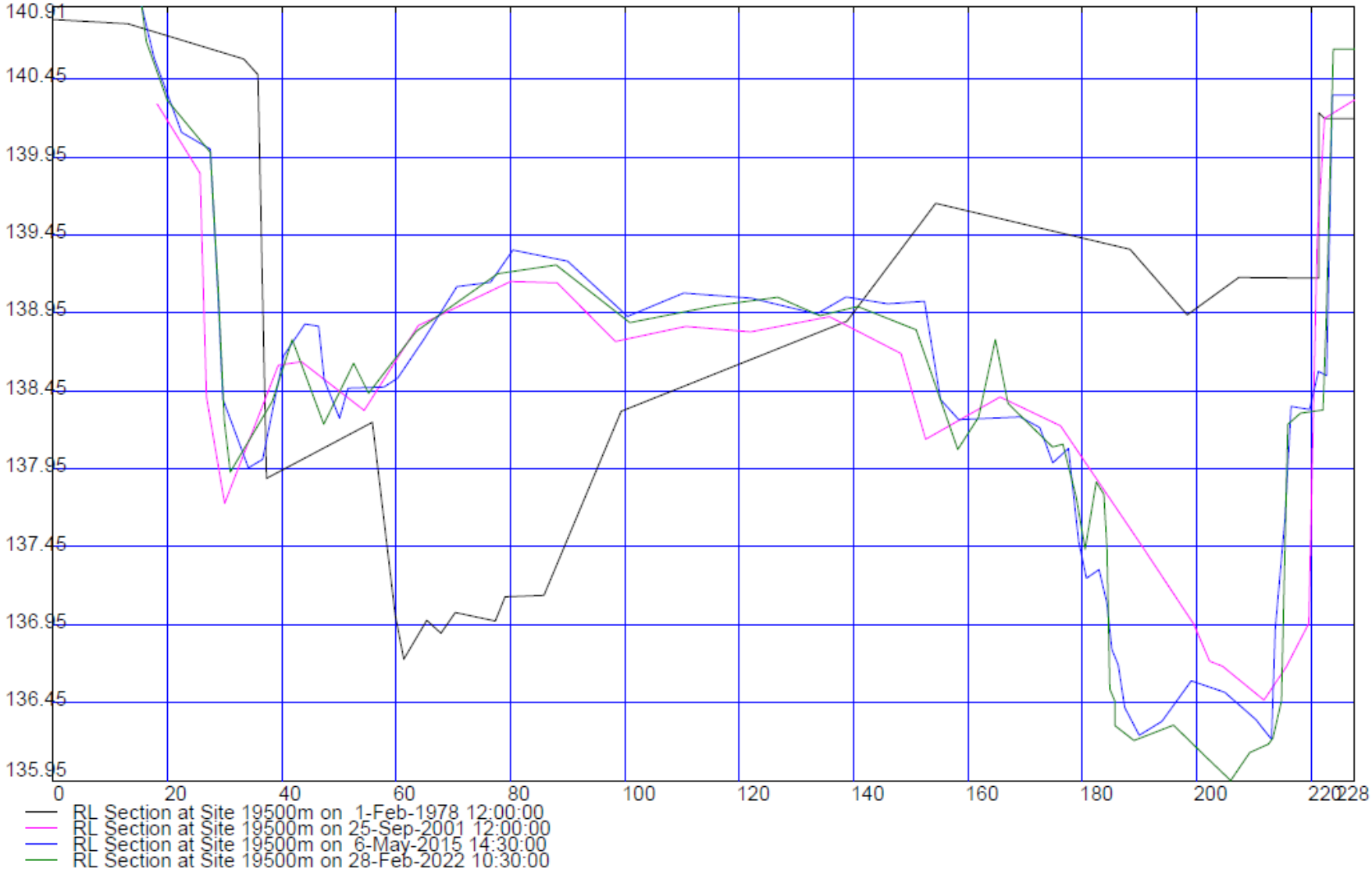

120.97
120.57
120.07
119.57
119.07
118.57
118.07
117.57
117.07
116.57
116.07
115.57
-132
-112
-92
-72
-52
-32
-12
8
28
48
68
88
108
128
148
168
187
RL Section at Site 12000m on 3-Feb-1978 12:00:00
RL Section at Site 12000m on 1-Nov-1991 12:00:00
RL Section at Site 12000m on 28-Sep-2001 14:15:00
RL Section at Site 12000m on 15-Apr-2015 12:30:00
RL Section at Site 12000m on 23-Feb-2022 13:00:00

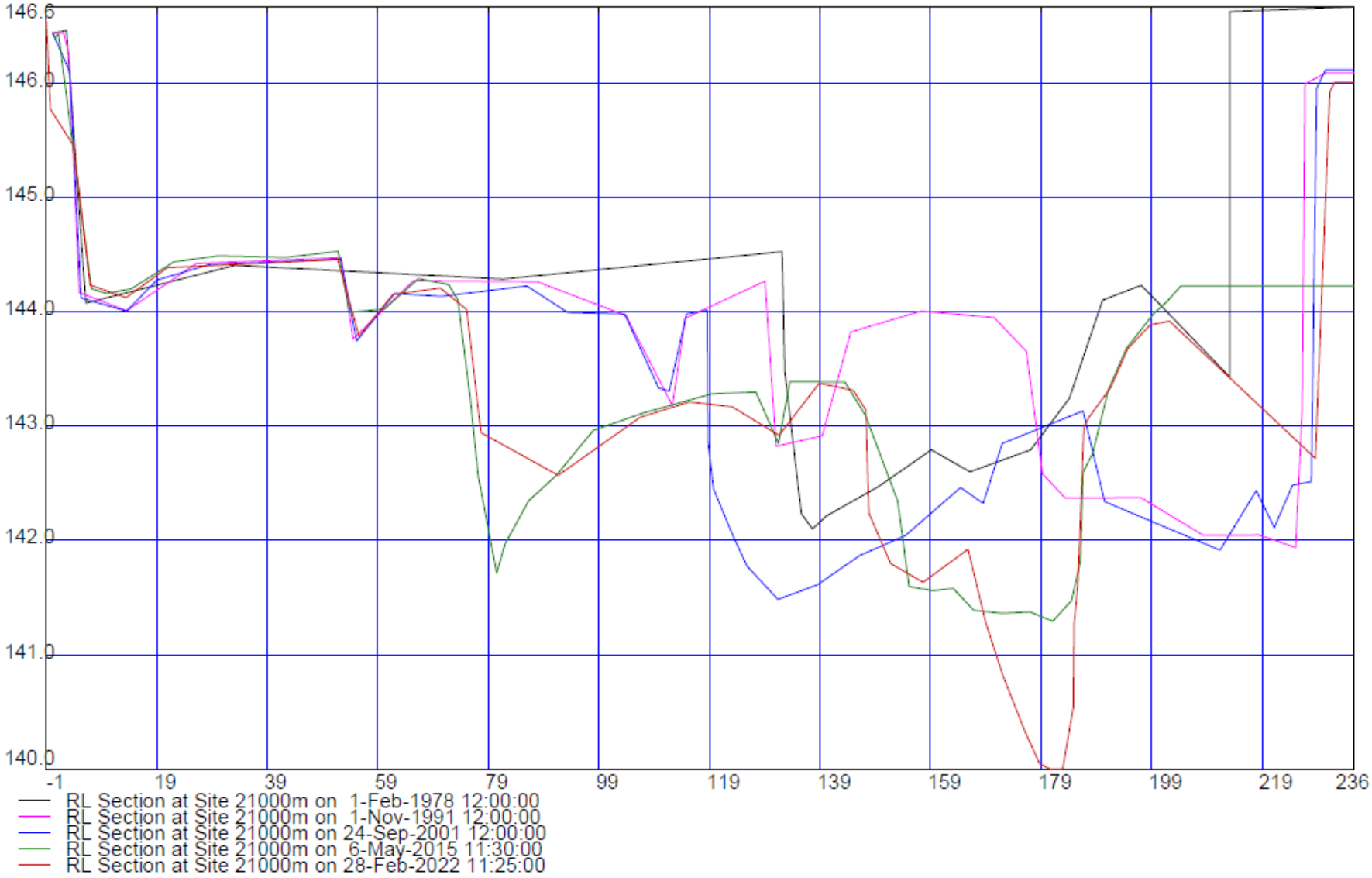

123.42
123.06
122.56
122.06
121.56
121.06
120.56
120.06
119.56
119.06
118.56
-84
-64
-44
-24
-4
16
36
56
76
96
116
136
156
176
196
216
236
255
RL Section at Site 13500m on 3-Feb-1978 12:00:00
RL Section at Site 13500m on 11-Mar-1991 12:00:00
RL Section at Site 13500m on 28-Sep-2001 11:45:00
RL Section at Site 13500m on 15-Apr-2015 14:00:00
RL Section at Site 13500m on 24-Feb-2022 10:20:00

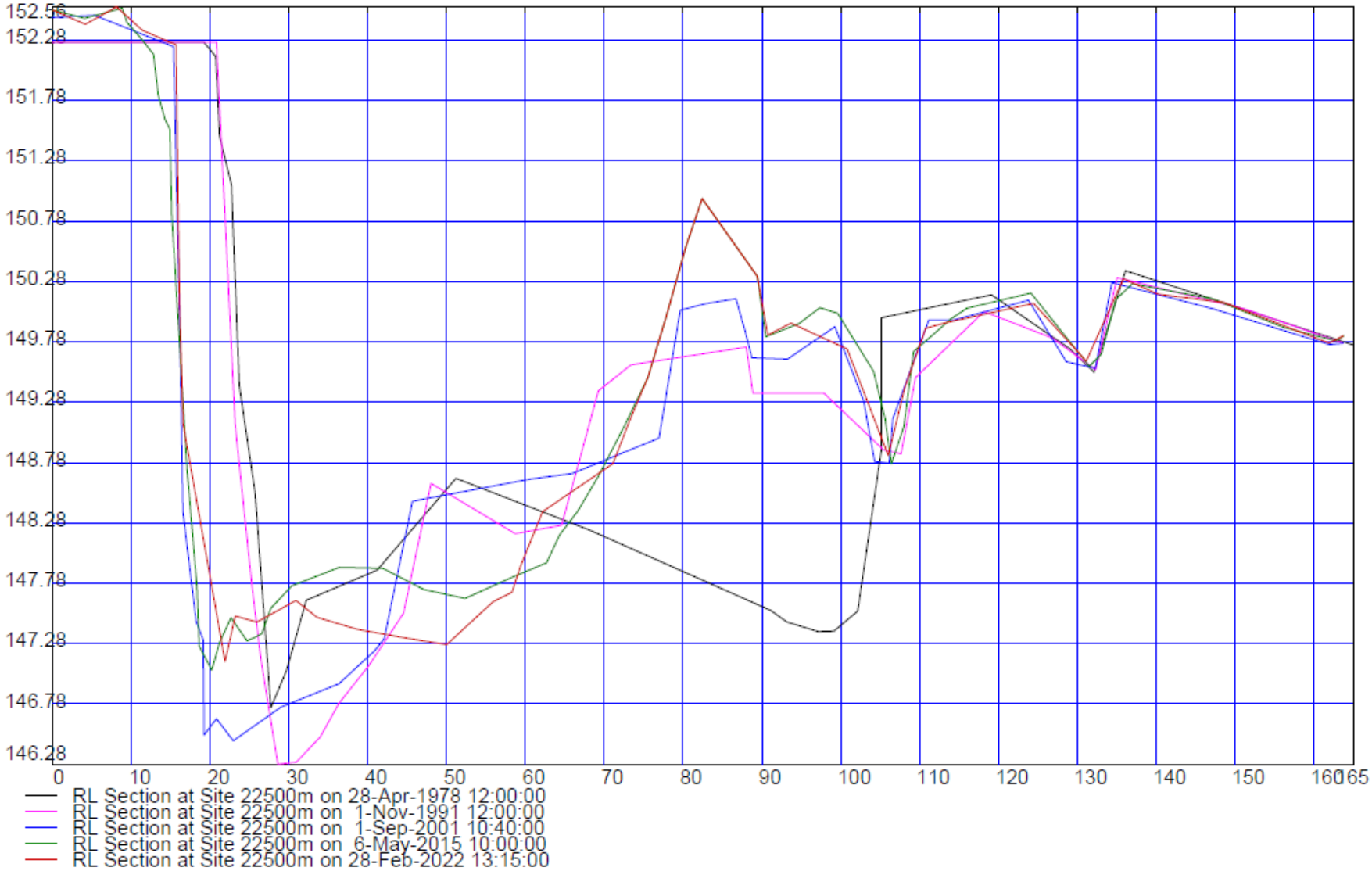

127.66
127.16
126.66
126.16
125.66
125.16
124.66
124.16
123.66
123.16
122.66
0
10
20
30
40
50
60
70
80
90
100
110
120
127
RL Section at Site 15000m on 3-Feb-1978 12:00:00
RL Section at Site 15000m on 11-Mar-1991 12:00:00
RL Section at Site 15000m on 28-Sep-2001 10:30:00
RL Section at Site 15000m on 6-May-2015 15:00:00
RL Section at Site 15000m on 24-Feb-2022 11:20:00


131.96
131.46
130.96
130.46
129.96
129.46
128.96
128.46
127.96
127.46
126.96
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
RL Section at Site 16500m on 2-Jan-1978 12:00:00
RL Section at Site 16500m on 11-Mar-1991 12:00:00
RL Section at Site 16500m on 26-Oct-2001 12:00:00
RL Section at Site 16500m on 20-Apr-2015 12:00:00
RL Section at Site 16500m on 24-Feb-2022 12:00:00

