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Äspö Hard Rock Laboratory

TRUE-1 Continuation project

History and current status on flow, pressure, water chemistry and installations at the TRUE-1 site

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August 2001

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Keywords: Chemistry, feature A, head, inflow, installations, pressure, TRUE-1

Abstract

The first TRUE stage was finalised during the year 2000. Since then, no experimental activity has been going on at the site. As a preparation for planned experiments in the project TRUE-1 Continuation, a study of the current situation regarding inflow to the tunnel, water pressure, groundwater chemistry and status of the borehole installations has been performed and is presented in this report. A specific objective of the study was also to assess the effects of removal of the inner packer in borehole KXTT4.

Sammanfattning

Den första etappen av TRUE-projektet (TRUE-1) avslutades år 2000. Sedan dess har ingen experimentell aktivitet pågått på experimentplatsen. Som en förberedelse för planerade experiment inom projektet TRUE-1 Continuation så har en studie genomförts i syfte att utreda platsens status vad gäller inflöde till tunneln, vattentryck, grundvattenkemi samt status på borrhålsinstallationerna. Ett specifikt syfte har varit att fastställa effekterna av borttagande av den innersta borrhålsmanschetten i borrhål KXTT4.

Contents

1 Introduction

The first TRUE Stage was finalised during the year 2000 (Winberg et al., 2000). The results were presented and discussed during an international seminar in September 2000 (Svensk Kärnbränslehantering AB, 2001). At this time it was identified that diffusion processes were readily observable. However, alternative explanations are at hand with regards to the source for the pore volume responsible for the noted retention. These included; 1) diffusion/sorption in the rock matrix (involving the altered rock zone adjacent to the feature and possible fault breccia fragments in the feature, promoted by the SKB TRUE Team), 2) diffusion/sorption in fine-grained fault gouge, and 3) diffusion into stagnant zones of water. Noted enhanced retention compared to diffusivity and sorption distribution coefficients determined in the laboratory was by some analysts attributed to the laboratory samples not being representative of the investigated fracture. Others attributed the noted enhancement to 3D effects, or heterogeneity within the flow path, both of which could provide more available flow wetted surface area, and hence more retention. The bottom line is that there exists ambiguity in the interpretation of transport/retention in the studied Feature A over the experimental time scales considered. It was identified that the only available means to resort amongst the alternative interpretations (conceptual models) of transport/retention in the investigated feature is to carry out the epoxy resin injection and subsequent excavation and analyses as planned. However, due to the close proximity to the neighbouring LTDE site, the fact that the two sites are hydraulically conducted, and LTDE (Byegård et al., 1999) having a high priority implies that the resin injection will be postponed in time at least till 2004.

During the seminar it was also identified that advantage should be taken of the instrumented borehole array at the TRUE-1 site to obtain more information about the fracture network which Feature A is part of, and Feature A's relation to this network. Locations for five of the six boreholes in the TRUE-1 array are shown in Figure 1-1 together with the main fractures in the rock volume.

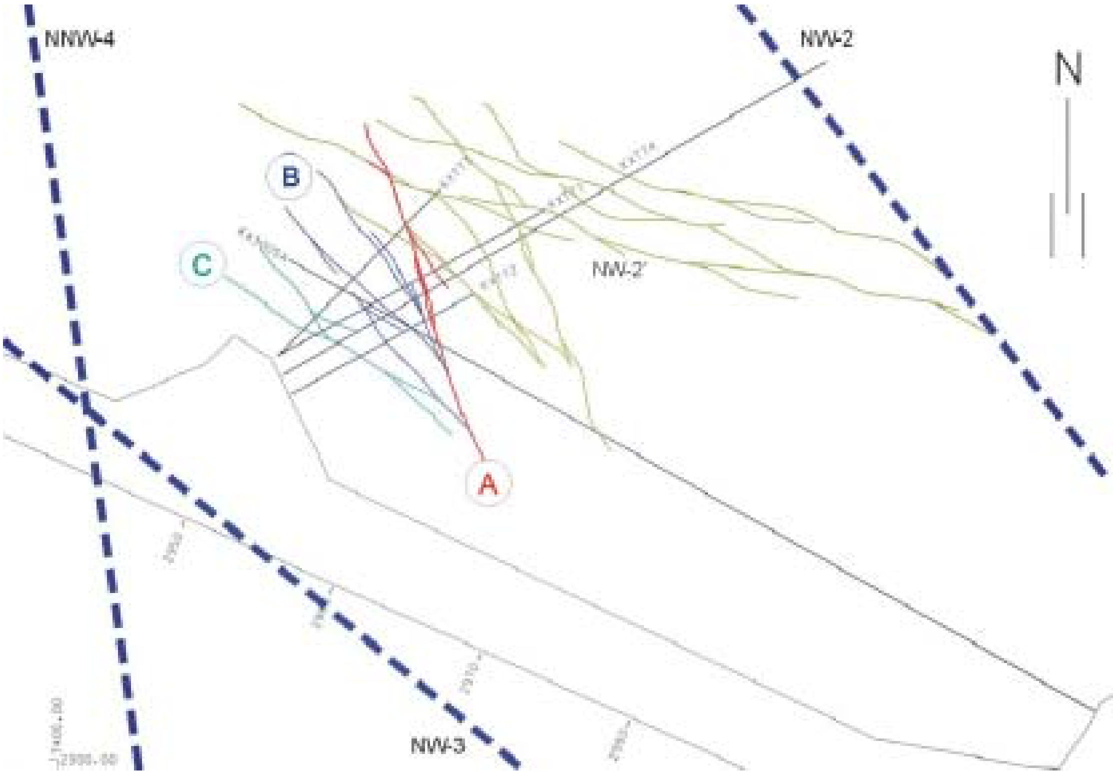


Figure 1-1. Horizontal section at Z=–400 masl showing structural model based on identified conductive geological structures in the TRUE-1 rock volume. Also, 5 of 6 boreholes in the TRUE-1 array are seen.

This memorandum is a pre-study for coming complementary tests within the TRUE Continuation project. Variations in flow, pressure and water chemistry are investigated on a long-term scale. Furthermore, the status of installations is presented.

2 Inflow to tunnel

The inflow to the tunnel is measured continuously and monitored in the Äspö Hydro Monitoring System (HMS). Since the TRUE-1 site is located at ~2950 m, the inflow along tunnel section 2840 – 2994 m is of particular interest. That inflow has been logged since early 1995. A plot of the inflow is presented in appendix 1 where also the inflow along tunnel section 2994 – 3179 m is seen. The plot in appendix 1 contains marks about drilling and other activities that coincide with major variations in inflow. These marks are to be seen as indications that the changes in inflow may be due to work done in connection to the drillings. Even though some short pulses of high inflow coincide in time with specific drillings it is not sure these drillings are the only explanations.

The major tendency is that the inflow has decreased during the measuring period, probably as a result of the drainage caused by the tunnel. Consequently, the decreasing inflow may be interpreted as a result of the growing cone of depression that develops around the tunnel. The inflow has decreased from ~100 m^3/24h to ~60 m^3/24h along tunnel section 2840 – 2994 m and from ~190 m^3/24h to ~140 m^3/24h along tunnel section 2994 – 3179 m.

There is no obvious evidence that the TRUE-1 project has caused greater variations in inflow to the tunnel than what is observed during the periods when TRUE-1 was not ongoing. Additionally, the TRUE-1 project does not seem to have caused any substantial changes in the inflow pattern. The observed variations in inflow are probably rather due to specific events as drilling through a major fracture zone or expanding/releasing packers that closes off such a zone. The effects of the LTDE project are seen as temporary higher inflow to the tunnel section 2994 – 3179 m during year 2000 and maybe even as temporary lower inflow to tunnel section 2840 – 2994 m the same year. (The site for the LTDE project is situated in the section 2994 – 3179 m.)

3 Pressure

3.1 Bounding fracture zones

The boreholes KA3010A and KA3067A are located in the bounding fracture zones of the TRUE-1 site. The pressures in these holes are presented as hydraulic head (unit; meter above sea level, masl) in appendix 2.

The figures in appendix 2 have marks about drilling and other activities that coincide with major variations in pressure. These marks are to be seen as indications that the changes in pressure may be due to work done in connection to the drillings. Even though some short pulses of high or low pressure coincides in time with specific drillings it is not sure these drillings are the only explanations.

On a big scale, the pressure has decreased from the start of measurements in 1995 until late 1996. Thereafter the pressure has been relatively stable except for some short variations and a period of low pressure while the LTDE project was running.