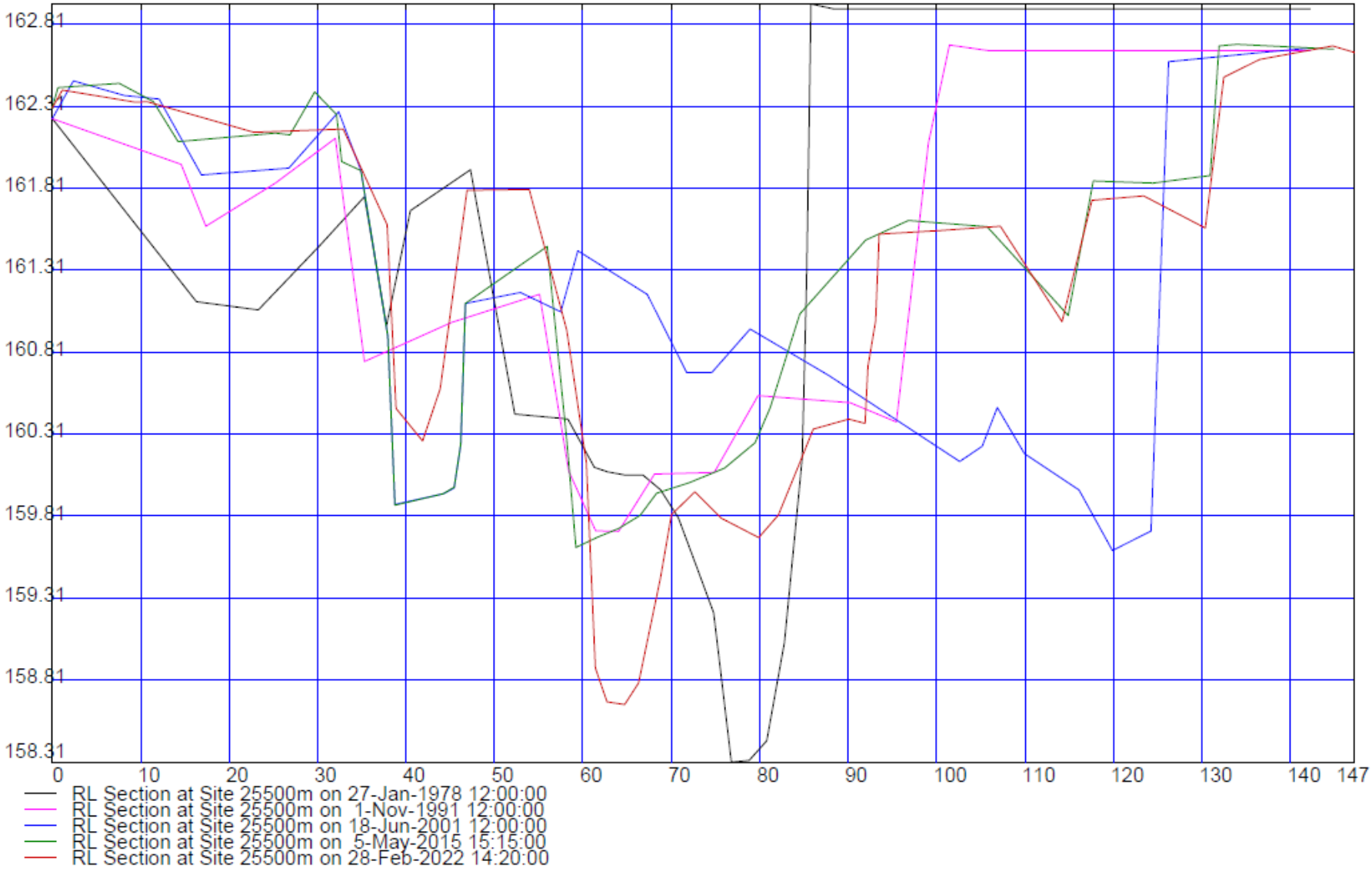

136.62
136.20
135.70
135.20
134.70
134.20
133.70
133.20
132.70
132.20
131.70
131.20
130.70
-6
44
94
144
194
244
294
344
394
444
494 515
RL Section at Site 18000m on 2-Jan-1978 12:00:00
RL Section at Site 18000m on 11-Mar-1991 12:00:00
RL Section at Site 18000m on 1-Sep-2001 12:00:00
RL Section at Site 18000m on 20-Apr-2015 14:00:00
RL Section at Site 18000m on 24-Feb-2022 13:40:00

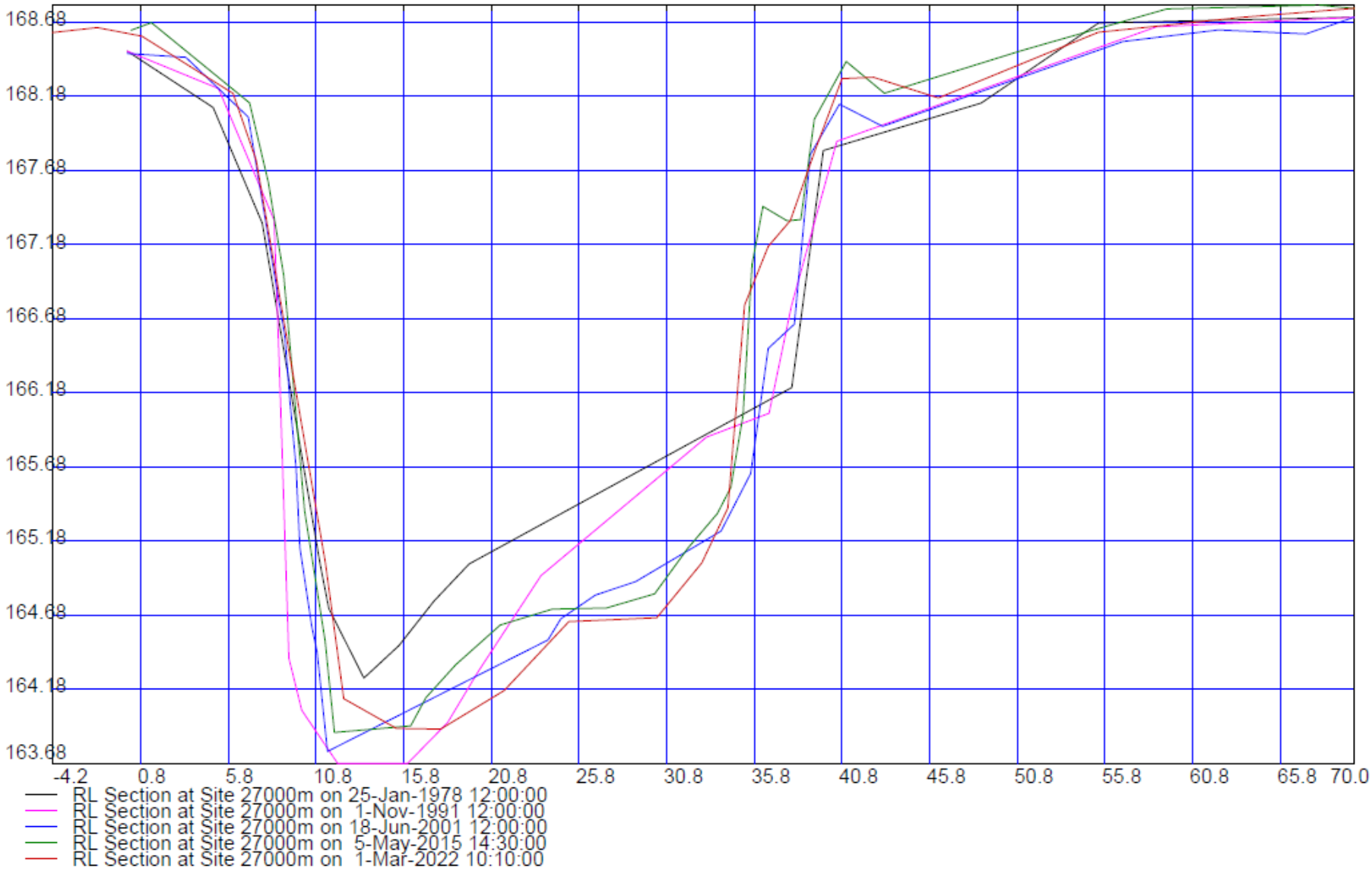

140.91
140.45
139.95
139.45
138.95
138.45
137.95
137.45
136.95
136.45
135.95
0
20
40
60
80
100
120
140
160
180
200
220
228
RL Section at Site 19500m on 1-Feb-1978 12:00:00
RL Section at Site 19500m on 25-Sep-2001 12:00:00
RL Section at Site 19500m on 6-May-2015 14:30:00
RL Section at Site 19500m on 28-Feb-2022 10:30:00

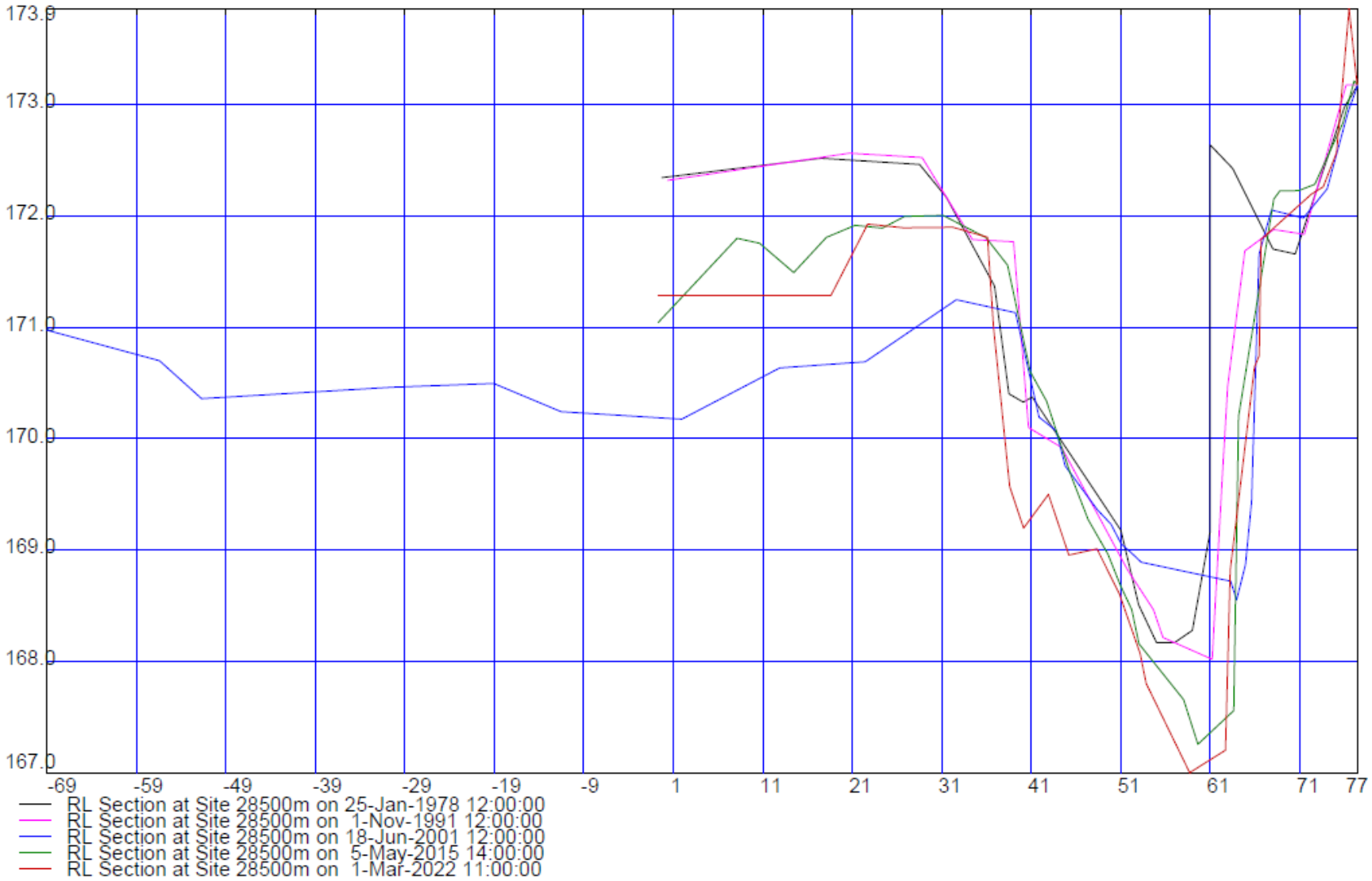

146.6
146.0
145.0
144.0
143.0
142.0
141.0
140.0
-1
19
39
59
79
99
119
139
159
179
199
219
236
RL Section at Site 21000m on 1-Feb-1978 12:00:00
RL Section at Site 21000m on 1-Nov-1991 12:00:00
RL Section at Site 21000m on 24-Sep-2001 12:00:00
RL Section at Site 21000m on 6-May-2015 11:30:00
RL Section at Site 21000m on 28-Feb-2022 11:25:00

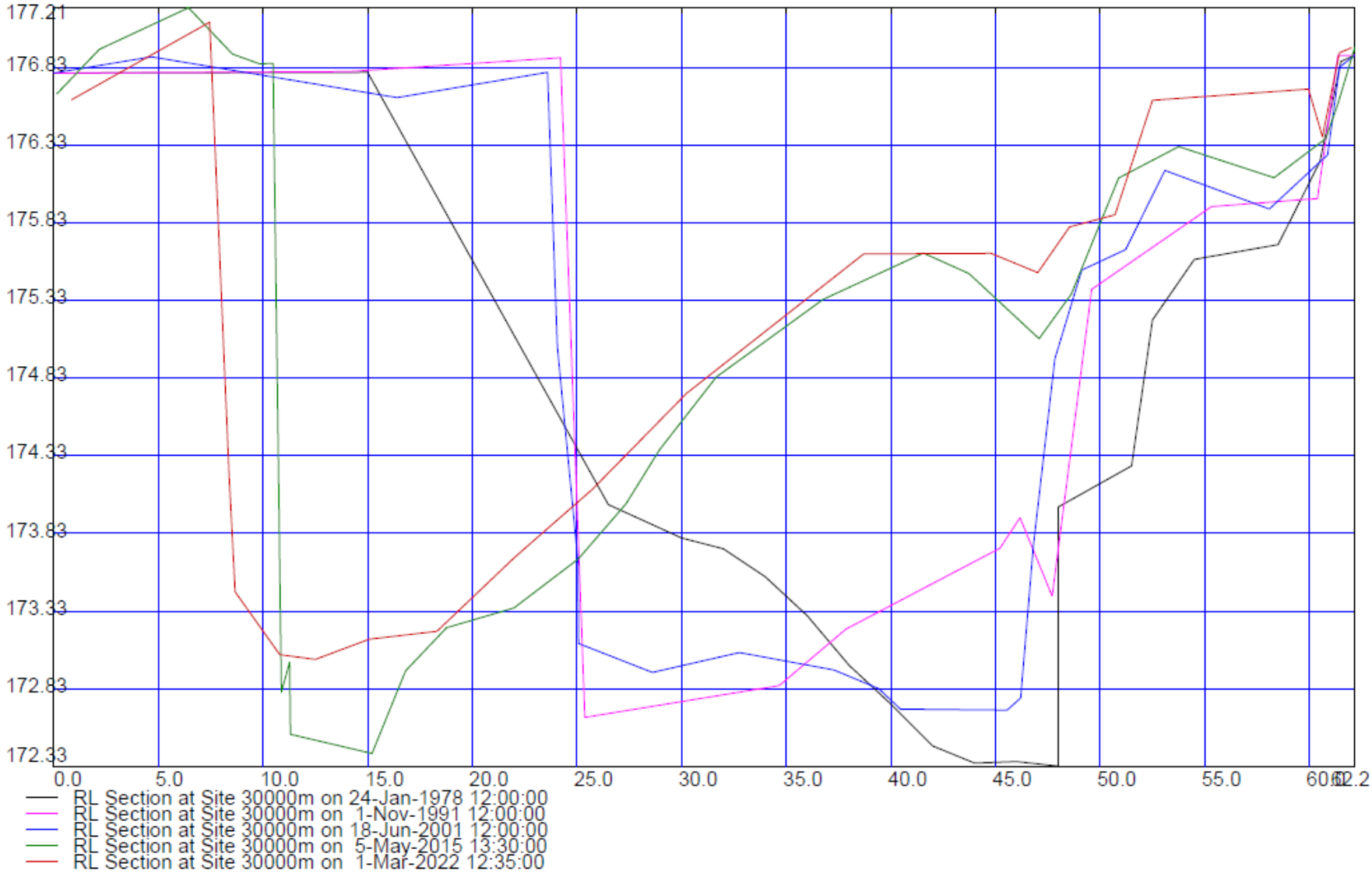

152.56
152.28
151.78
151.28
150.78
150.28
149.78
149.28
148.78
148.28
147.78
147.28
146.78
146.28
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
165
RL Section at Site 22500m on 28-Apr-1978 12:00:00
RL Section at Site 22500m on 1-Nov-1991 12:00:00
RL Section at Site 22500m on 1-Sep-2001 10:40:00
RL Section at Site 22500m on 6-May-2015 10:00:00
RL Section at Site 22500m on 28-Feb-2022 13:15:00