In total, the pressure in KA3010A has decreased with ~8 m. In KA3067A, the pressure has decreased with ~5 – 7 m, depending on the section. What concerns the different sections in KA3067A, the outer ones seem to decrease more than the inner ones. (Sections are numbered from the inner part of the hole and outwards as shown in "5 Status of installation".) The deeper the section is situated in the hole, the less is the decrease in pressure, and thereby the difference between sections increases. A possible explanation for this may be that the outermost sections are closer to the tunnel and thus are drained first due to higher transmissivity and a higher pressure gradient.

There is no obvious evidence that the TRUE-1 project has caused greater variations in pressure in the bounding fracture zones than what is observed during the periods when TRUE-1 was not ongoing. Additionally, the TRUE-1 project does not seem to have caused any substantial changes in the pressure pattern. The observed variations in pressure are probably rather due to specific events as drilling through a major fracture zone or expanding/releasing packers that closes off such a zone. The effects of the LTDE project are seen as temporary lower pressure during year 2000. The current pressures are similar to the ones measured at the end of TRUE-1.

3.2 TRUE-1 array

The TRUE-1 array consists of the boreholes KXTT1, KXTT2, KXTT3, KXTT4, KXTT5 and KA3005A together. The pressures in these holes are presented in appendix 3, some as pressure (unit; kPa) and some as hydraulic head (unit; meter above sea level, masl).

The figures in appendix 3 have marks about drilling and other activities that coincide with major variations in pressure. These marks are to be seen as indications that the changes in pressure may be due to work done in connection to the drillings. Even though some short pulses of high or low pressure coincides in time with specific drillings it is not sure these drillings are the only explanations.

The pressures in these holes have been recorded since 1995 and they are still recorded. The exceptions are that the logging of pressure in KXTT1 was ended in December 1999 and the logging of pressure in KXTT5 was started in December 1999. Furthermore, in December 1999 were the packers and sensors in KXTT4 reconfigured. At that moment it was not possible to establish the innermost section why section 1 in KXTT4 only exists until December 1999. Section 2 in KXTT4 was at the same time redefined to include what was earlier both section 1 and section 2. See further “5 Status of installation” for a complete presentation of current section setups. Figures of pressure from November 1999 until January 2000 (i.e. by the time for reconfiguration of KXTT4) exist in appendix 4.

The big scale tendencies are similar for all the six holes, pressure decreases during the measuring period and the differences between outer and inner sections increase. In total, the pressures have decreased about ~15 – 30 m. The greatest decrease in pressure occurs from the start until ~April 1997. Thereafter, the pressure decrease slows down. Variations occur during whole the measuring period and some of them coincide with drillings. Temporary lower pressures occur during year 2000 (i.e. the period for the LTDE project) but it seems as if they recover by the end of the LTDE project.

By the 14th of June, a leakage was found in the pressure system that operates the packers in KXTT4. The leak was stopped and the pressure on packers in KXTT4 was increased, and that affected all the boreholes in the TRUE-1 array. Section 2 of KA3005A shows a temporary high pressure at the 14th of June. Sections 3, 4 and 5 of KXTT4 show a remaining pressure increase of ~3 m. Sections 3 and 4 in KXTT3 increase ~1.5 and ~2 m respectively. Sections 4 and 5 in KXTT4 increase~2 and ~3.5 m respectively. Section 4 in KXTT5 increases by 35 kPa. A possible reason for this remaining pressure increase in these sections may be that the packers closing off sections 3, 4 and 5 in KXTT4 did not tighten up decently until their expansion pressure was increased. Thus, these sections were leaking and thereby a lower pressure in those propagated to other sections in other boreholes that intersected the same features.

The outermost sections tend to decrease more than the innermost ones, this is similar to the relations between sections in the bounding fracture zones. The explanation is probably the same; the outermost sections are closer to the tunnel and thereby are drained first due to higher transmissivity and a higher pressure gradient. For borehole KA3005A there is an opposite situation, as the innermost sections are closer to the tunnel than the outermost.

The current pressures are similar to the ones at the end of TRUE-1 (January 1999) for the innermost sections, representing the bounding structure NW-2 and feature A, whereas the outermost sections, representing Features B and D, have about 10 m lower pressures. There is no obvious evidence that the TRUE-1 project has caused greater variations in pressure in the TRUE-1 array than what is observed during the periods when TRUE-1 was not ongoing. Additionally, the TRUE-1 project does not seem to have caused any substantial changes in the pressure pattern. The observed variations in pressure are probably rather due to specific events as drilling through a major fracture zone or expanding/releasing packers that closes off such a zone. The effects of the LTDE project are seen as temporary lower pressure during year 2000.

3.3 Reconfiguration of KXTT4

As mentioned above, the instrumentation in KXTT4 was reconfigured in December 1999. From the figures in appendix 4 it is seen that the reconfiguration temporarily affects all sections in the whole TRUE-1 array as well as the boreholes in the bounding fracture zones (KA3010A and KA3067A).

By the end of November 1999 something happens to section 3 in KXTT4, the pressure falls substantially and it is probably due to a leakage in connection to the pressure sensor for that section. This leakage affects most of the other sections in most of the other boreholes. If the pressure before 30^{th} of November 1999 is assumed to be the undisturbed pressure, then it is possible to estimate which sections that are affected by the reconfiguration and which are not.

From the figures in appendix 4 it is seen that the only section recording in KA3010A (section 2) is affected by the reconfiguration, the pressure is ~1 m lower after the reconfiguration than it was before the 30^{th} of November. All sections in KA3067A decrease with ~1 m at the time for the instrumentation. The sections 1 and 2 in KXTT2 are not affected by the reconfiguration, but the sections 3, 4 and 5 decrease with ~3 m. Neither are the sections 1 and 2 in KXTT3 affected by the reconfiguration but the sections 3 and 4 decrease with ~2 m. The new section 2 of KXTT4 obtains a pressure which is an intermediate value of the earlier section 2 and section 1. Section 3 in KXTT4 is not affected by the reconfiguration but sections 4 and 5 decrease with ~2.5 m. Finally, none of the sections in KA3005A is affected by the reconfiguration.

4 Groundwater chemistry

The chemistry of section 2 in KXTT3 has been investigated by sampling of water at irregular intervals. The water has been analysed with respect to concentrations of Na, K, Mg, Ca, SO_4, SO_4-S, Cl, Br and HCO_3^-. Furthermore, electrical conductivity and pH of the samples has been analysed. The results of the analyses are seen in appendix 5.

4.1 Na, Ca, SO_4, SO_4-S and Cl

The concentrations of these matters follow the same big scale pattern. From the first sampling (~April 1996) until ~July/December 1997 the concentrations increases slightly, thereafter the concentrations decrease slowly until the last sampling (September 2000). A small local maximum in the concentrations is seen in October 1999.

4.2 Mg

Mg shows some similarities with the big scale pattern of Na, Ca, SO_4, SO_4-S and Cl. But, Mg shows the highest concentration at the first sampling and the over all tendency thereafter is a decrease of Mg concentration. A local minimum is seen in July 1997 and a local maximum in October 1999.

4.3 K

K is decreasing during whole the period (from ~14 mg/l to ~12 mg/l) April 1996 to September 2000. Fluctuations exist but are not as obvious as for the earlier mentioned matters.

4.4 Br

Br varies during the sampling period. The major trend is that the concentration increases from first sampling until ~December 1997 and thereafter decreases. Local maxima are seen in March and December 1997 and also October 1999.

4.5 HCO_3

HCO_3 increases during February 1996 (three samples analysed with a lower quality method). Thereafter, HCO_3 decreases until October 1997. From October 1997, HCO_3 increases from 43 mg/l to 148 mg/l in September 2000.

4.6 Electrical conductivity

The big scale trend is that electrical conductivity increases from February 1996 until October 1997. Thereafter, the conductivity decreases. There is a tendency of increasing conductivity from April 1999 until September 2000.

4.7 pH

It is not possible to identify any clear trend what concerns pH. pH varies around 7.5 during whole the period.

5 Status of installation

Table 5-1. Current installations in the TRUE-1 array

Borehole	section number	Feature	section length (m)	circulation lines	Comment
KA3005A	1	?	51.03-58.11		no logging of pressure
	2	B	46.78-50.03	X	
	3	A	44.78-45.78	X	dummy: ∅=51 mm, l=0.5 m
	4	A?	39.03-43.78		
	5	?	6.53-38.03		
KXTT2	1	?	16.55-18.30		
	2	A	14.55-15.55	X	dummy: ∅=51 mm, l=0.5 m
	3	B	11.55-13.55	X	
	4	B	7.55-10.55		
	5	D	3.05-6.55		
KXTT3	1	NW-2'	15.42-17.43		
	2	A	12.42-14.42	X	dummy: ∅=51 mm, l=1.5 m
	3	B	8.92-11.42	X	
	4	B+D	3.17-7.92		
KXTT4	2	NW-2+NW-2'	14.92-49.31		earlier divided into section 1 & 2
	3	A	11.92-13.92	X	dummy: ∅=51 mm, l=1.5 m
	4	B	8.42-10.92	X	
	5	B+D	3.17-7.42		
KXTT5	1	NW-2'	10.81-25.85		
	2	A	9.61-9.81	X	
	3	B	6.11-8.61		
	4	B+D	3.11-5.11		

Table 5-2. Current installations in the bounding fracture zones

Borehole	section number	Feature	section length (m)	circulation lines	Comment
KA3010A	1	-	16.06-60.56		no logging of pressure
	2	NW-2	8.56-15.06	X	
KA3067A	1	?	34.55-40.05		
	2	?	30.55-33.55	X	
	3	NW-2?	28.05-29.55	X	
	4	NW-3	6.55-27.05		

6 Conclusions and recommendations

None of the presented parameters show any major change that can be directly related to the TRUE-1 project. The variations in inflow to the tunnel, pressure and chemistry seem to be dependent on several other more important factors than TRUE-1.