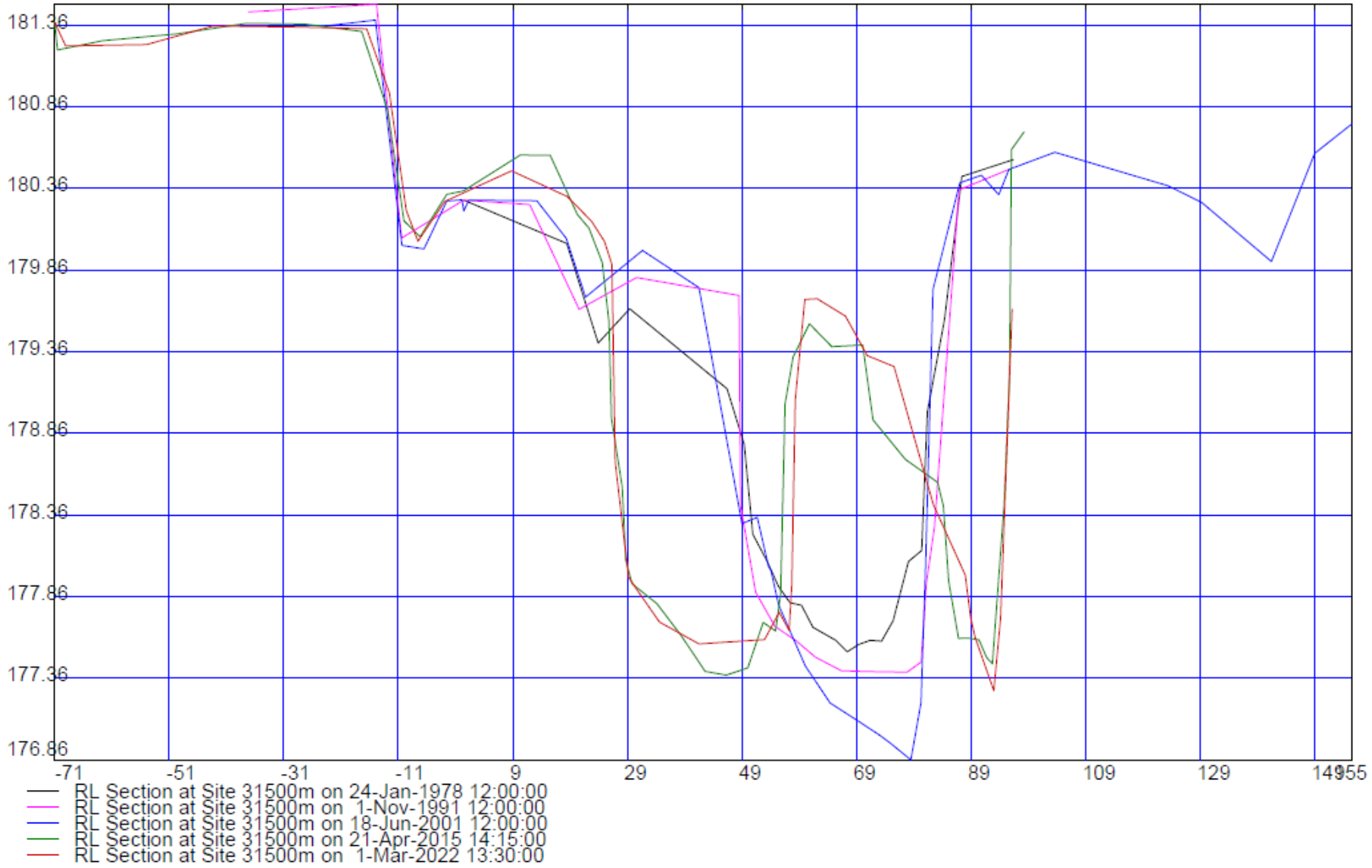

159.7
159.3
158.3
157.3
156.3
155.3
154.3
153.3
152.3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
206
RL Section at Site 24000m on 28-Apr-1978 12:00:00
RL Section at Site 24000m on 1-Nov-1991 12:00:00
RL Section at Site 24000m on 21-Sep-2001 13:30:00
RL Section at Site 24000m on 6-May-2015 11:00:00
RL Section at Site 24000m on 15-Mar-2022 11:00:00

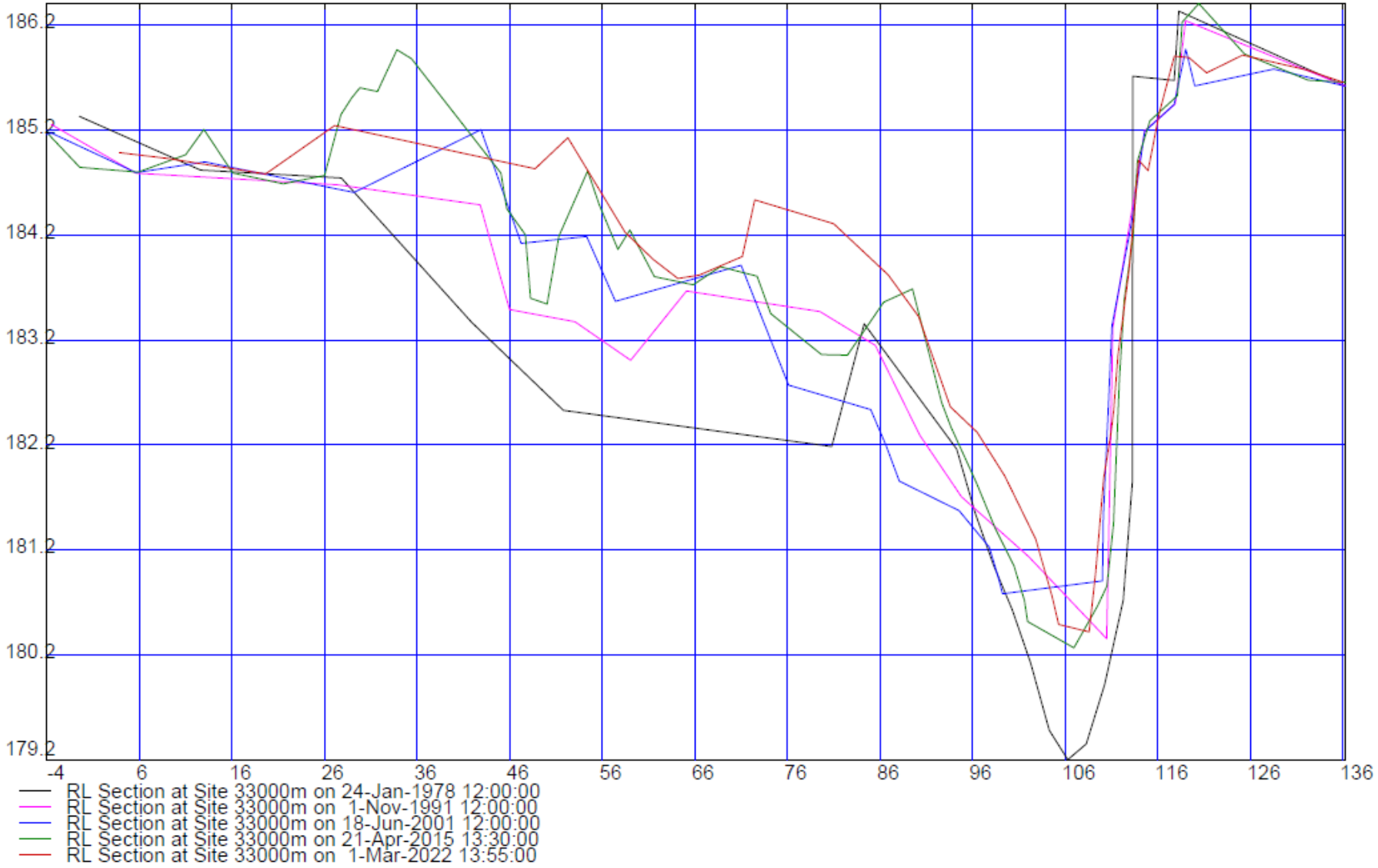

162.81
162.31
161.81
161.31
160.81
160.31
159.81
159.31
158.81
158.31
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
147
RL Section at Site 25500m on 27-Jan-1978 12:00:00
RL Section at Site 25500m on 1-Nov-1991 12:00:00
RL Section at Site 25500m on 18-Jun-2001 12:00:00
RL Section at Site 25500m on 5-May-2015 15:15:00
RL Section at Site 25500m on 28-Feb-2022 14:20:00

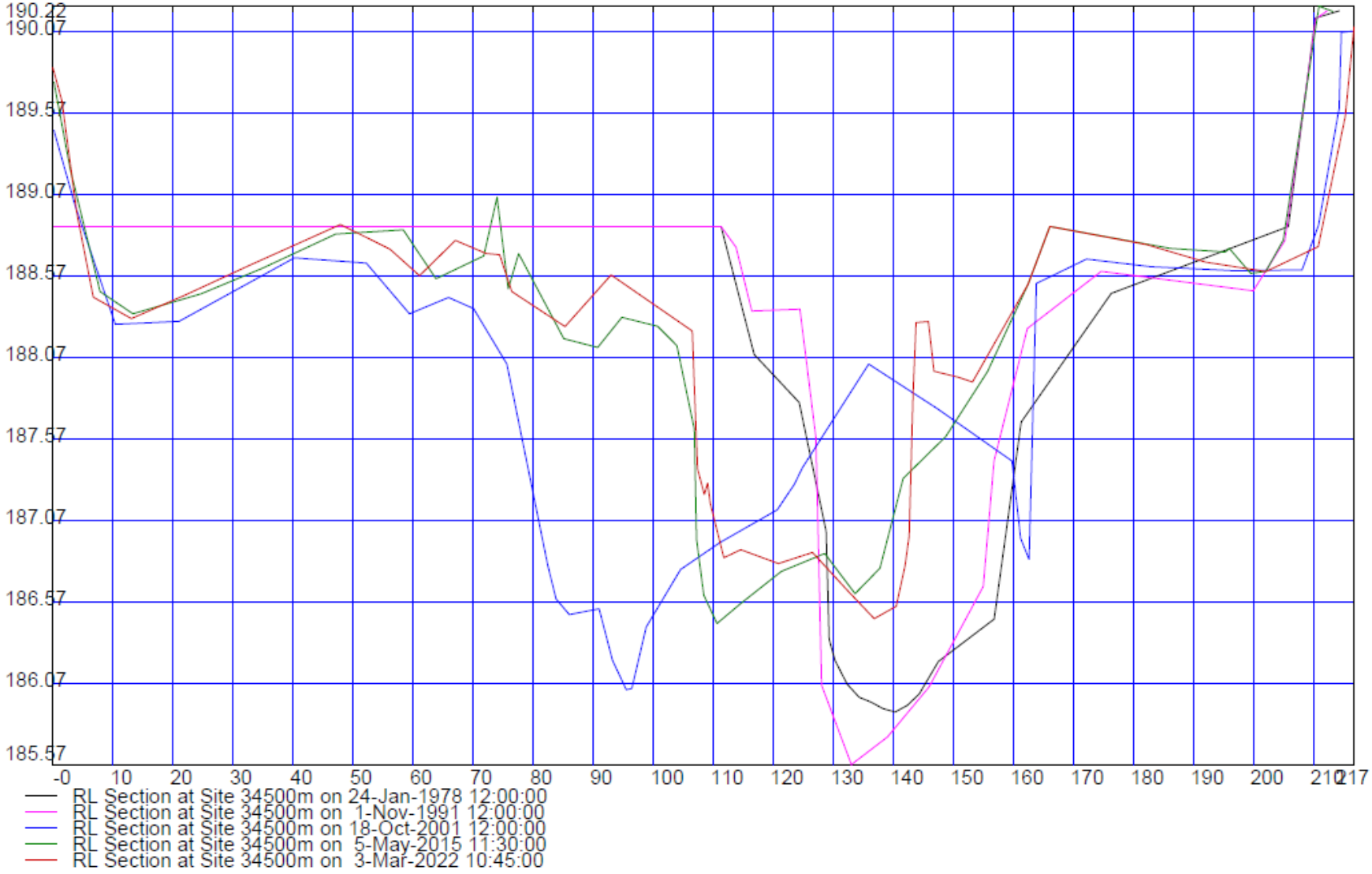

168.68
168.18
167.68
167.18
166.68
166.18
165.68
165.18
164.68
164.18
163.68
-4.2
0.8
5.8
10.8
15.8
20.8
25.8
30.8
35.8
40.8
45.8
50.8
55.8
60.8
65.8
70.0
RL Section at Site 27000m on 25-Jan-1978 12:00:00
RL Section at Site 27000m on 1-Nov-1991 12:00:00
RL Section at Site 27000m on 18-Jun-2001 12:00:00
RL Section at Site 27000m on 5-May-2015 14:30:00
RL Section at Site 27000m on 1-Mar-2022 10:10:00

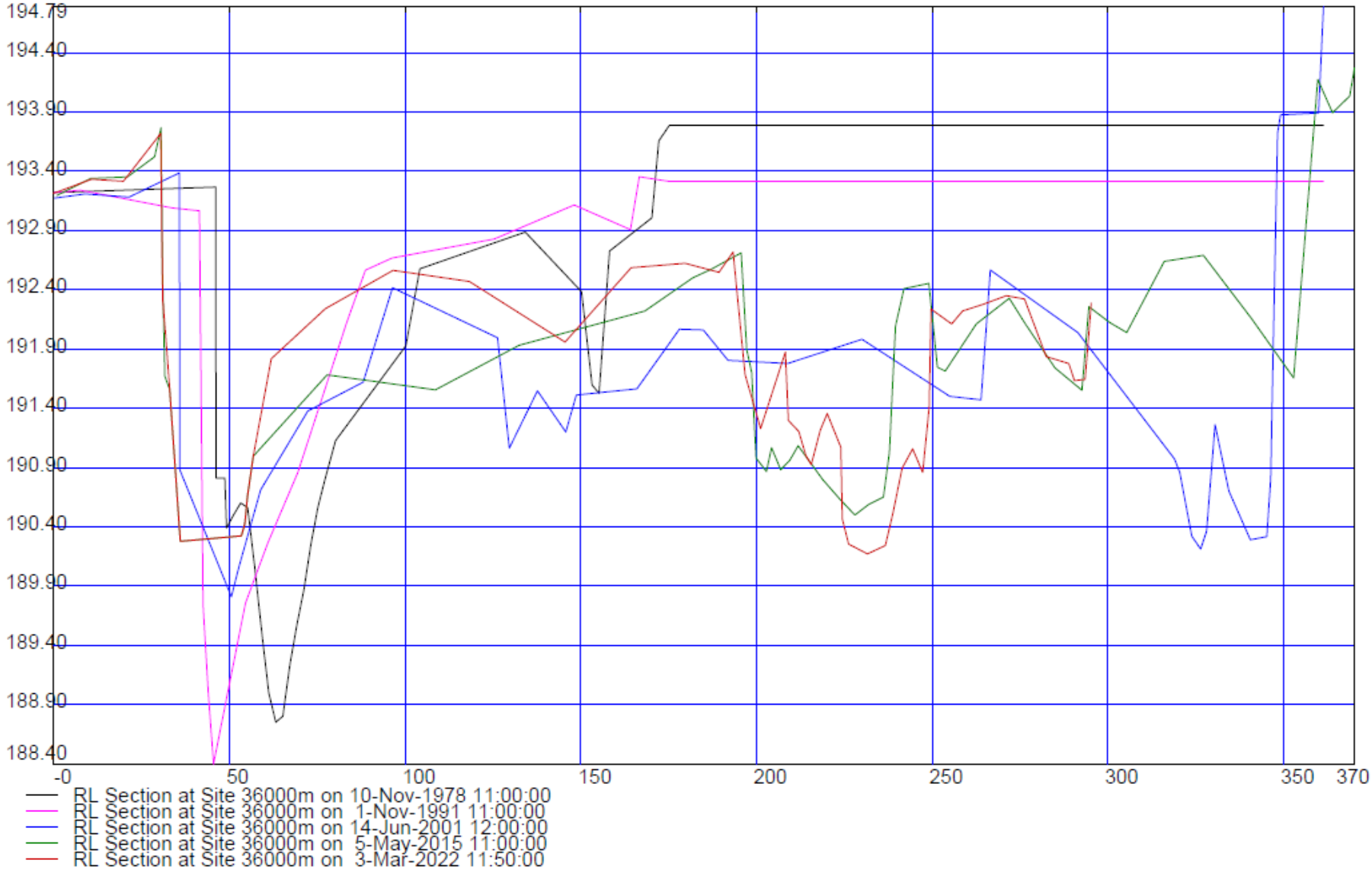

173.0
172.0
171.0
170.0
169.0
168.0
167.0
-69
-59
-49
-39
-29
-19
-9
1
11
21
31
41
51
61
71
77
RL Section at Site 28500m on 25-Jan-1978 12:00:00
RL Section at Site 28500m on 1-Nov-1991 12:00:00
RL Section at Site 28500m on 18-Jun-2001 12:00:00
RL Section at Site 28500m on 5-May-2015 14:00:00
RL Section at Site 28500m on 1-Mar-2022 11:00:00