The tunnel drains the rock and enables the development of a cone of depression, which is seen as increasing pressure differences between sections. Additionally, the drainage is seen as decreasing inflow to the tunnel.

Most salt concentrations decrease and the concentration of HCO_3 increases while the electrical conductivity decreases. This is an indication of surface water penetrating deep and mixing with the origin water in the rock fractures. The indicated deep penetration of surface water is consistent with the drainage caused by the tunnel. Further, there is a quite high resemblance between the shapes of salt concentration curves and the shape of the inflow to tunnel curve (along section 2994-3179 m).

None of the sections of particular interest (i.e. those intersecting the fractures of main interest – section 3 in KXTT4 and section 2 in KXTT2, KXTT3 and KXTT5) have shown any substantial changes due to the reconfiguration of KXTT4. Thereby, there is no reason to reinstall the packers and pressure sensors in KXTT4 only to obtain the same setup as in the TRUE-1 project.

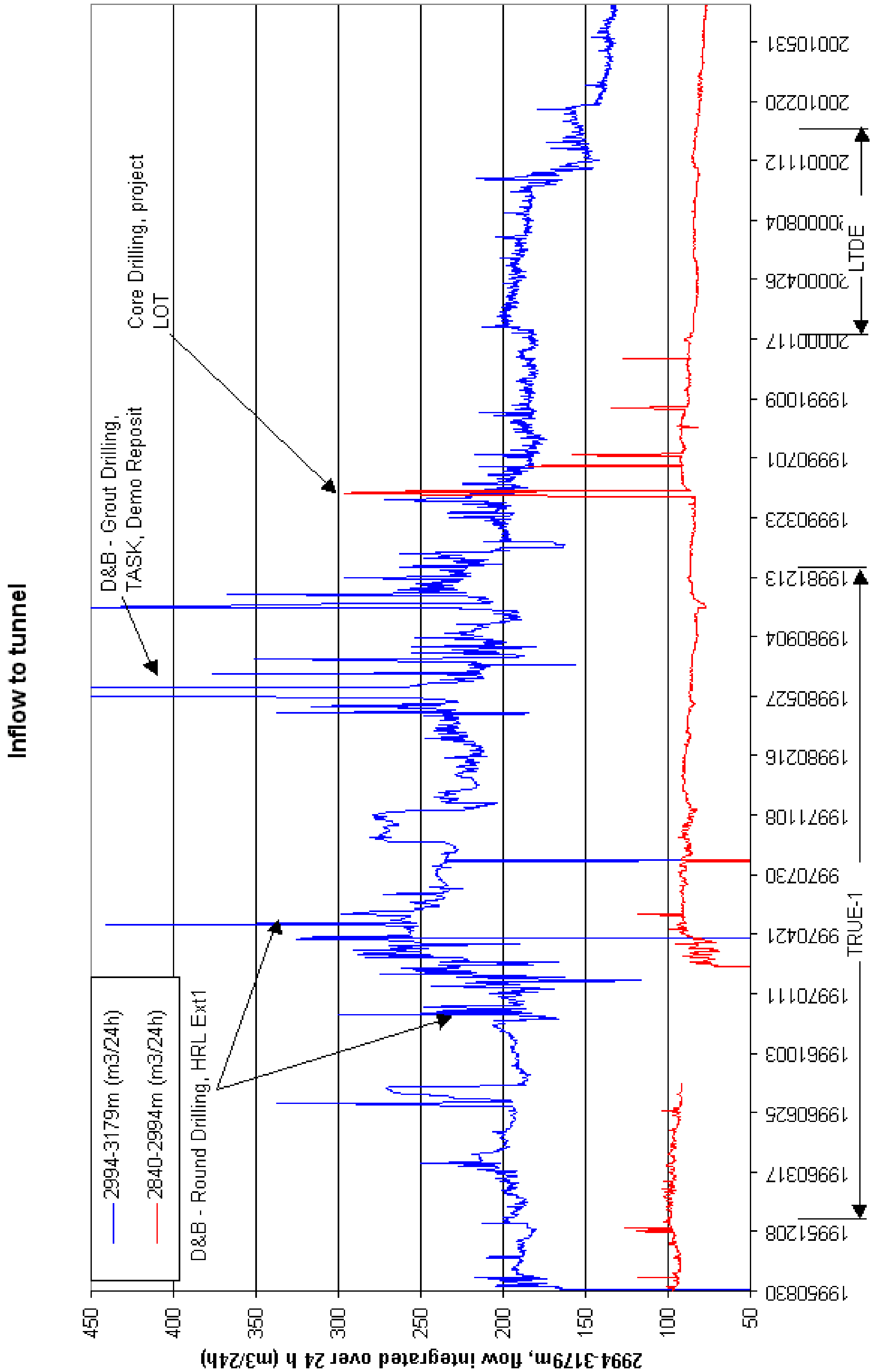
7 References

Byegård, J., Johansson, H., Andersson, P., Hansson, K., Winberg, A., 1999. Test plan for the long term diffusion experiment. Äspö Hard Rock Laboratory International Progress Report IPR-99-36.

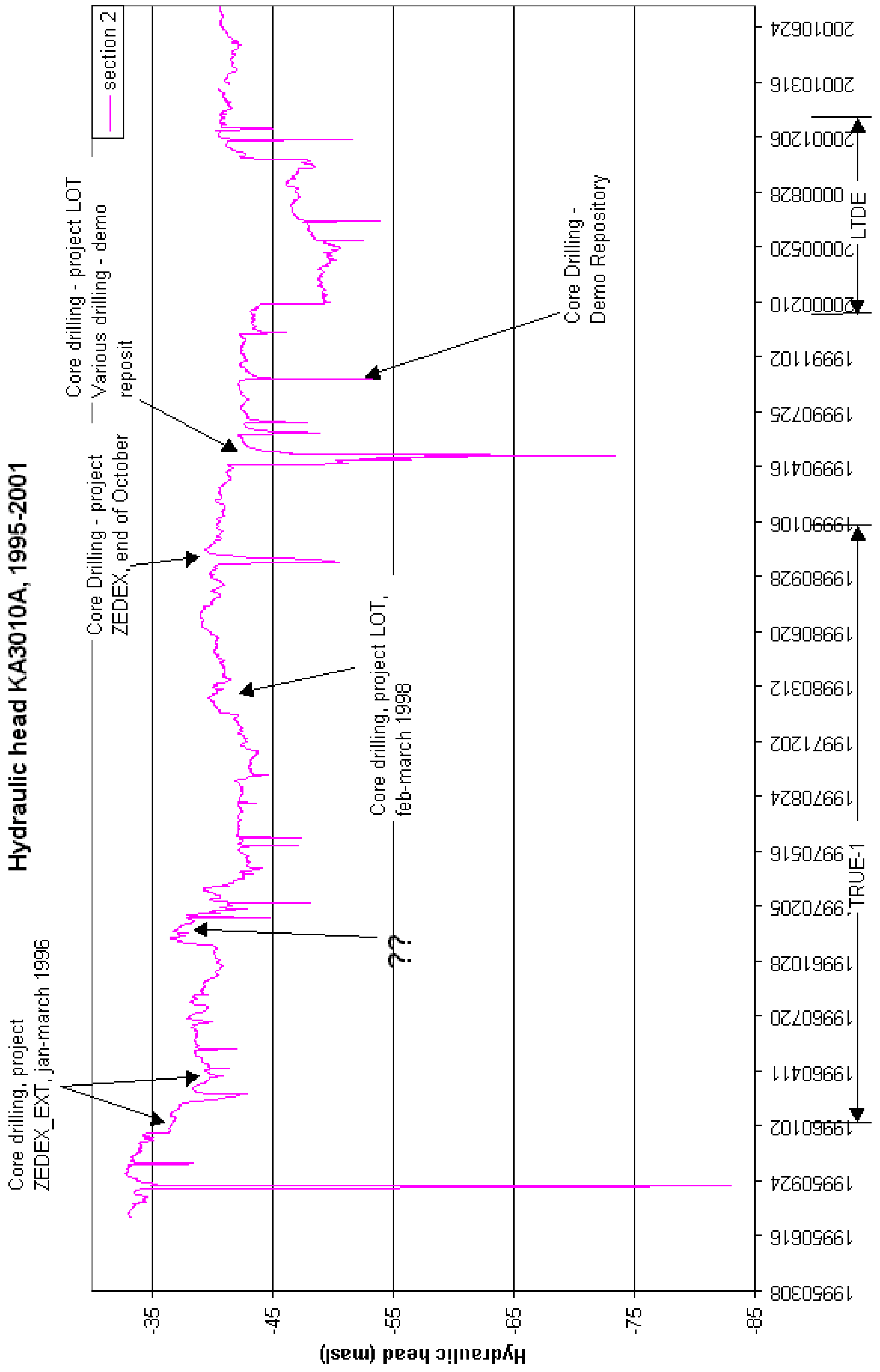
Svensk Kärnbränslehantering AB, 2001. First TRUE Stage – Transport of solutes in an interpreted single fracture. Proceedings from the 4th International Seminar Äspö, September 9-11, 2000. Swedish Nuclear Fuel and Waste Management Company, SKB Technical Report TR-01-24.