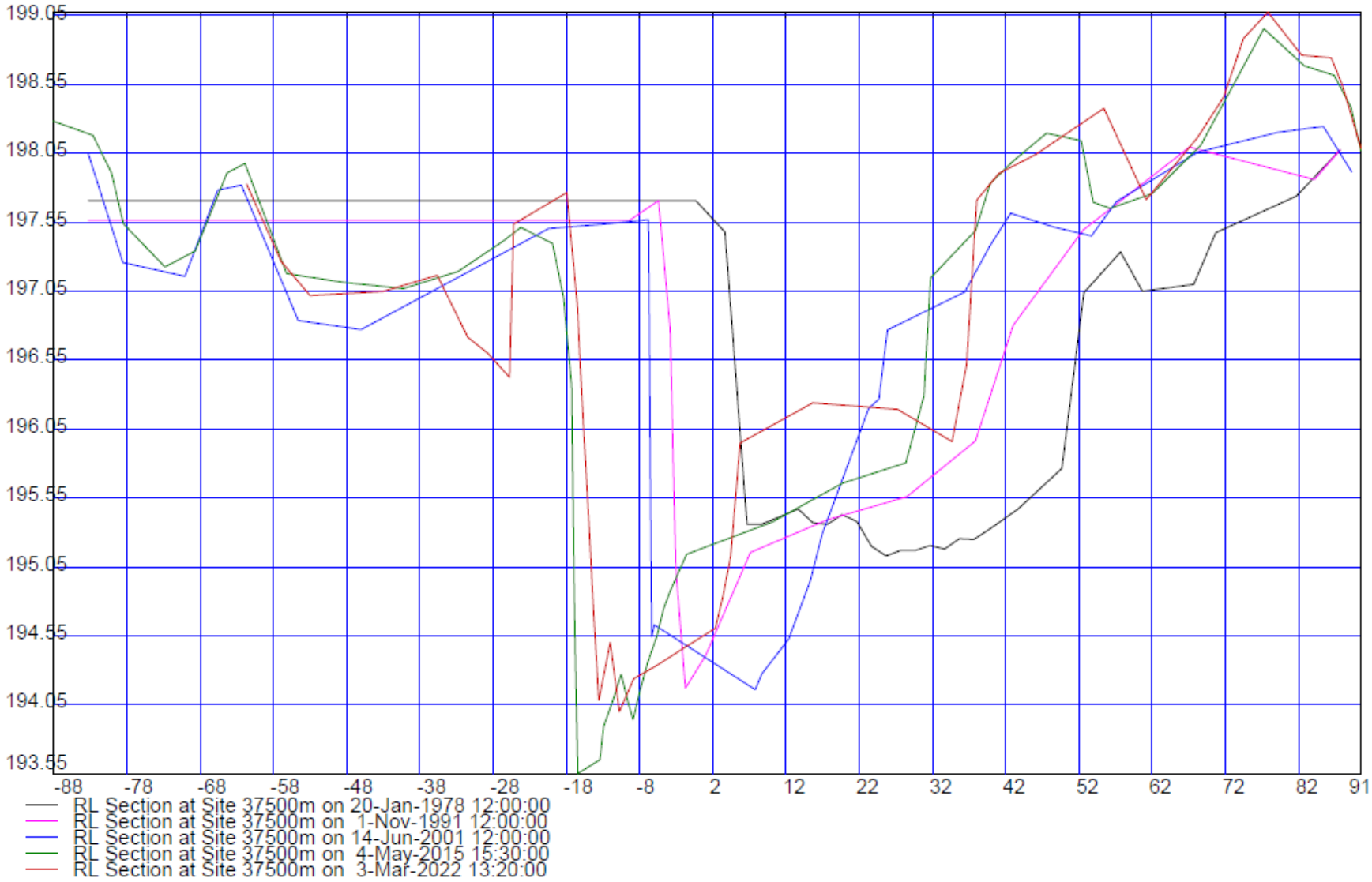

177.21
176.83
176.33
175.83
175.33
174.83
174.33
173.83
173.33
172.83
172.33
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
62.2
RL Section at Site 30000m on 24-Jan-1978 12:00:00
RL Section at Site 30000m on 1-Nov-1991 12:00:00
RL Section at Site 30000m on 18-Jun-2001 12:00:00
RL Section at Site 30000m on 5-May-2015 13:30:00
RL Section at Site 30000m on 1-Mar-2022 12:35:00

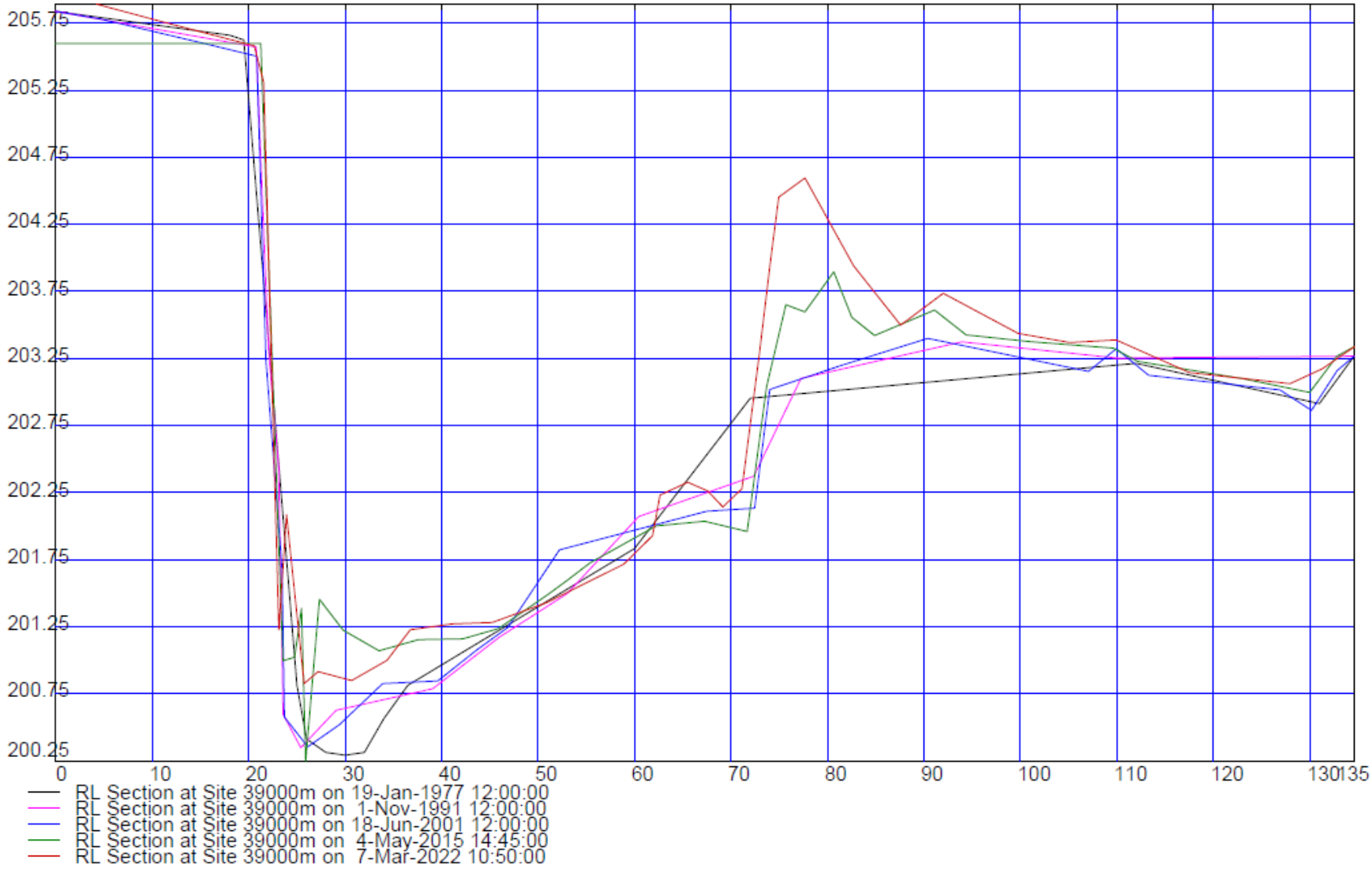

181.36
180.86
180.36
179.86
179.36
178.86
178.36
177.86
177.36
176.86
-71
-51
-31
-11
9
29
49
69
89
109
129
149
155
RL Section at Site 31500m on 24-Jan-1978 12:00:00
RL Section at Site 31500m on 1-Nov-1991 12:00:00
RL Section at Site 31500m on 18-Jun-2001 12:00:00
RL Section at Site 31500m on 21-Apr-2015 14:15:00
RL Section at Site 31500m on 1-Mar-2022 13:30:00

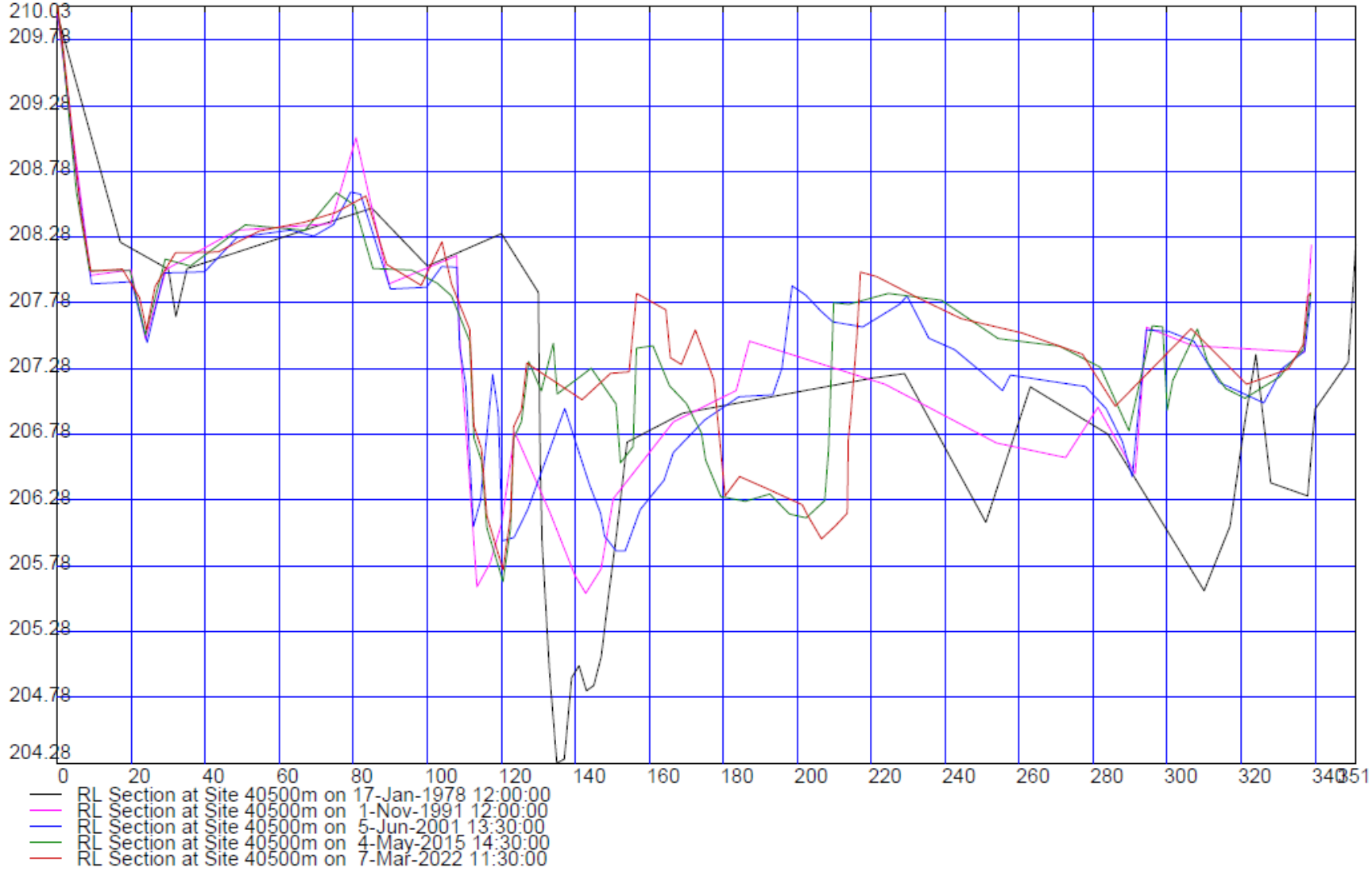

186.2
185.2
184.2
183.2
182.2
181.2
180.2
179.2
-4
6
16
26
36
46
56
66
76
86
96
106
116
126
136
RL Section at Site 33000m on 24-Jan-1978 12:00:00
RL Section at Site 33000m on 1-Nov-1991 12:00:00
RL Section at Site 33000m on 18-Jun-2001 12:00:00
RL Section at Site 33000m on 21-Apr-2015 13:30:00
RL Section at Site 33000m on 1-Mar-2022 13:55:00