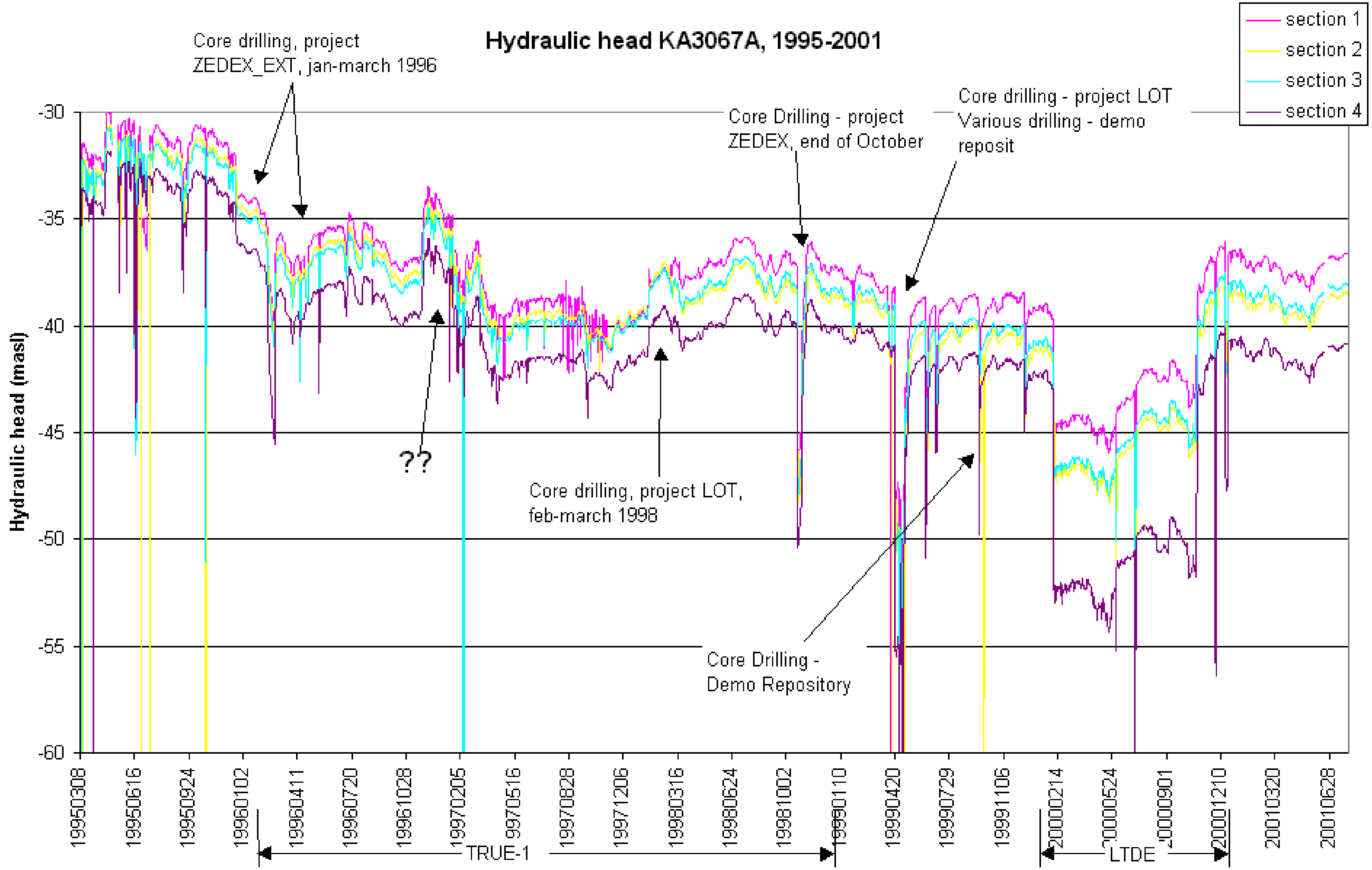
Winberg, A., Andersson, P., Hermanson, J., Byegård, J., Cvetkovic, V. and Birgersson, L. 2000 : Äspö Hard Rock Laboratory, Final report of the first stage of the tracer retention understanding experiments, Swedish Nuclear Fuel and Waste Management Company, SKB Technical report TR-00-07.

Appendix 1 – Inflow to tunnel



Appendix 2 – Bounding fracture zones




Hydraulic head KA3067A, 1995-2001
section 1
section 2
section 3
section 4
Hydraulic head (masl)
-30
-35
-40
-45
-50
-55
-60
Core drilling, project ZEDEX_EXT, jan-march 1996
Core Drilling - project ZEDEX, end of October
Core drilling - project LOT Various drilling - demo reposit
??
Core drilling, project LOT, feb-march 1998
Core Drilling - Demo Repository
19950308
19950616
19950924
19960102
19960411
19960720
19961028
19970205
19970516
19970828
19971206
19980316
19980624
19981002
19990110
19990420
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19991106
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20000524
20000901
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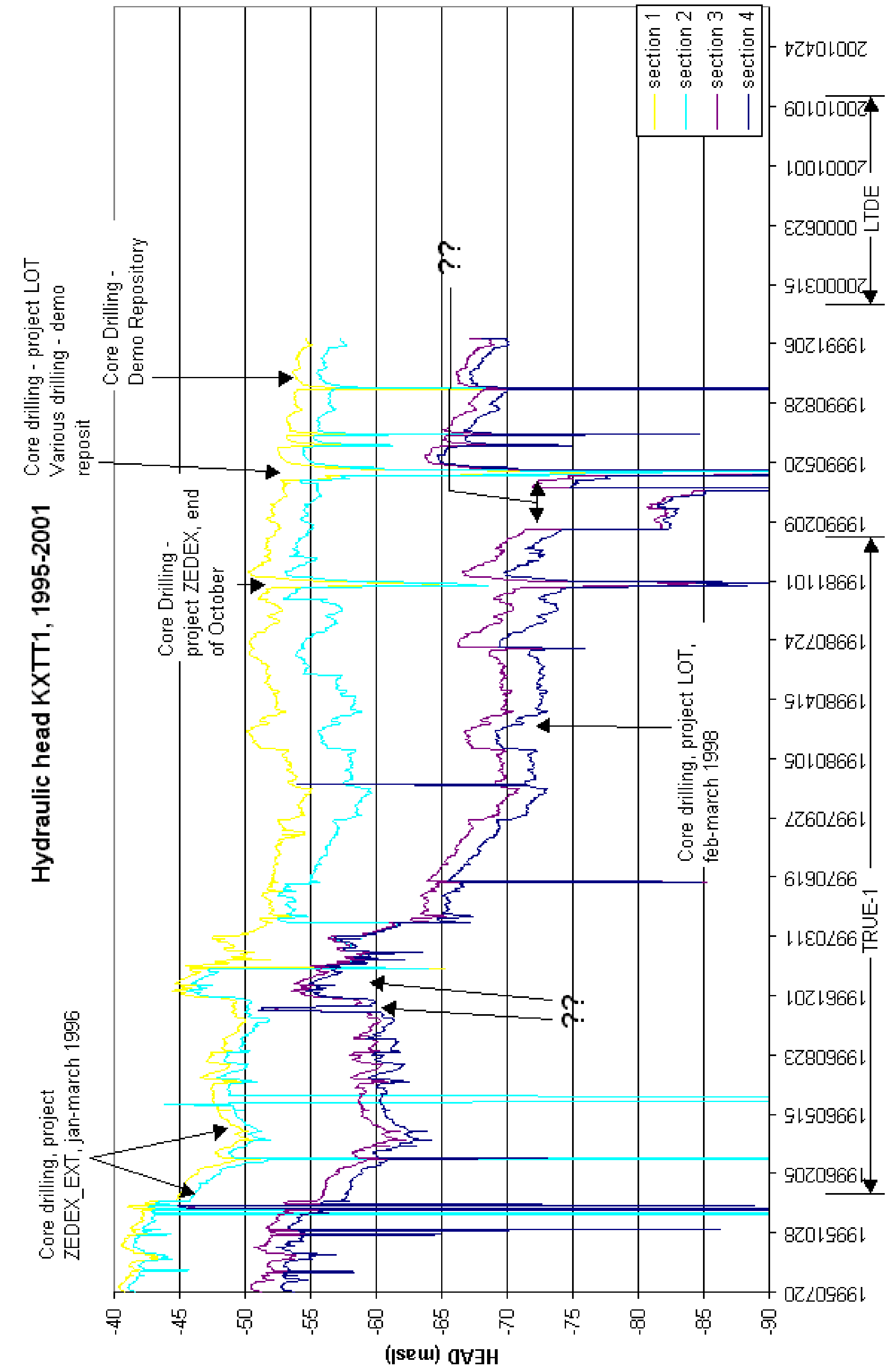
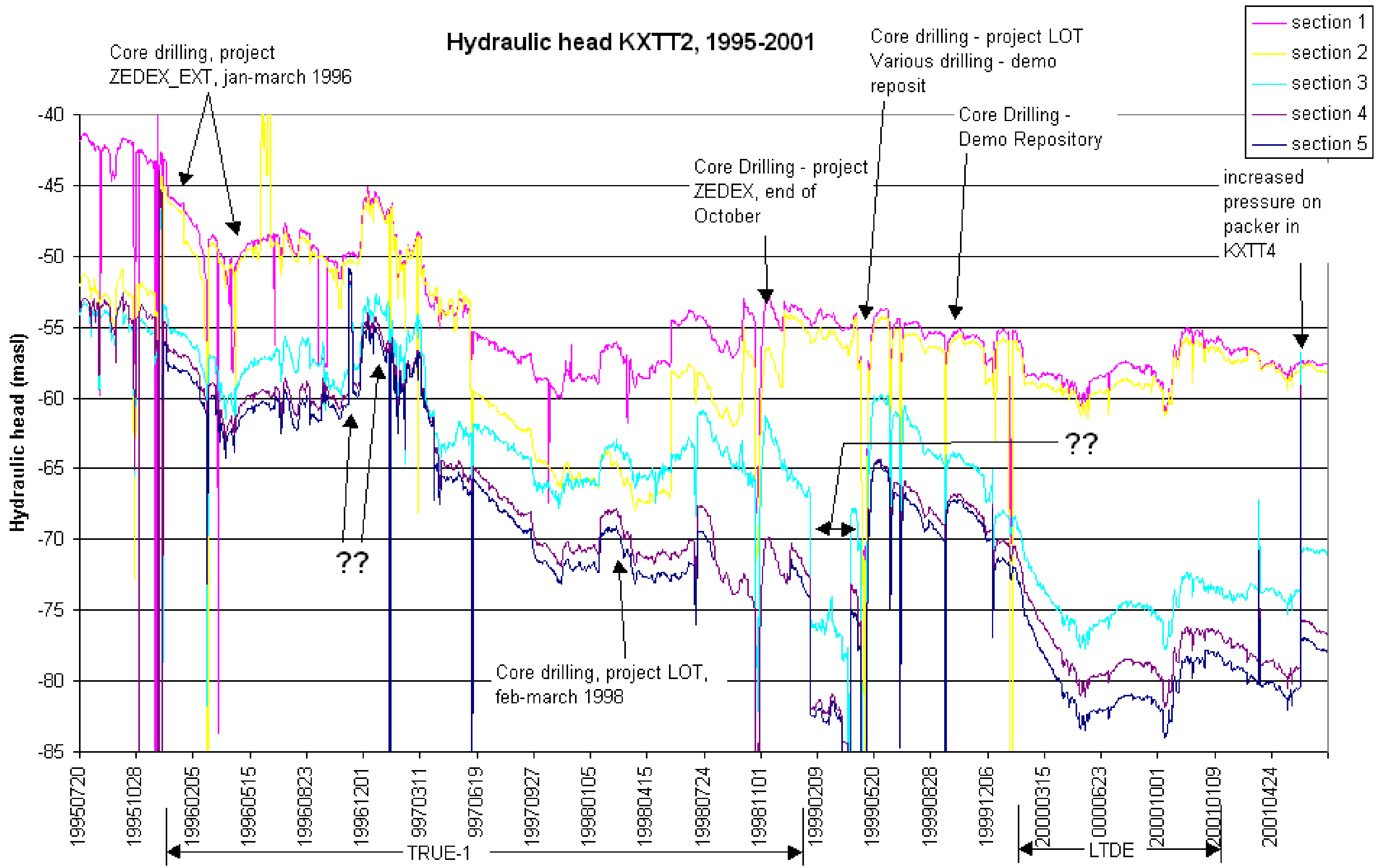
20010320
20010628
TRUE-1
LTDE

Appendix 3 – TRUE-1 Array

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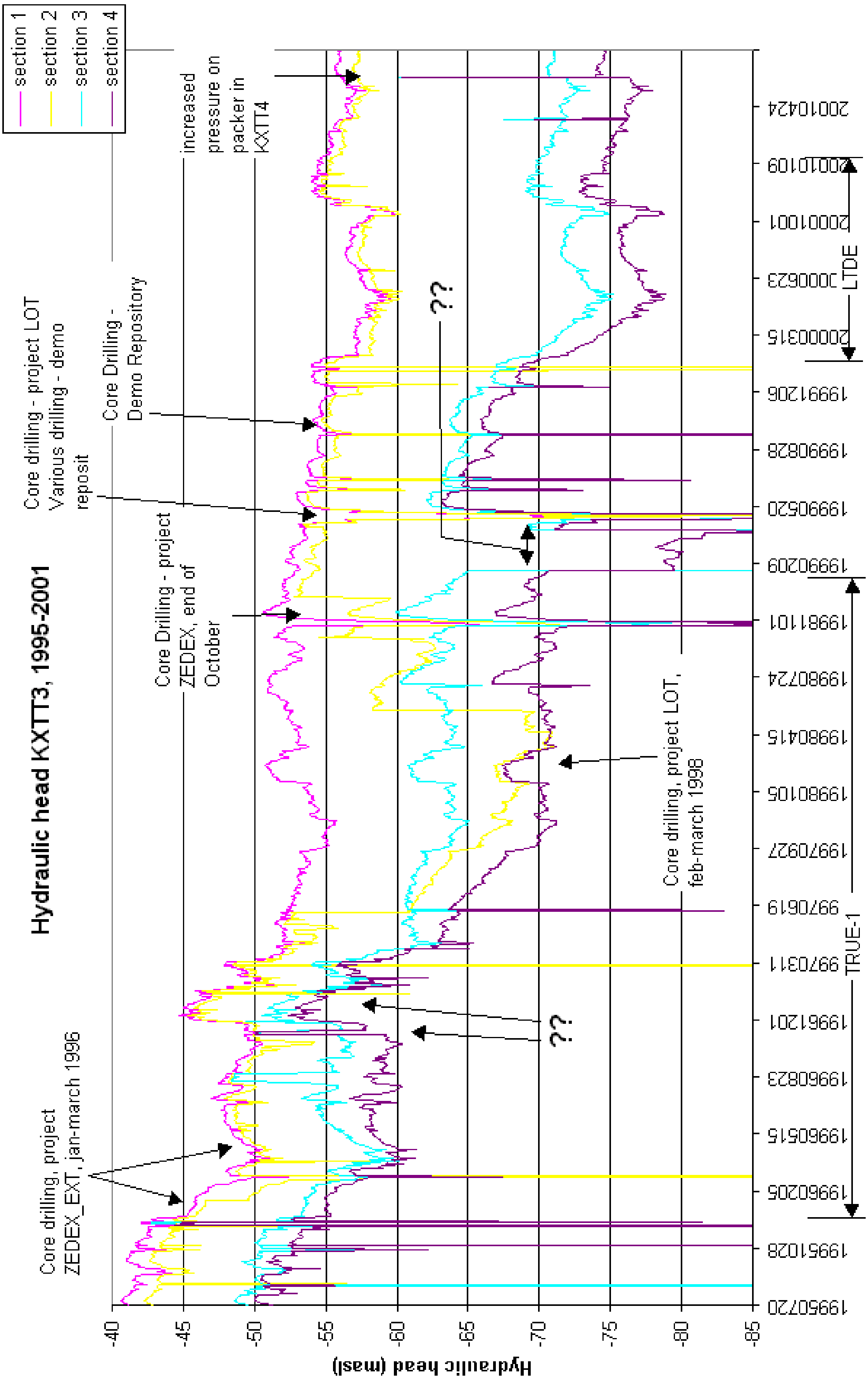
section 1
section 2
section 3
section 4
section 5
Hydraulic head (masl)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
19950720
19951028
19960205
19960515
19960823
19961201
9970311
9970619
19970927
19980105
19980415
19980724
19981101
19990209
19990520
19990828
19991206
20000315
0000623
20001001
20010109
20010424
Core drilling, project ZEDEX_EXT, jan-march 1996
Core Drilling - project ZEDEX, end of October
Core drilling - project LOT Various drilling - demo reposit
Core Drilling - Demo Repository
increased pressure on packer in KXTT4
??
??
Core drilling, project LOT, feb-march 1998
TRUE-1
LTDE