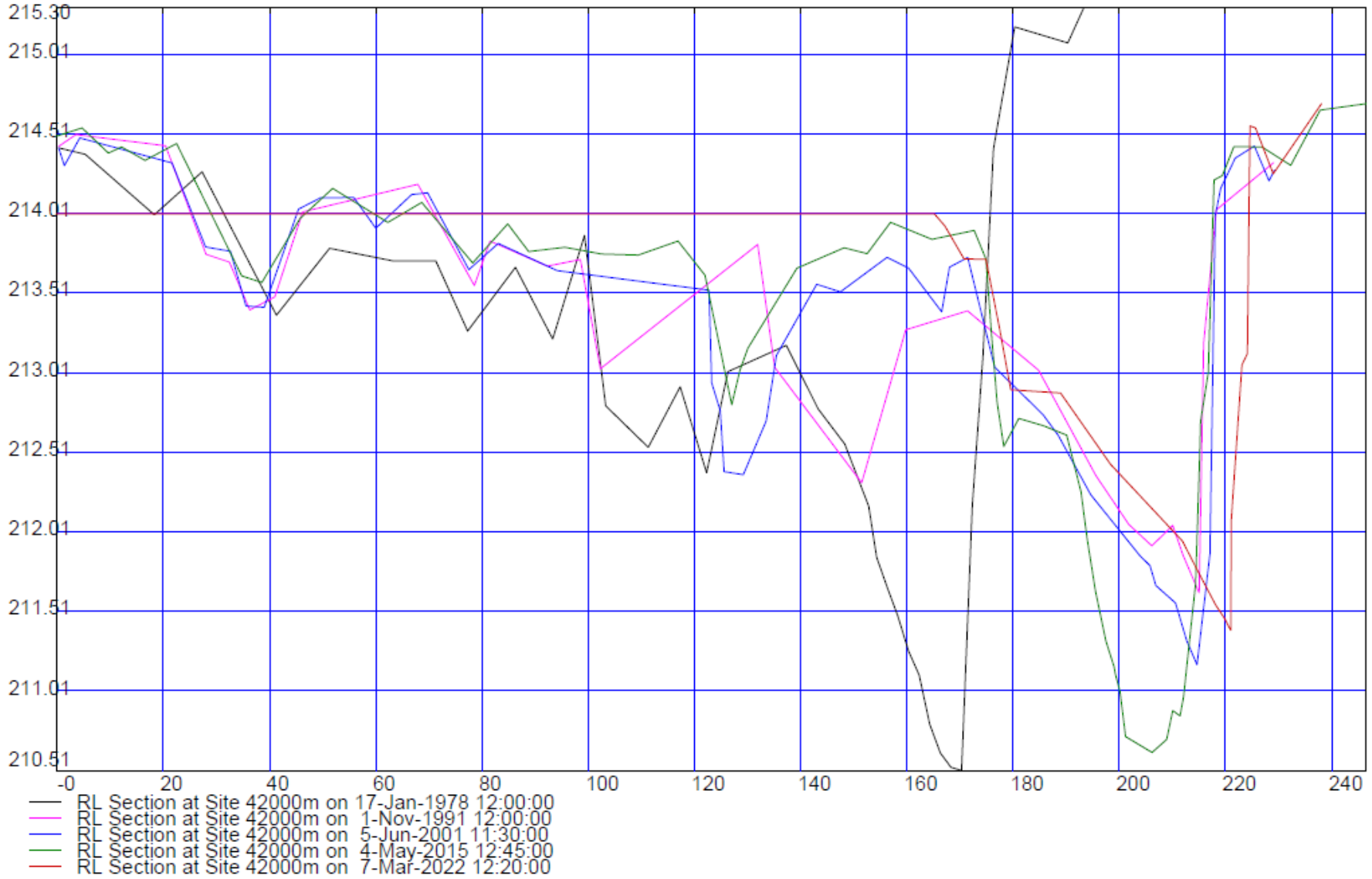

190.22
190.07
189.57
189.07
188.57
188.07
187.57
187.07
186.57
186.07
185.57
-0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
217
RL Section at Site 34500m on 24-Jan-1978 12:00:00
RL Section at Site 34500m on 1-Nov-1991 12:00:00
RL Section at Site 34500m on 18-Oct-2001 12:00:00
RL Section at Site 34500m on 5-May-2015 11:30:00
RL Section at Site 34500m on 3-Mar-2022 10:45:00

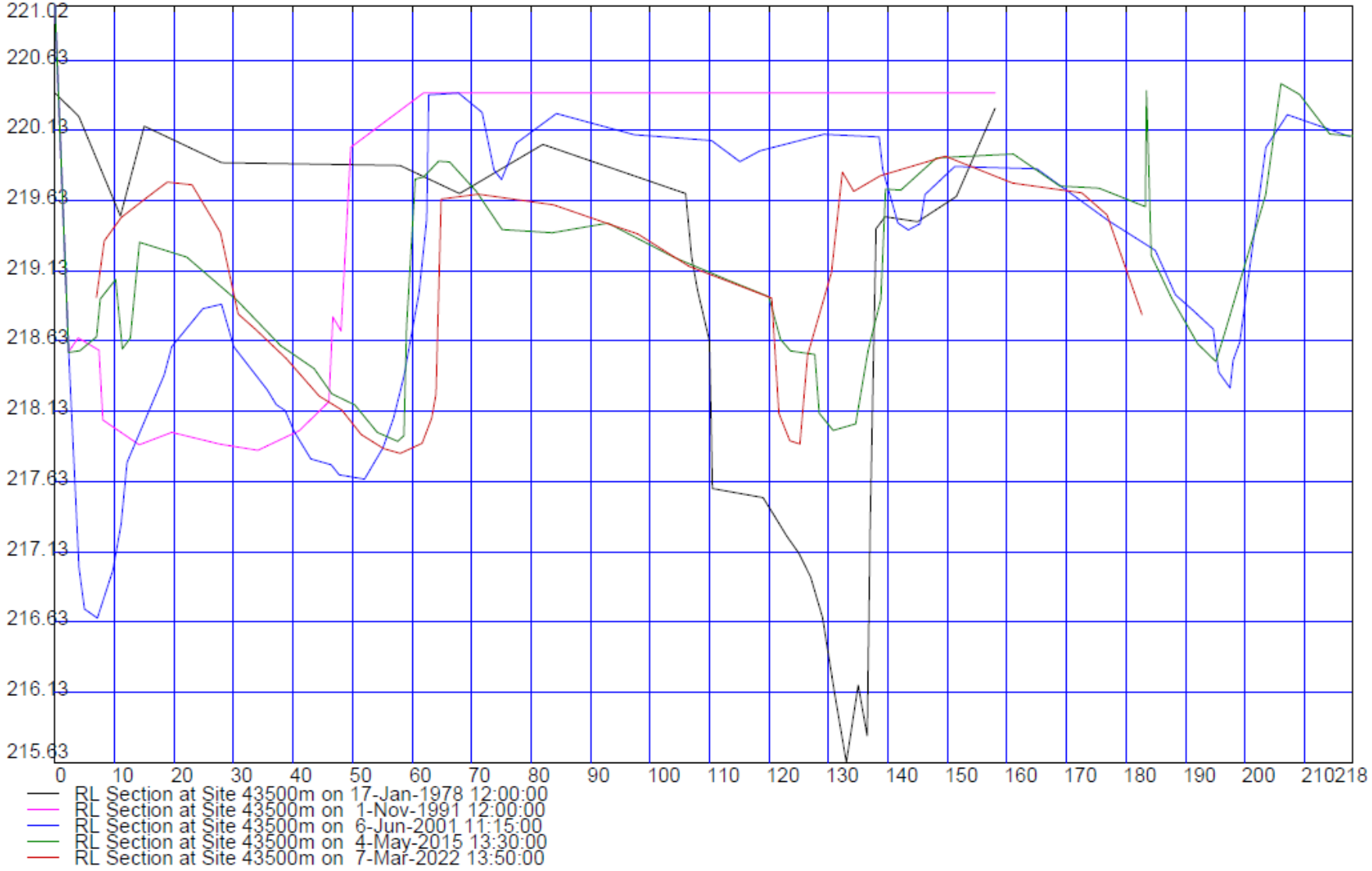

194.79
194.40
193.90
193.40
192.90
192.40
191.90
191.40
190.90
190.40
189.90
189.40
188.90
188.40
-0
50
100
150
200
250
300
350
370
RL Section at Site 36000m on 10-Nov-1978 11:00:00
RL Section at Site 36000m on 1-Nov-1991 11:00:00
RL Section at Site 36000m on 14-Jun-2001 12:00:00
RL Section at Site 36000m on 5-May-2015 11:00:00
RL Section at Site 36000m on 3-Mar-2022 11:50:00

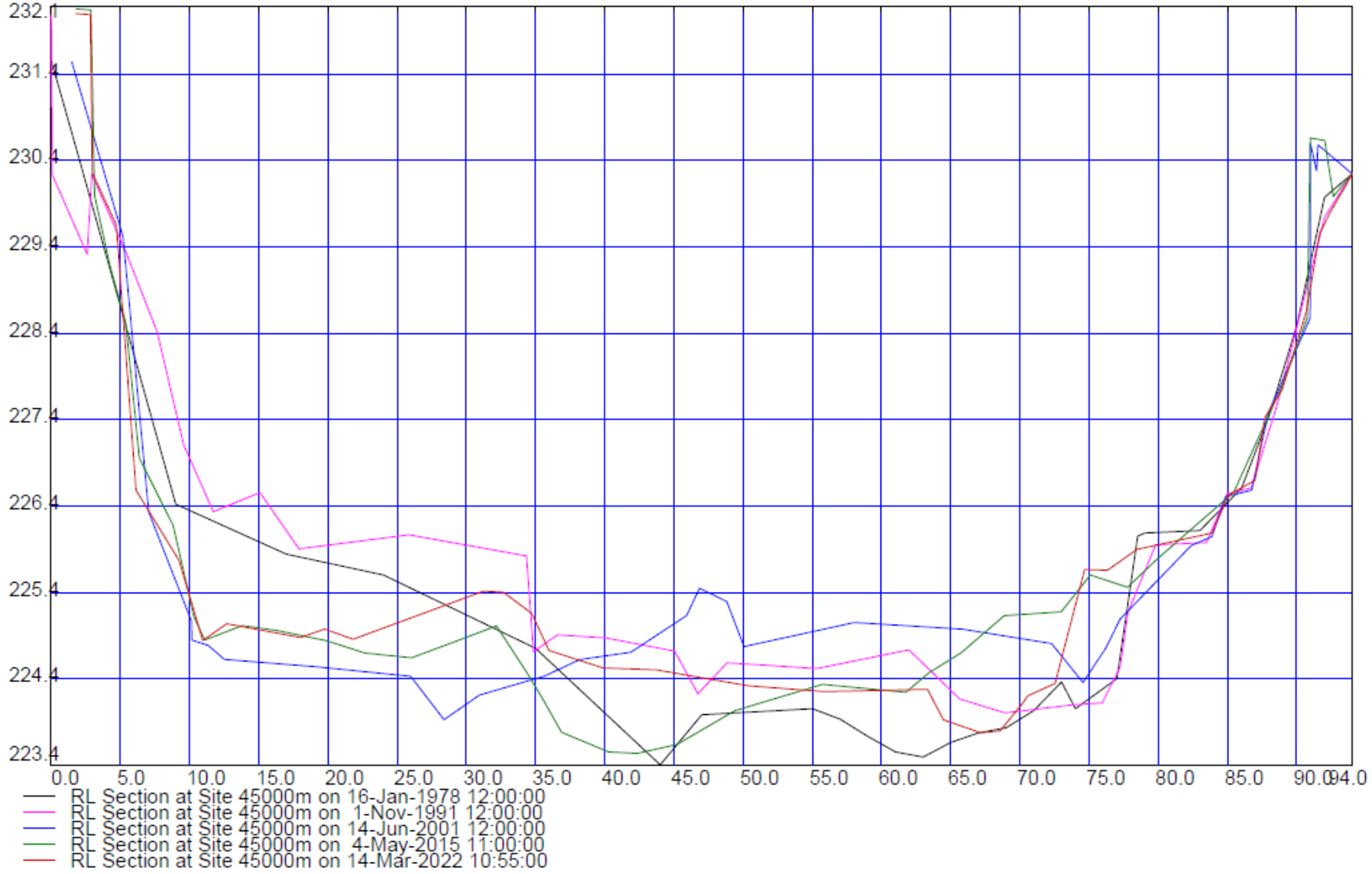

199.05
198.55
198.05
197.55
197.05
196.55
196.05
195.55
195.05
194.55
194.05
193.55
-88
-78
-68
-58
-48
-38
-28
-18
-8
2
12
22
32
42
52
62
72
82
91
RL Section at Site 37500m on 20-Jan-1978 12:00:00
RL Section at Site 37500m on 1-Nov-1991 12:00:00
RL Section at Site 37500m on 14-Jun-2001 12:00:00
RL Section at Site 37500m on 4-May-2015 15:30:00
RL Section at Site 37500m on 3-Mar-2022 13:20:00

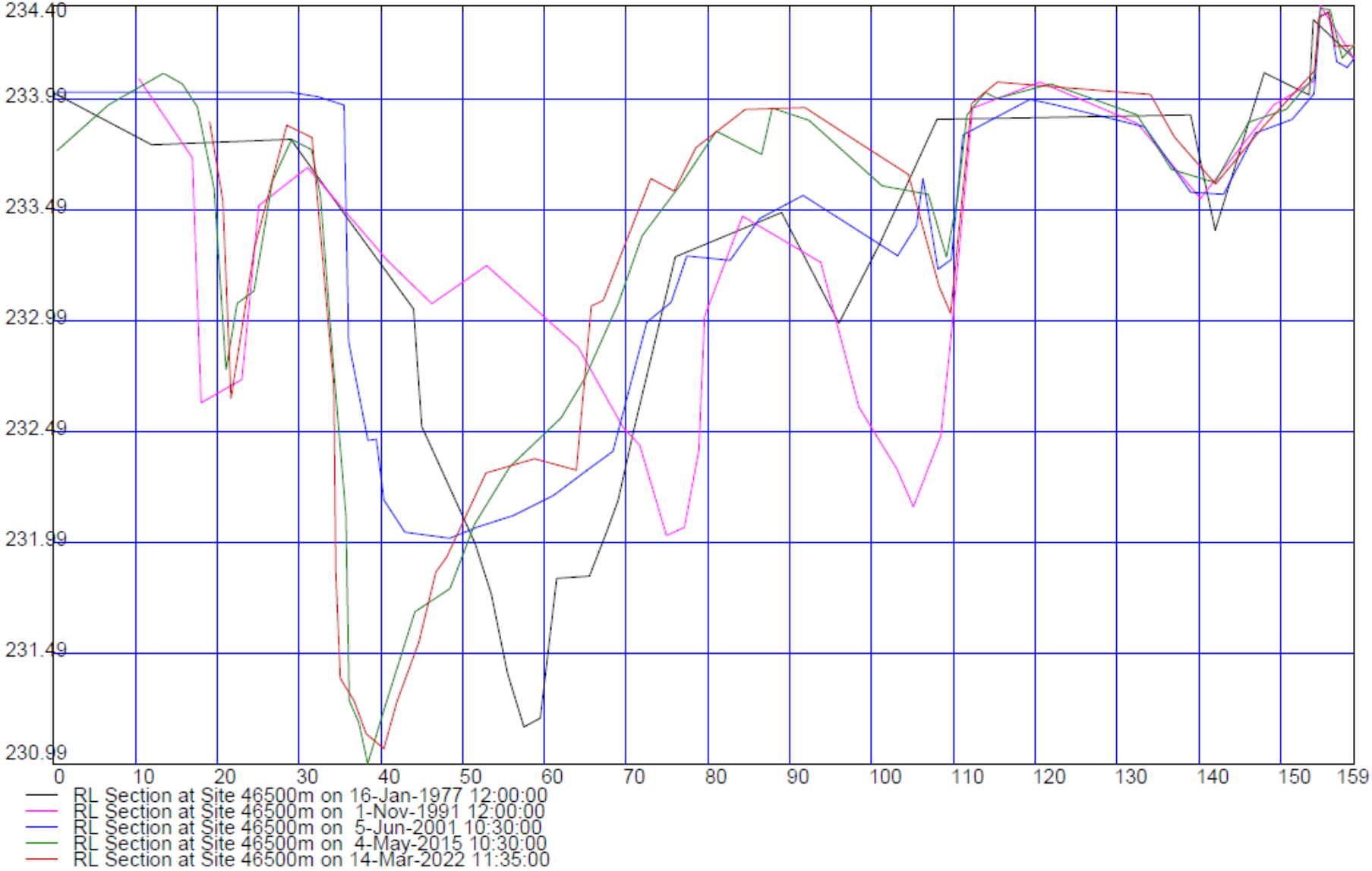

205.75
205.25
204.75
204.25
203.75
203.25
202.75
202.25
201.75
201.25
200.75
200.25
0
10
20
30
40
50
60
70
80
90
100
110
120
130135
RL Section at Site 39000m on 19-Jan-1977 12:00:00
RL Section at Site 39000m on 1-Nov-1991 12:00:00
RL Section at Site 39000m on 18-Jun-2001 12:00:00
RL Section at Site 39000m on 4-May-2015 14:45:00
RL Section at Site 39000m on 7-Mar-2022 10:50:00