Hydraulic head KXTT3, 1995-2001
section 1
section 2
section 3
section 4
Hydraulic head (masl)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
19950720
19951028
19960205
19960515
19960823
19961201
19970311
19970619
19970927
19980105
19980415
19980724
19981101
19990209
19990520
19990828
19991206
20000315
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20010109
20010424
TRUE-1
LTDE
Core drilling, project ZEDEX_EXT, jan-march 1996
??
Core drilling, project LOT, feb-march 1998
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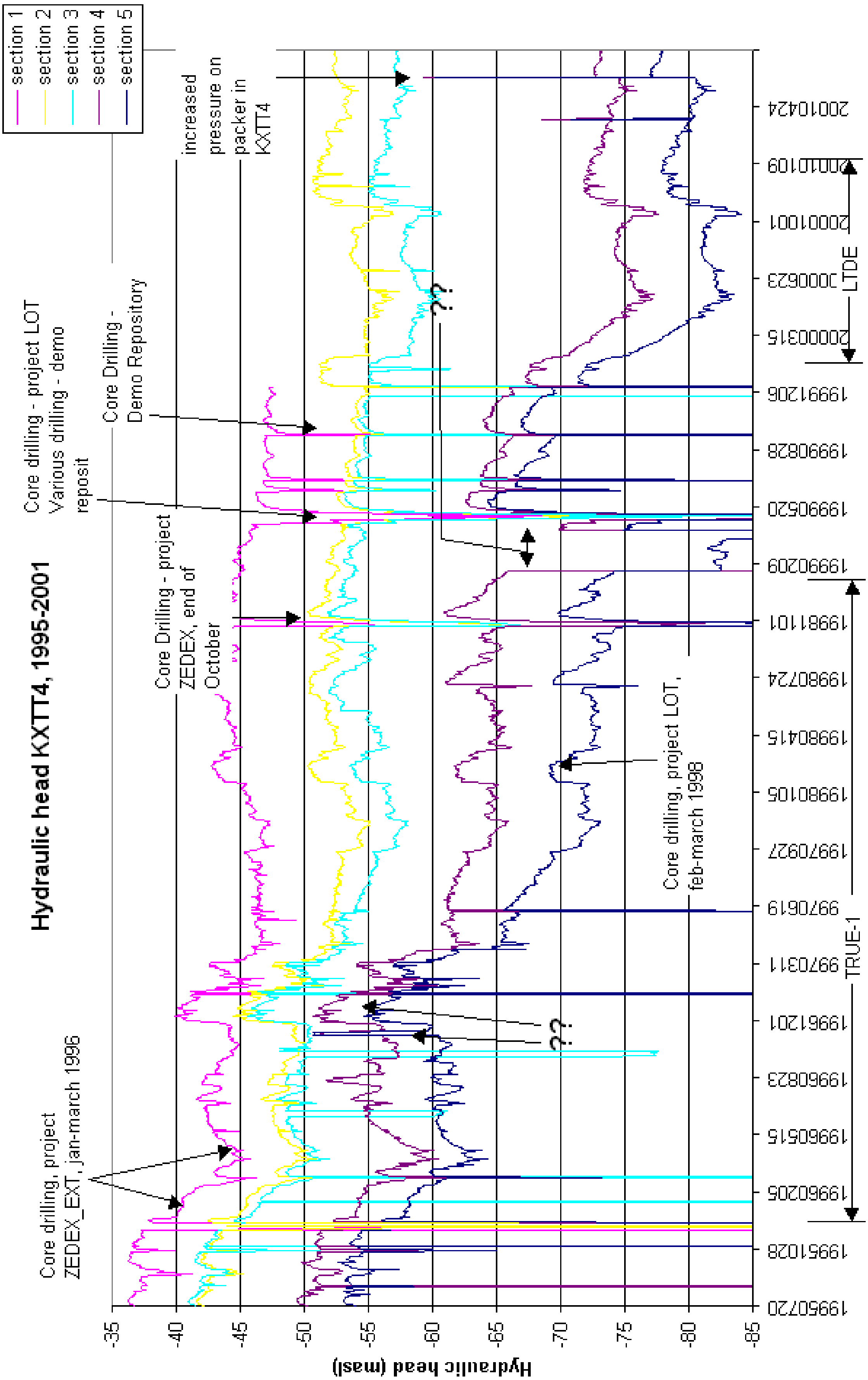
increased pressure on packer in KXTT4



Hydraulic head KXTT4, 1995-2001
Hydraulic head (masl)
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
19950720
19951028
19960205
19960515
19960823
19961201
19970311
19970619
19970927
19980105
19980415
19980724
19981101
19990209
19990520
19990828
19991206
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20010109
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section 1
section 2
section 3
section 4
section 5
Core drilling, project ZEDEX_EXT, jan-march 1996
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TRUE-1
Core drilling, project LOT, feb-march 1998
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Core Drilling - Demo Repository
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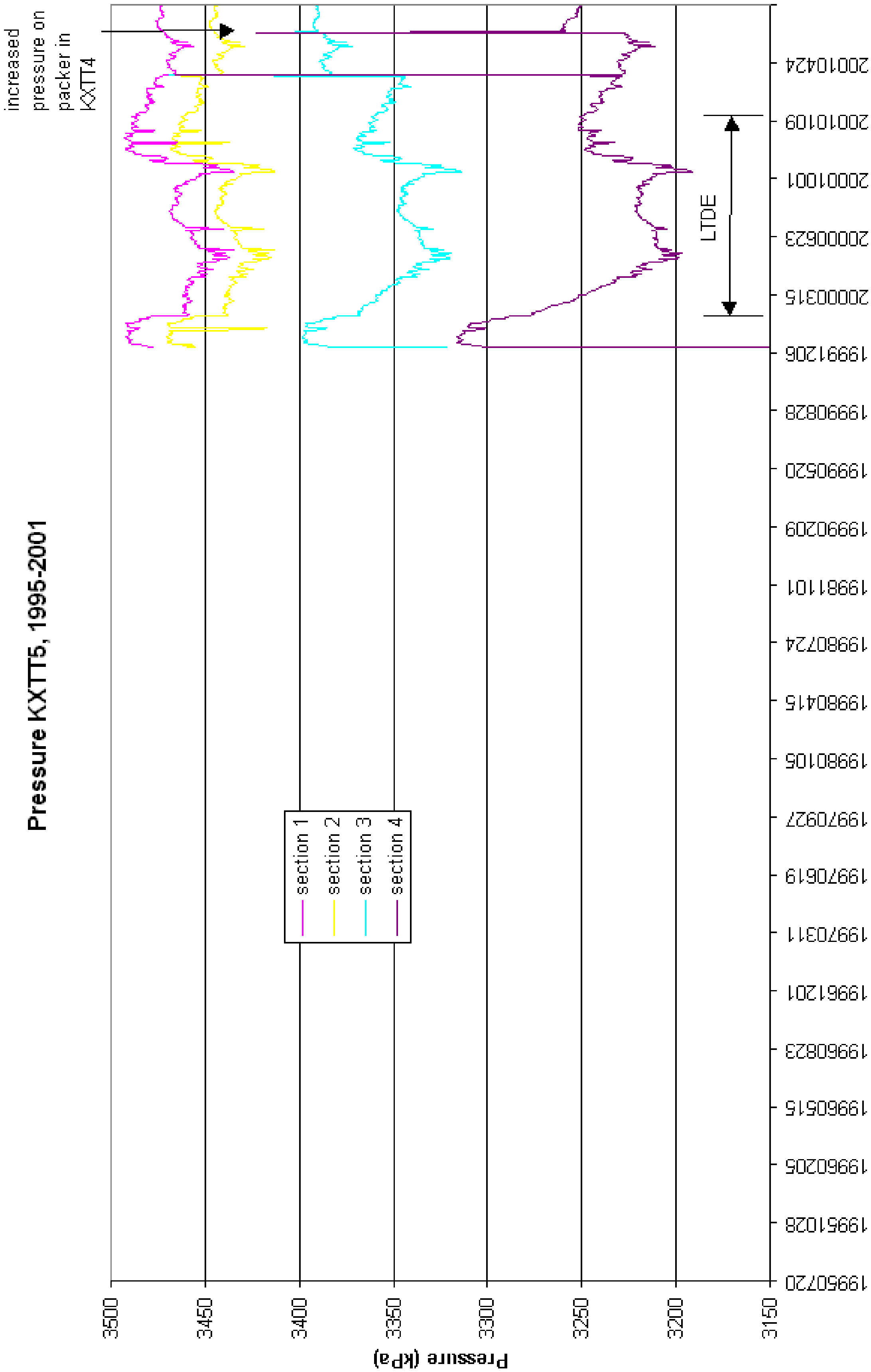
increased pressure on packer in KXTT4
LTDE



Pressure KXTT5, 1995-2001
increased pressure on packer in KXTT4
LTDE
section 1
section 2
section 3
section 4
Pressure (kPa)
3500
3450
3400
3350
3300
3250
3200
3150
19950720
19951028
19960205
19960515
19960823
19961201
19970311
19970619
19970927
19980105
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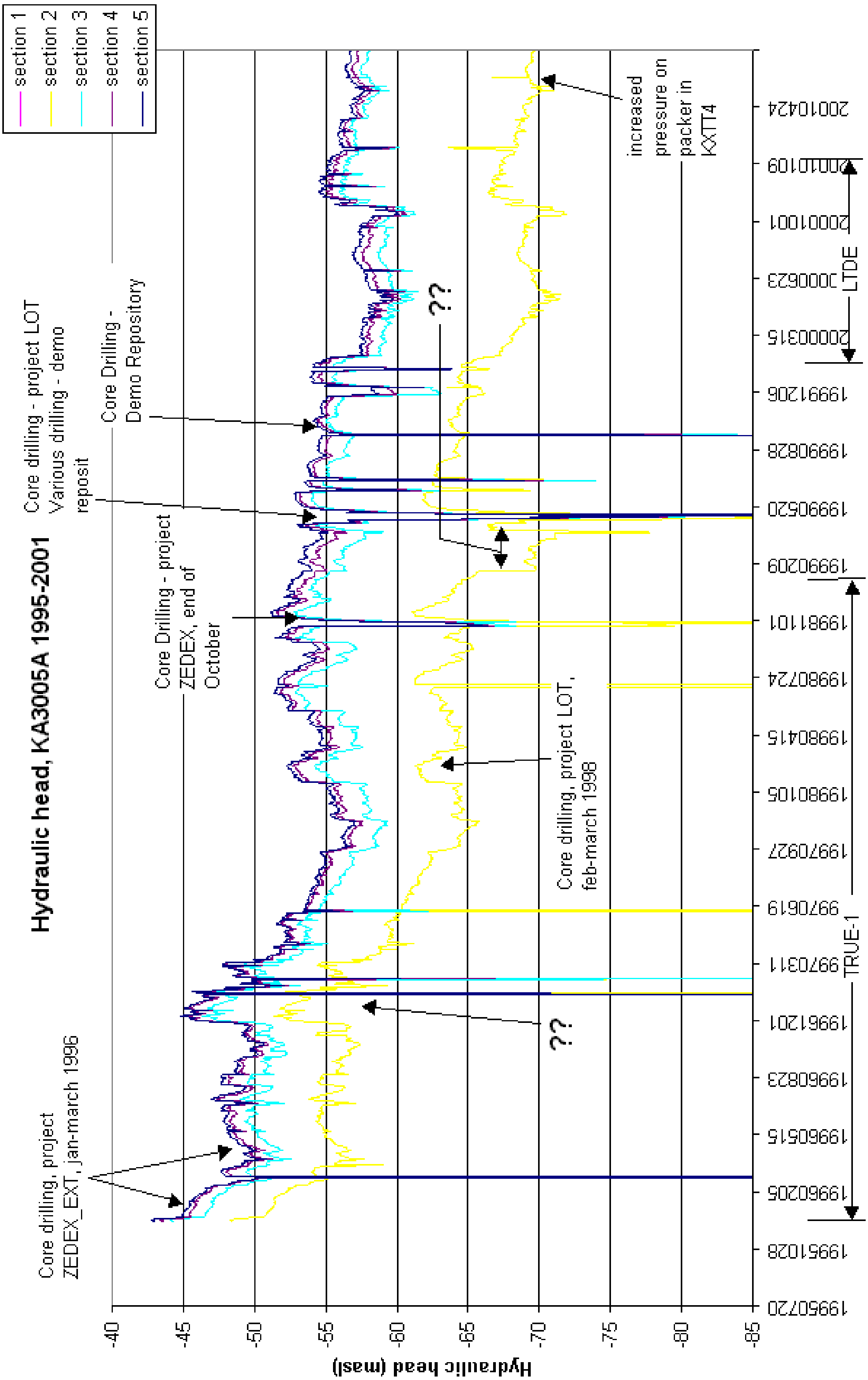
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LTDE
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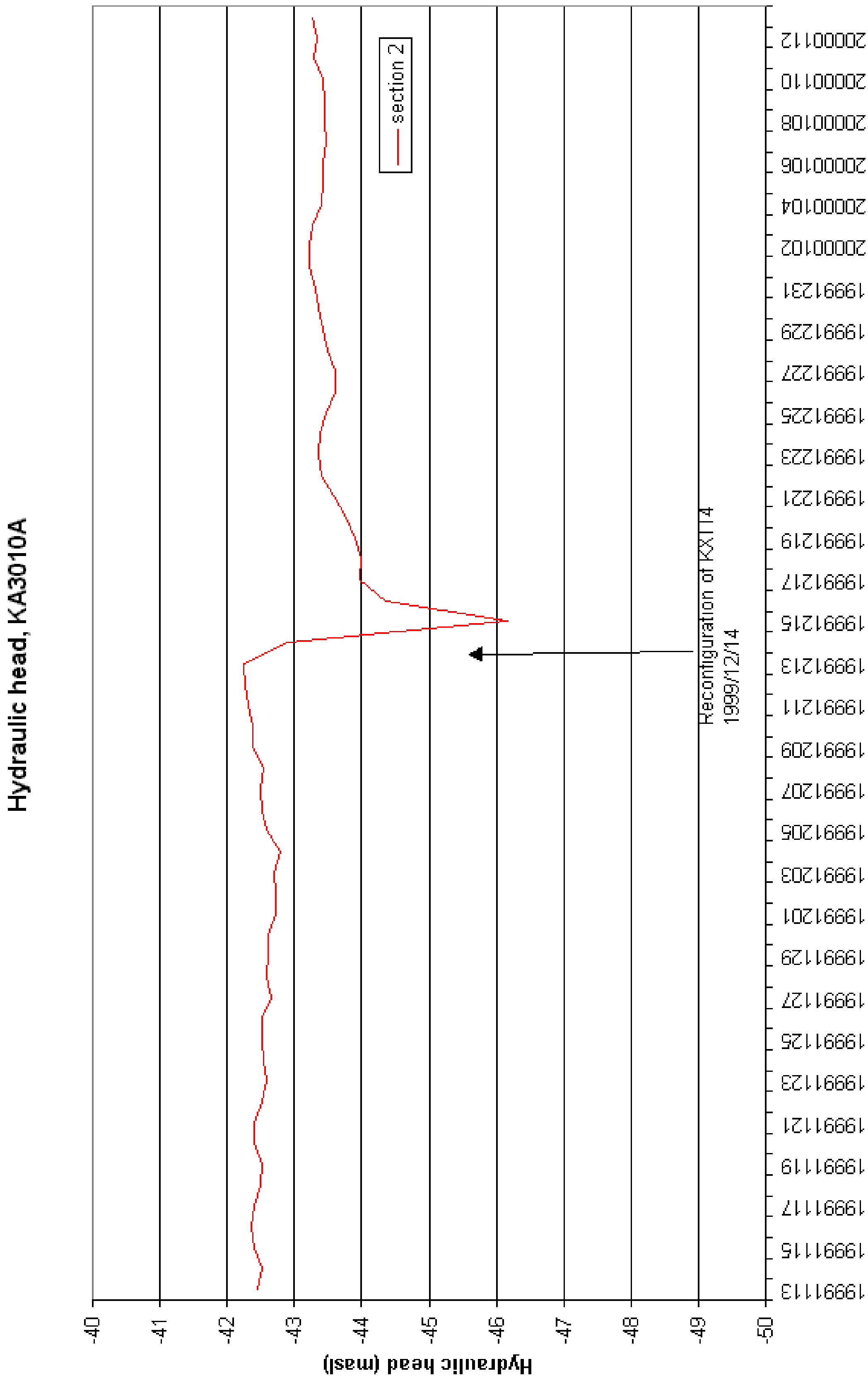
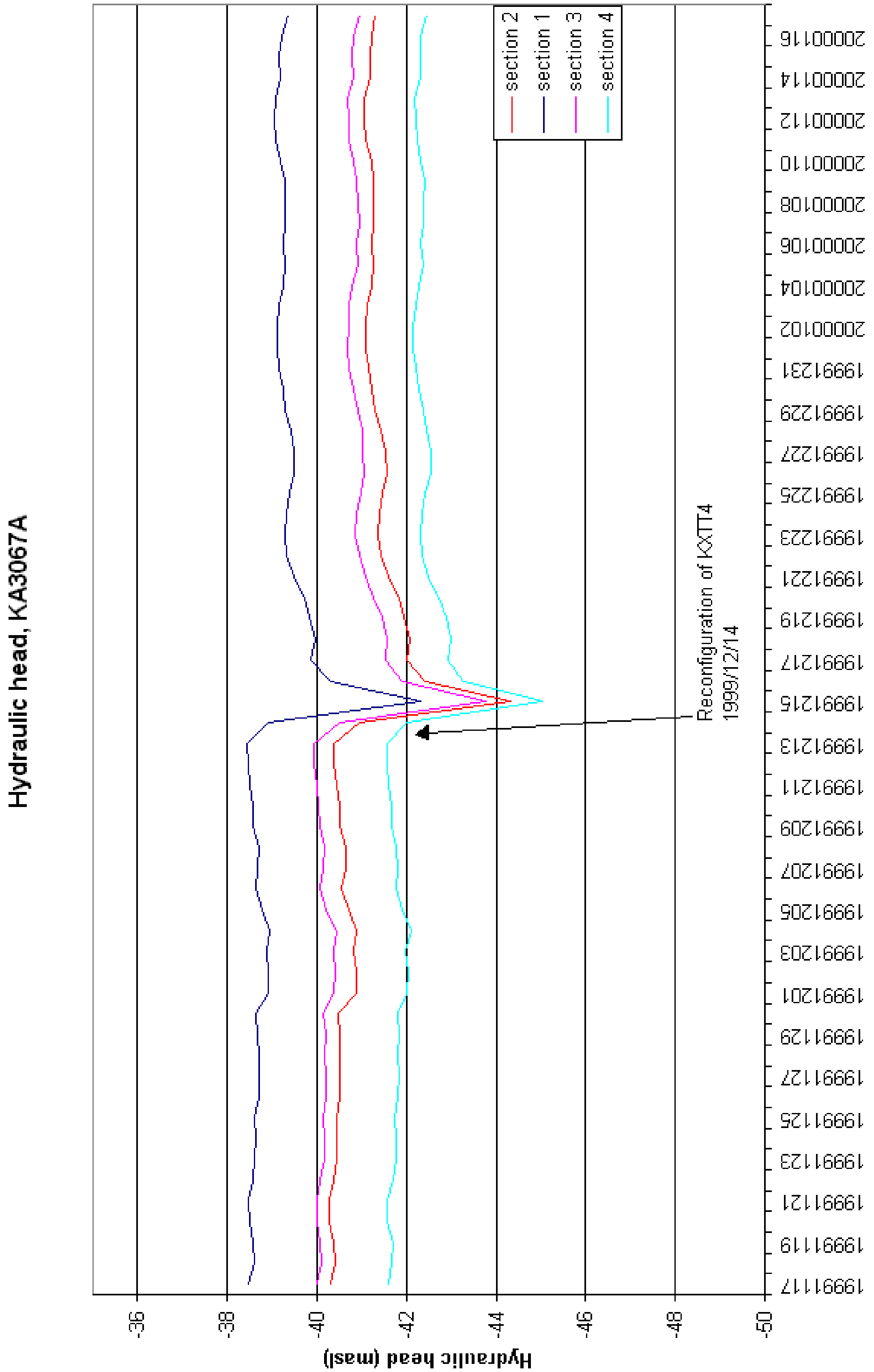
increased pressure on packer in KXTT4