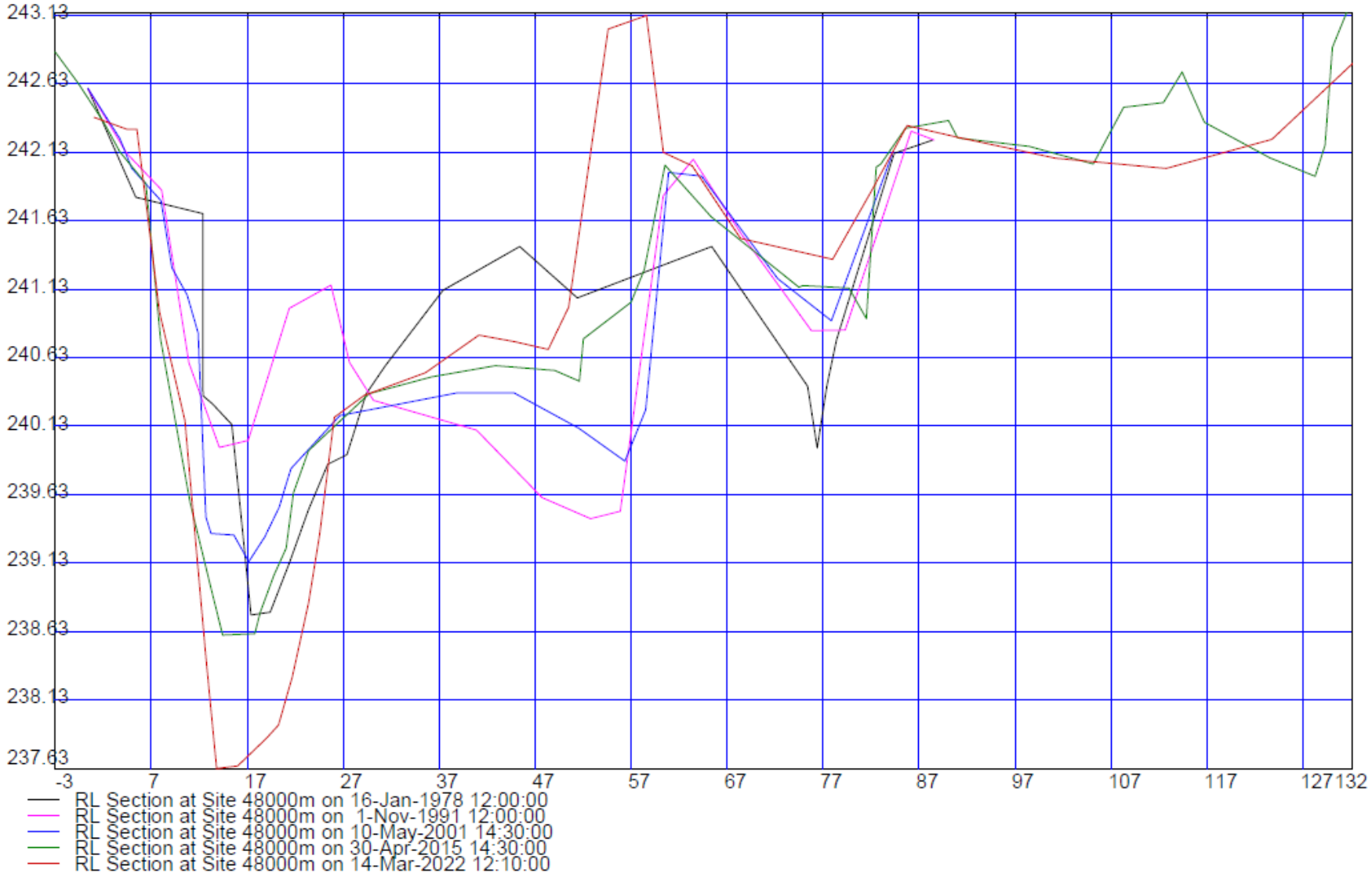

210.03
209.78
209.28
208.78
208.28
207.78
207.28
206.78
206.28
205.78
205.28
204.78
204.28
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
351
RL Section at Site 40500m on 17-Jan-1978 12:00:00
RL Section at Site 40500m on 1-Nov-1991 12:00:00
RL Section at Site 40500m on 5-Jun-2001 13:30:00
RL Section at Site 40500m on 4-May-2015 14:30:00
RL Section at Site 40500m on 7-Mar-2022 11:30:00

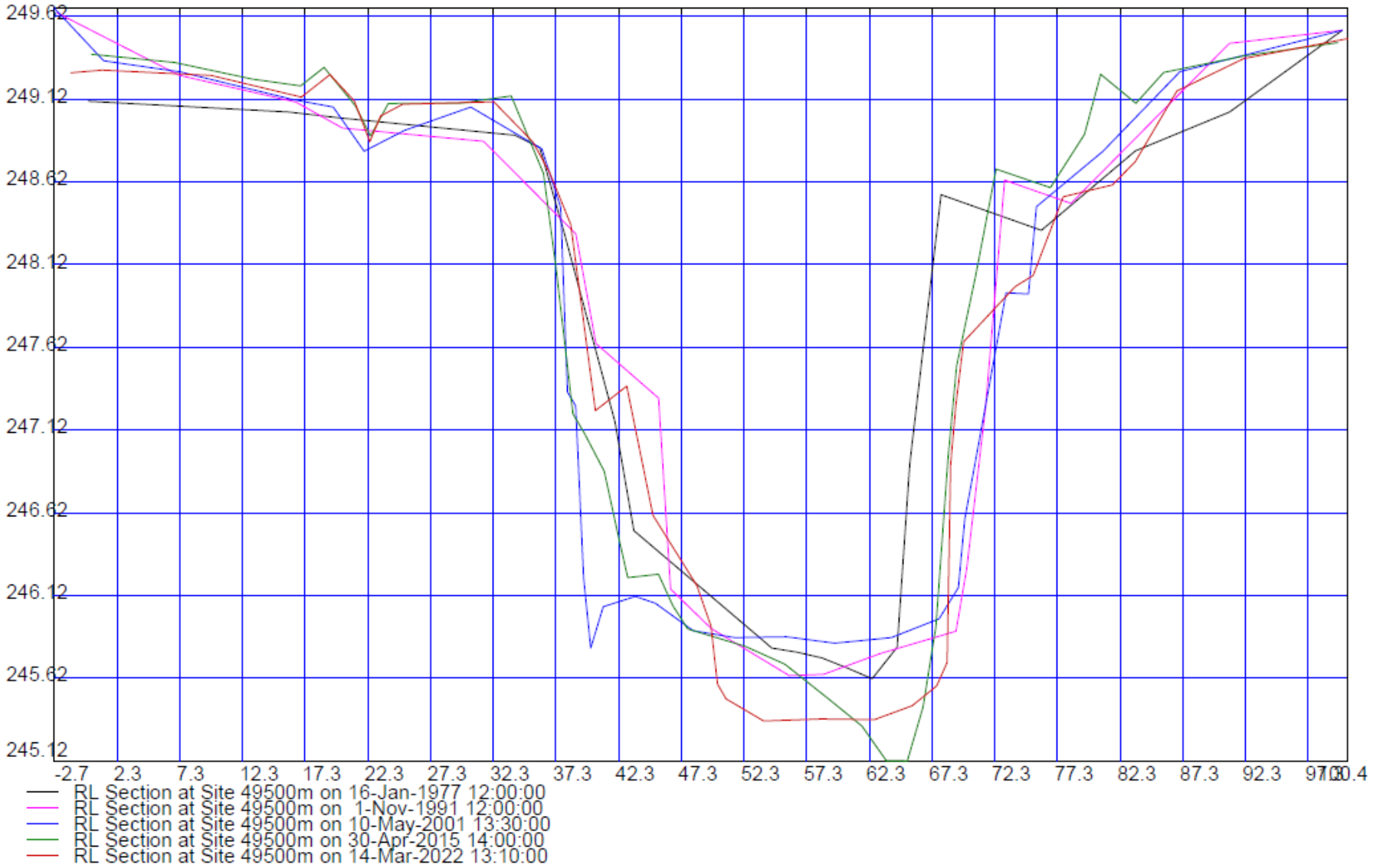

215.30
215.01
214.51
214.01
213.51
213.01
212.51
212.01
211.51
211.01
210.51
-0
20
40
60
80
100
120
140
160
180
200
220
240
RL Section at Site 42000m on 17-Jan-1978 12:00:00
RL Section at Site 42000m on 1-Nov-1991 12:00:00
RL Section at Site 42000m on 5-Jun-2001 11:30:00
RL Section at Site 42000m on 4-May-2015 12:45:00
RL Section at Site 42000m on 7-Mar-2022 12:20:00

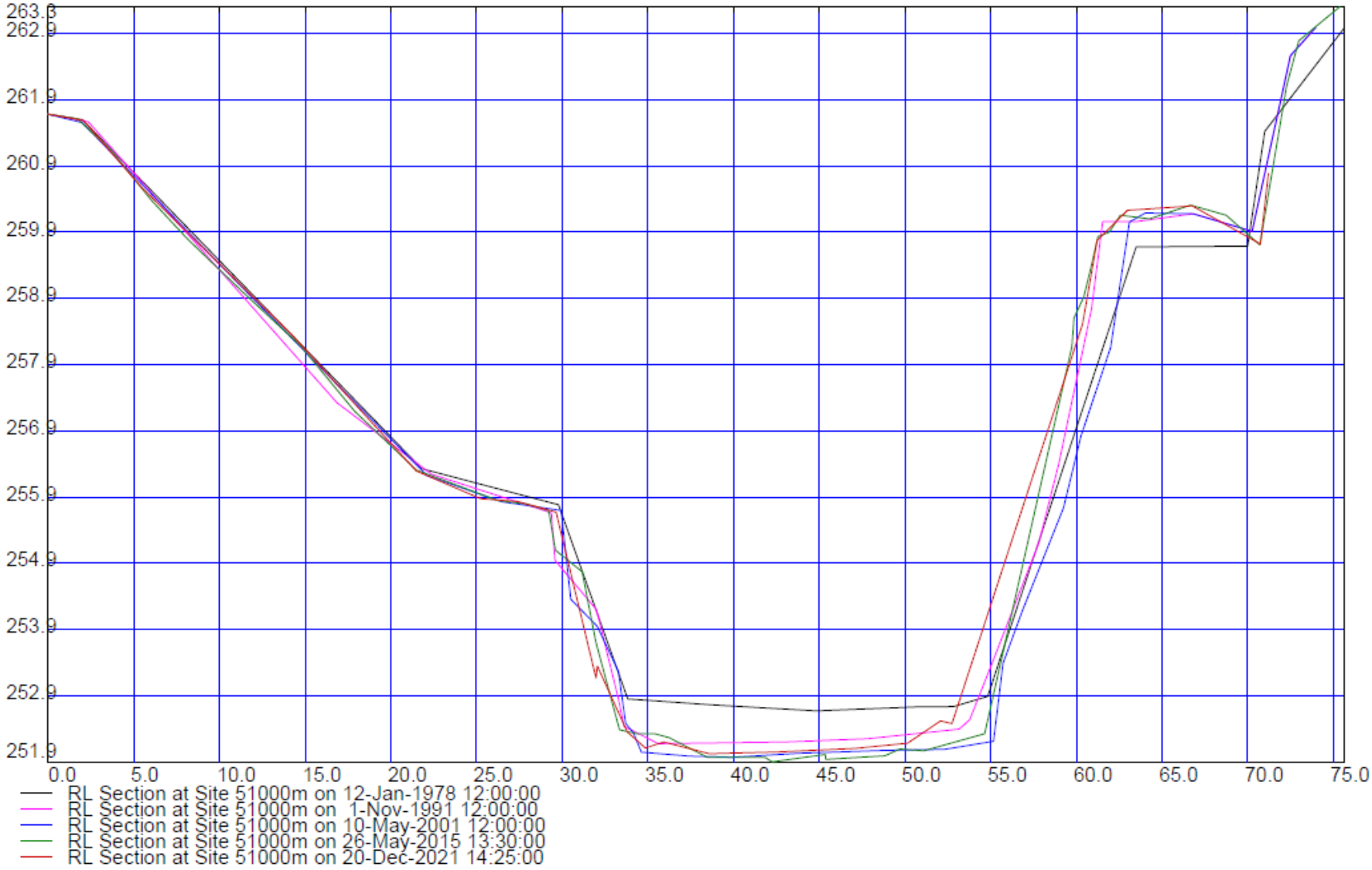

221.02
220.63
220.13
219.63
219.13
218.63
218.13
217.63
217.13
216.63
216.13
215.63
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210218
RL Section at Site 43500m on 17-Jan-1978 12:00:00
RL Section at Site 43500m on 1-Nov-1991 12:00:00
RL Section at Site 43500m on 6-Jun-2001 11:15:00
RL Section at Site 43500m on 4-May-2015 13:30:00
RL Section at Site 43500m on 7-Mar-2022 13:50:00

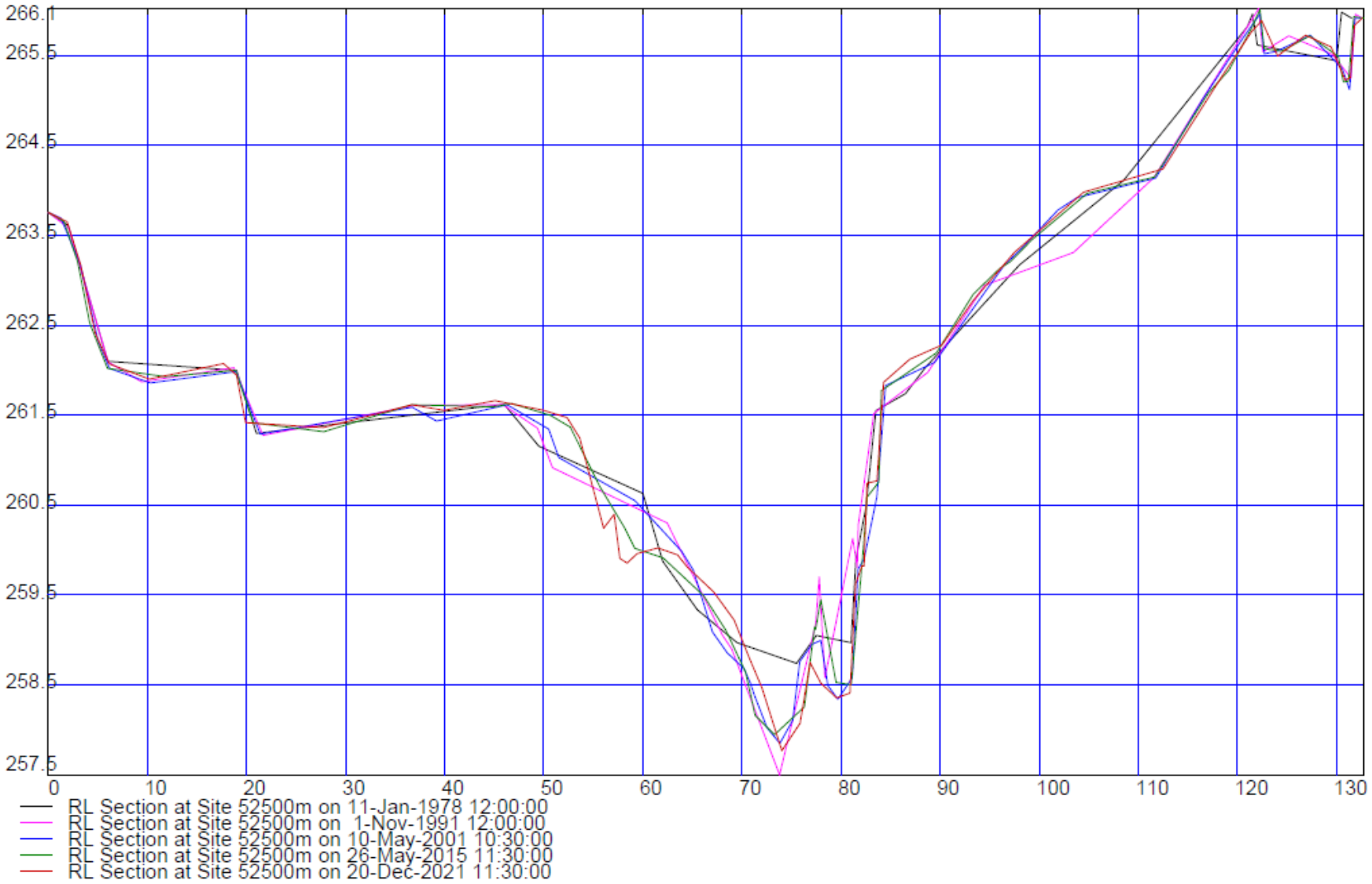

232.1
231.4
230.4
229.4
228.4
227.4
226.4
225.4
224.4
223.4
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
94.0
RL Section at Site 45000m on 16-Jan-1978 12:00:00
RL Section at Site 45000m on 1-Nov-1991 12:00:00
RL Section at Site 45000m on 14-Jun-2001 12:00:00
RL Section at Site 45000m on 4-May-2015 11:00:00
RL Section at Site 45000m on 14-Mar-2022 10:55:00

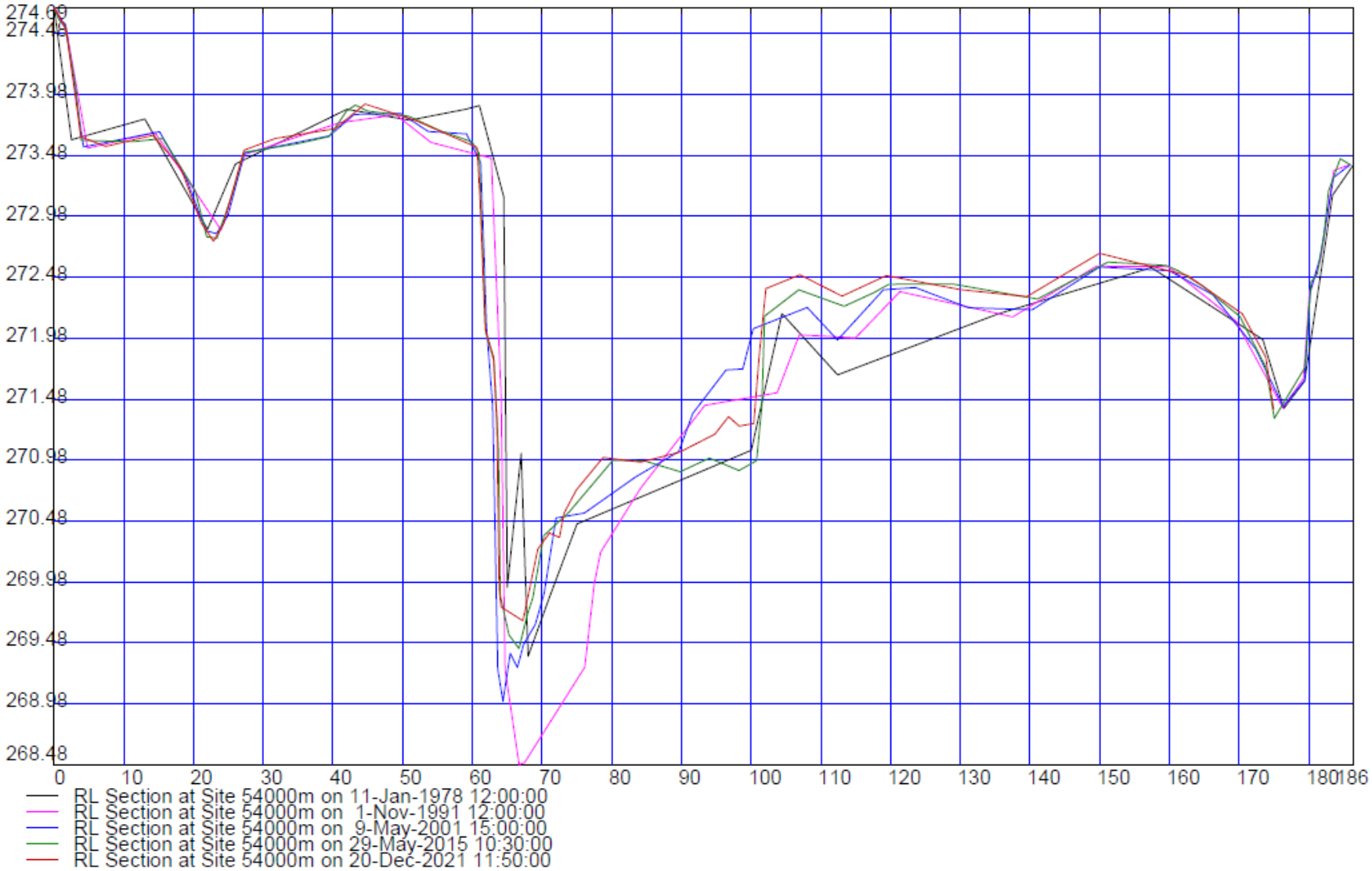

234.40
233.99
233.49
232.99
232.49
231.99
231.49
230.99
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
159
RL Section at Site 46500m on 16-Jan-1977 12:00:00
RL Section at Site 46500m on 1-Nov-1991 12:00:00
RL Section at Site 46500m on 5-Jun-2001 10:30:00
RL Section at Site 46500m on 4-May-2015 10:30:00
RL Section at Site 46500m on 14-Mar-2022 11:35:00

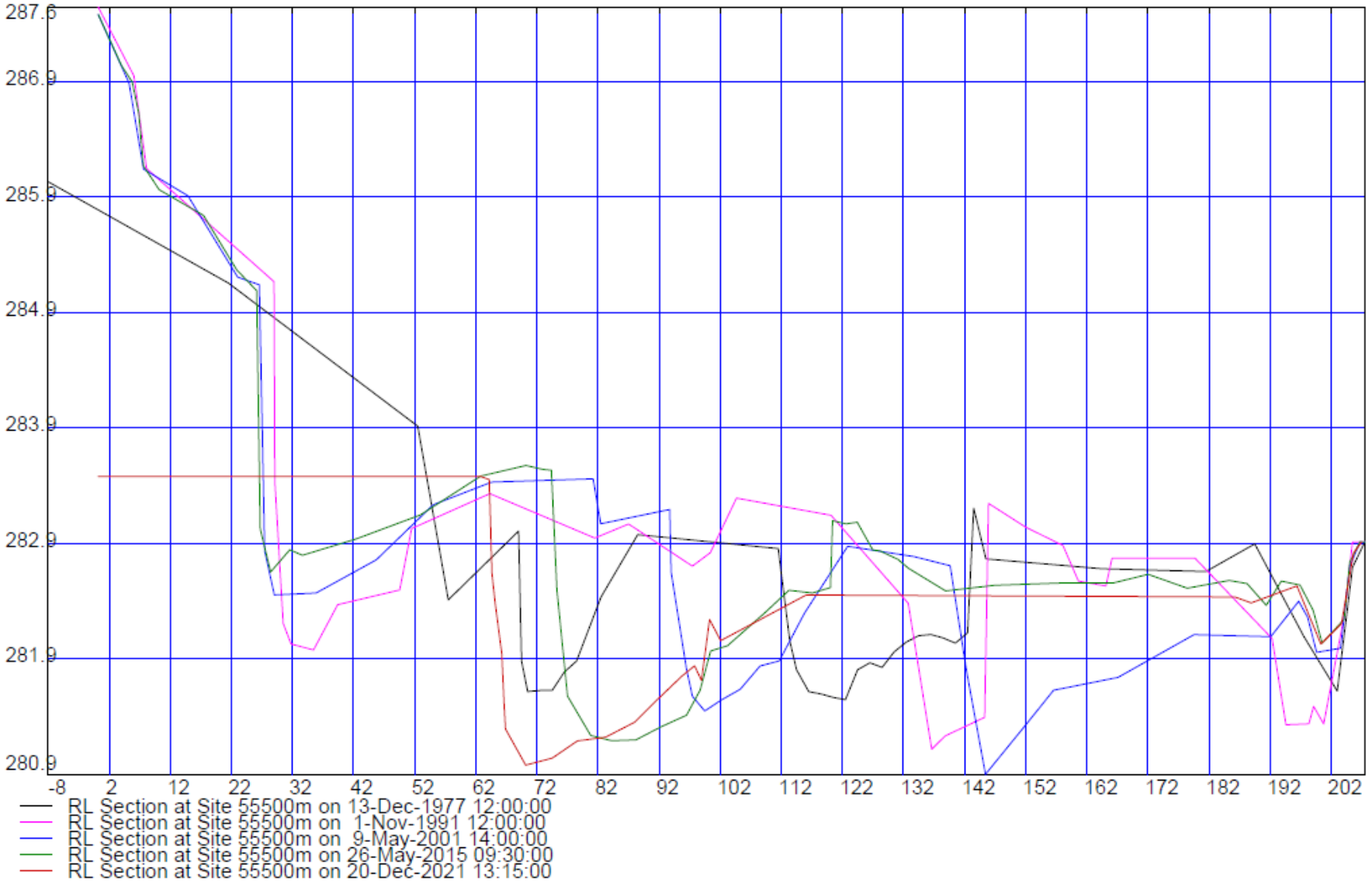

243.13
242.63
242.13
241.63
241.13
240.63
240.13
239.63
239.13
238.63
238.13
237.63
-3
7
17
27
37
47
57
67
77
87
97
107
117
127
132
RL Section at Site 48000m on 16-Jan-1978 12:00:00
RL Section at Site 48000m on 1-Nov-1991 12:00:00
RL Section at Site 48000m on 10-May-2001 14:30:00
RL Section at Site 48000m on 30-Apr-2015 14:30:00
RL Section at Site 48000m on 14-Mar-2022 12:10:00

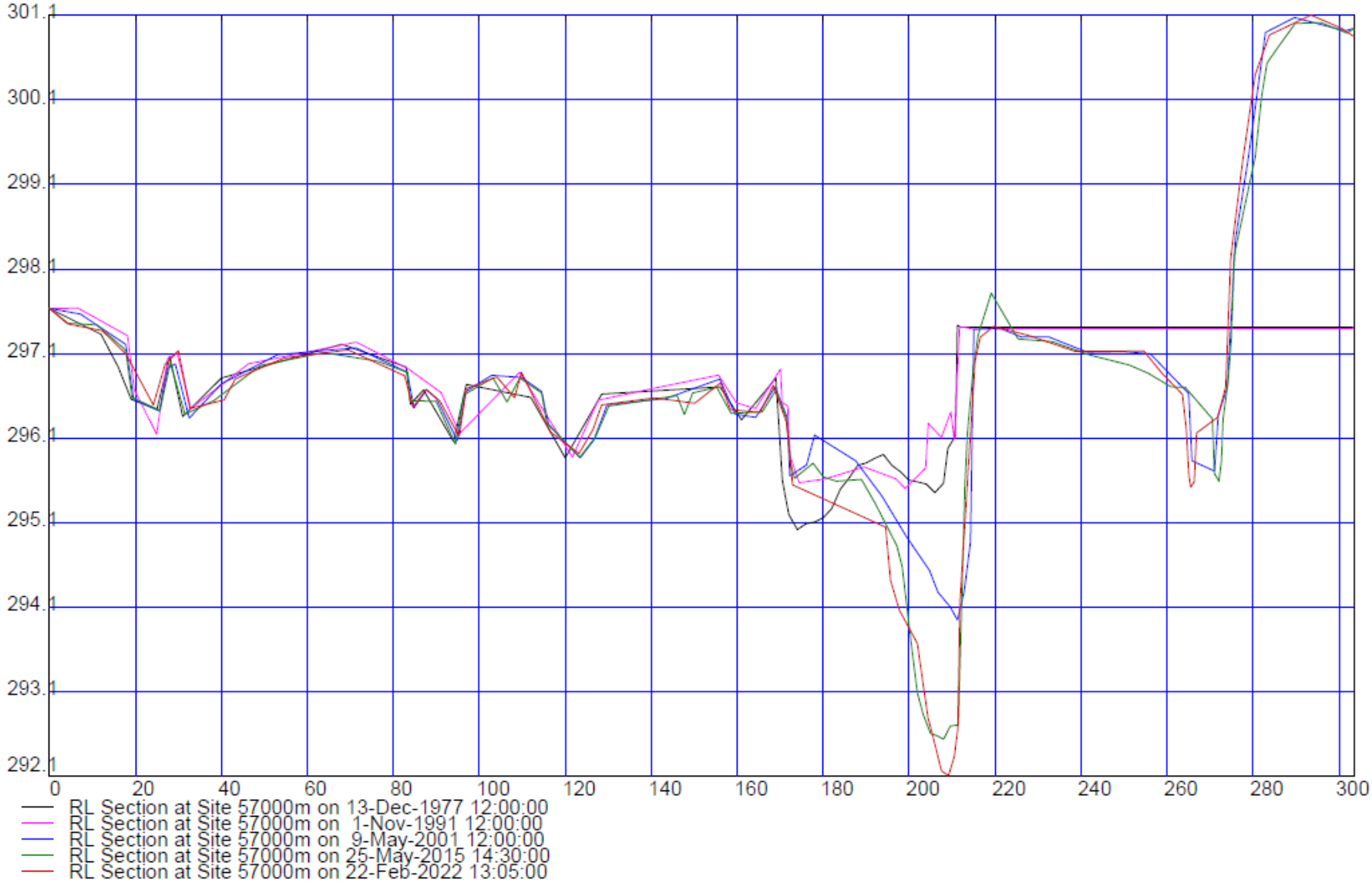

249.62
249.12
248.62
248.12
247.62
247.12
246.62
246.12
245.62
245.12
-2.7
2.3
7.3
12.3
17.3
22.3
27.3
32.3
37.3
42.3
47.3
52.3
57.3
62.3
67.3
72.3
77.3
82.3
87.3
92.3
RL Section at Site 49500m on 16-Jan-1977 12:00:00
RL Section at Site 49500m on 1-Nov-1991 12:00:00
RL Section at Site 49500m on 10-May-2001 13:30:00
RL Section at Site 49500m on 30-Apr-2015 14:00:00
RL Section at Site 49500m on 14-Mar-2022 13:10:00

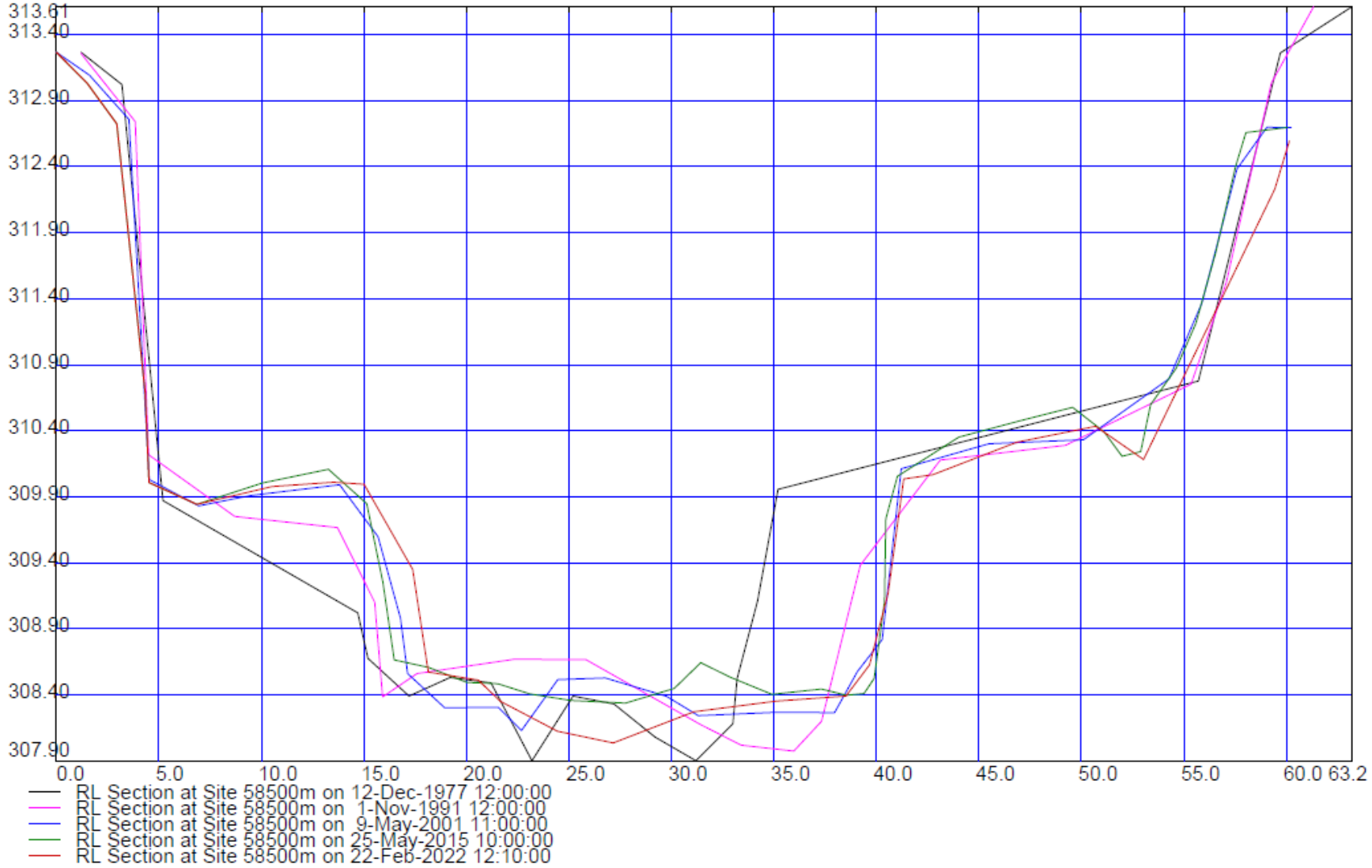

263.9
262.9
261.9
260.9
259.9
258.9
257.9
256.9
255.9
254.9
253.9
252.9
251.9
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
RL Section at Site 51000m on 12-Jan-1978 12:00:00
RL Section at Site 51000m on 1-Nov-1991 12:00:00
RL Section at Site 51000m on 10-May-2001 12:00:00
RL Section at Site 51000m on 26-May-2015 13:30:00
RL Section at Site 51000m on 20-Dec-2021 14:25:00

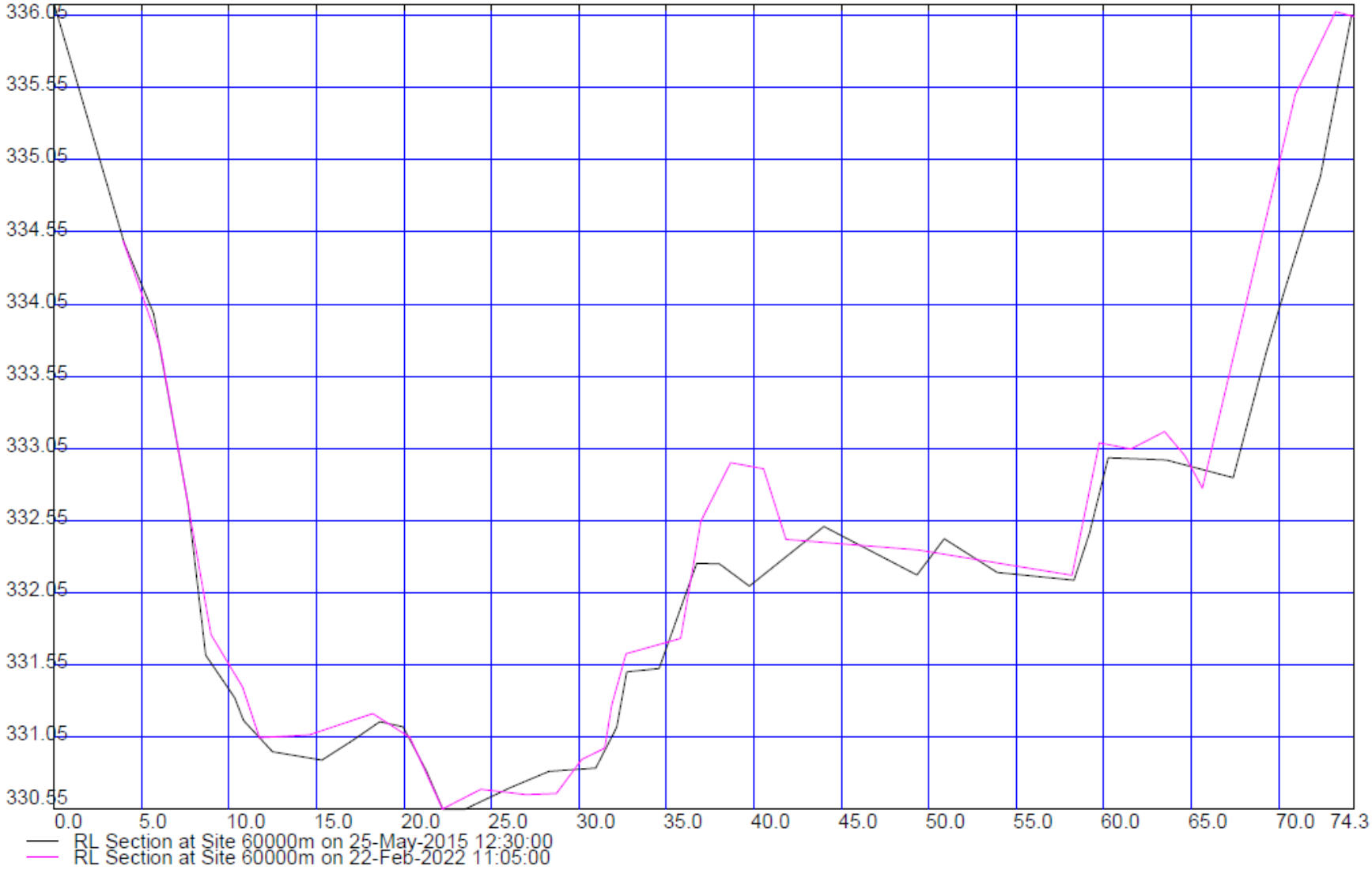

266.1
265.5
264.5
263.5
262.5
261.5
260.5
259.5
258.5
257.5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
RL Section at Site 52500m on 11-Jan-1978 12:00:00
RL Section at Site 52500m on 1-Nov-1991 12:00:00
RL Section at Site 52500m on 10-May-2001 10:30:00
RL Section at Site 52500m on 26-May-2015 11:30:00
RL Section at Site 52500m on 20-Dec-2021 11:30:00


274.48
273.98
273.48
272.98
272.48
271.98
271.48
270.98
270.48
269.98
269.48
268.98
268.48
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180186
RL Section at Site 54000m on 11-Jan-1978 12:00:00
RL Section at Site 54000m on 1-Nov-1991 12:00:00
RL Section at Site 54000m on 9-May-2001 15:00:00
RL Section at Site 54000m on 29-May-2015 10:30:00
RL Section at Site 54000m on 20-Dec-2021 11:50:00


287.6
286.9
285.9
284.9
283.9
282.9
281.9
280.9
-8
2
12
22
32
42
52
62
72
82
92
102
112
122
132
142
152
162
172
182
192
202
RL Section at Site 55500m on 13-Dec-1977 12:00:00
RL Section at Site 55500m on 1-Nov-1991 12:00:00
RL Section at Site 55500m on 9-May-2001 14:00:00
RL Section at Site 55500m on 26-May-2015 09:30:00
RL Section at Site 55500m on 20-Dec-2021 13:15:00


301.1
300.1
299.1
298.1
297.1
296.1
295.1
294.1
293.1
292.1
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
RL Section at Site 57000m on 13-Dec-1977 12:00:00
RL Section at Site 57000m on 1-Nov-1991 12:00:00
RL Section at Site 57000m on 9-May-2001 12:00:00
RL Section at Site 57000m on 25-May-2015 14:30:00
RL Section at Site 57000m on 22-Feb-2022 13:05:00


313.61
313.40
312.90
312.40
311.90
311.40
310.90
310.40
309.90
309.40
308.90
308.40
307.90
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0 63.2
RL Section at Site 58500m on 12-Dec-1977 12:00:00
RL Section at Site 58500m on 1-Nov-1991 12:00:00
RL Section at Site 58500m on 9-May-2001 11:00:00
RL Section at Site 58500m on 25-May-2015 10:00:00
RL Section at Site 58500m on 22-Feb-2022 12:10:00


336.05
335.55
335.05
334.55
334.05
333.55
333.05
332.55
332.05
331.55
331.05
330.55
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
74.3
RL Section at Site 60000m on 25-May-2015 12:30:00
RL Section at Site 60000m on 22-Feb-2022 11:05:00

Appendix G: Mangatainoka River Site Photos (8 August 2023)

Figure G1: Mangaroa Road downstream of bridge near XS 4500 (visible gravel beaches and scouring in the background)

Figure G2: End of Nireaha Hukanui Road XS 3900

Figure G3: End of Nireaha Hukanui Road XS 3900 (lots of gravel)

Figure G4: Hamua Hukanui Road XS 3356 downstream of bridge (no gravel on the 2021 aerial photo)

Figure G5: Hamua Hukanui Road XS 3358 upstream of bridge

Figure G6: End of Te Hawera Road XS 3300

Figure G7: End of Te Hawera Road XS 3300 (steep pile of gravel more than 1 metre high)

Figure G8: End of Te Hawera Road XS 3300

Figure G9: Pukewhai Road downstream of XS 2700

Figure G10: Pukewhai Road downstream of XS 2700

Figure G11: Halls Road near XS 1011

Figure G12: Halls Road at XS 1011

Figure G13: Hirock gravel extraction site XS 900

Figure G14: Hirock gravel extraction site XS900

Figure G15: Tutaekara Road upstream of XS 2295 at bridge

Figure G16: Steep gravel beach at Tutaekara Road upstream of XS 2300 near the bridge

Figure G17: Gravel beach with vegetation upstream of Scarborough road bridge XS 1500

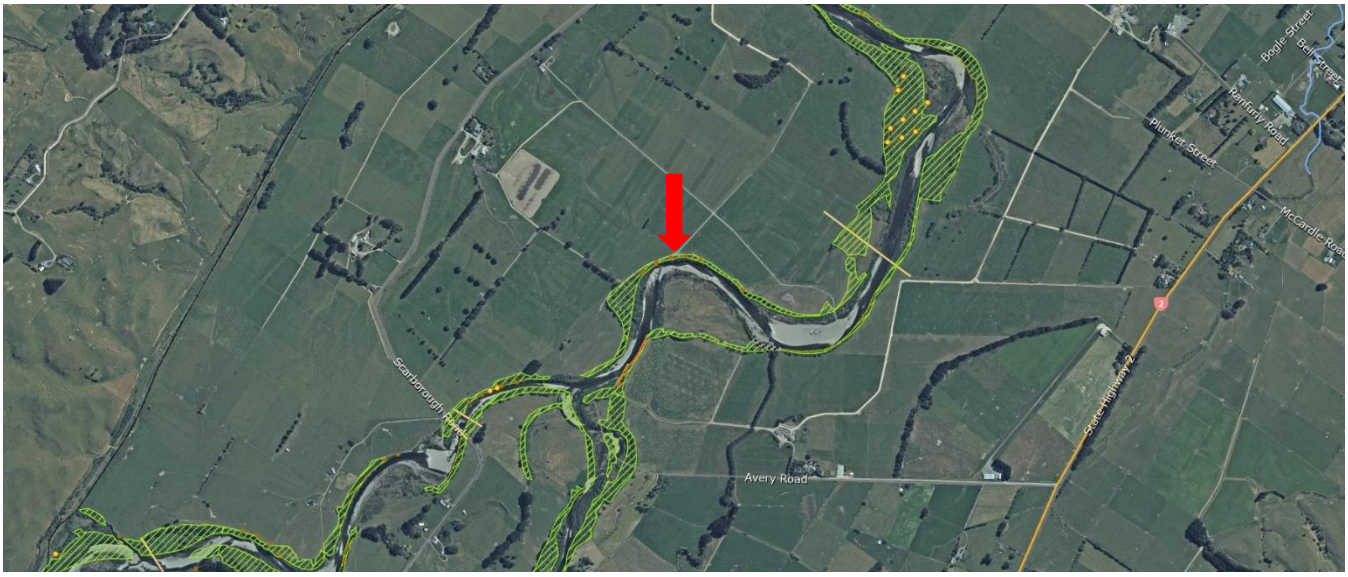


Figure G18: Logan Mchardy's property upstream of XS 1350

Figure G19: Logan Mchardy’s property upstream of XS 1350

Figure G20: Upstream of the Cemetery near XS 0450

Figure G21: Mangatainoka Town Bridge at XS 380

Figure G22: Makuri Street upstream of XS 300

Figure G23: Steep gravel beach (about 2 metres high) at Makuri Street upstream of XS 300

horizons.govt.nz

24 hour freephone 0508 800 800
fax 06 952 2929 | **email** help@horizons.govt.nz
Private Bag 11025, Manawatu Mail Centre, Palmerston North 4442