Appendix 4 – Reconfiguration of KXTT4

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Hydraulic head (masl)
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-38
-40
-42
-44
-46
-48
-50
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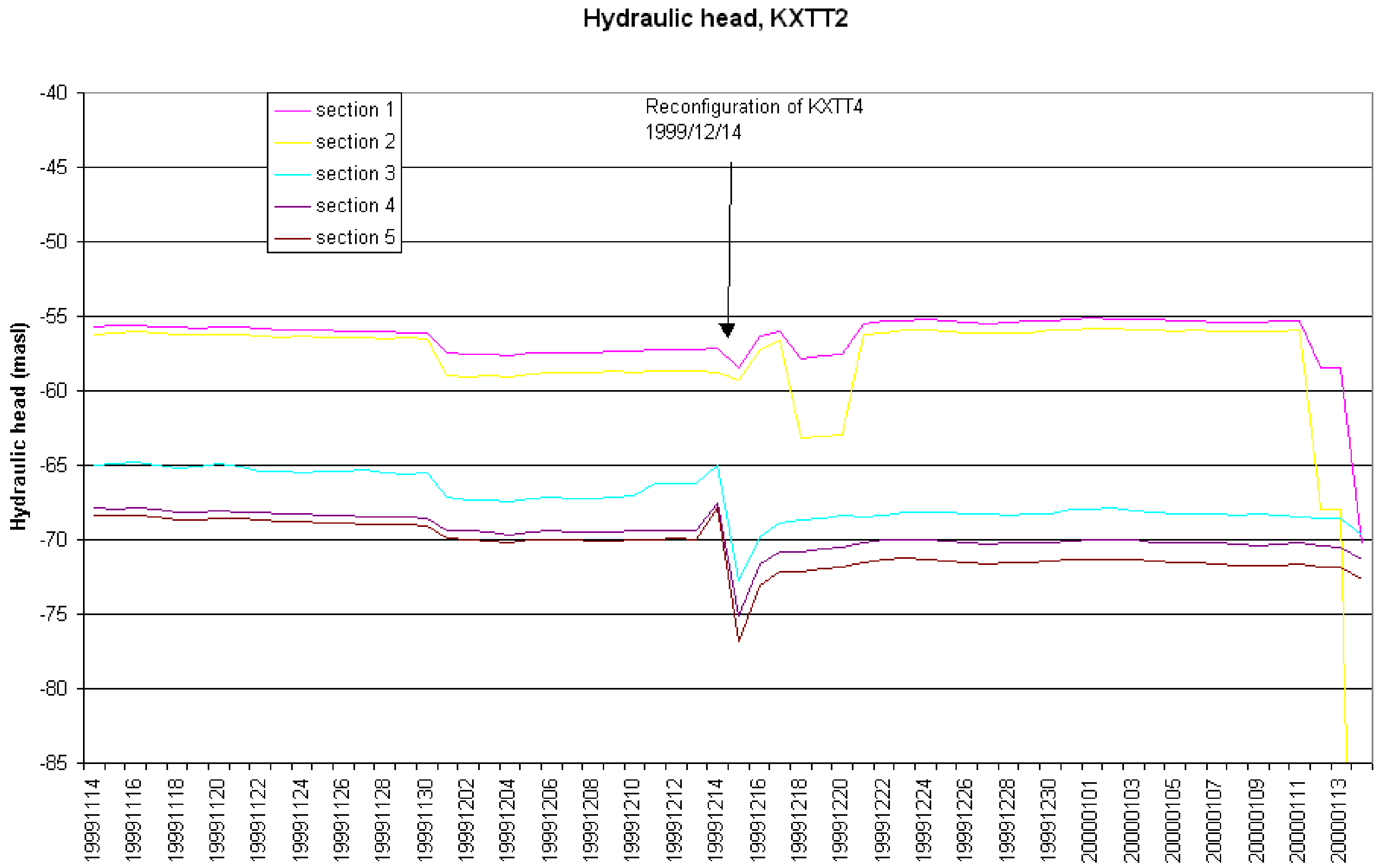
section 3
section 4
Reconfiguration of KXTT4
1999/12/14


Hydraulic head, KXTT2
Hydraulic head (masl)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
section 1
section 2
section 3
section 4
section 5
Reconfiguration of KXTT4
1999/12/14
19991114
19991116
19991118
19991120
19991122
19991124
19991126
19991128
19991130
19991202
19991204
19991206
19991208
19991210
19991212
19991214
19991216
19991218
19991220
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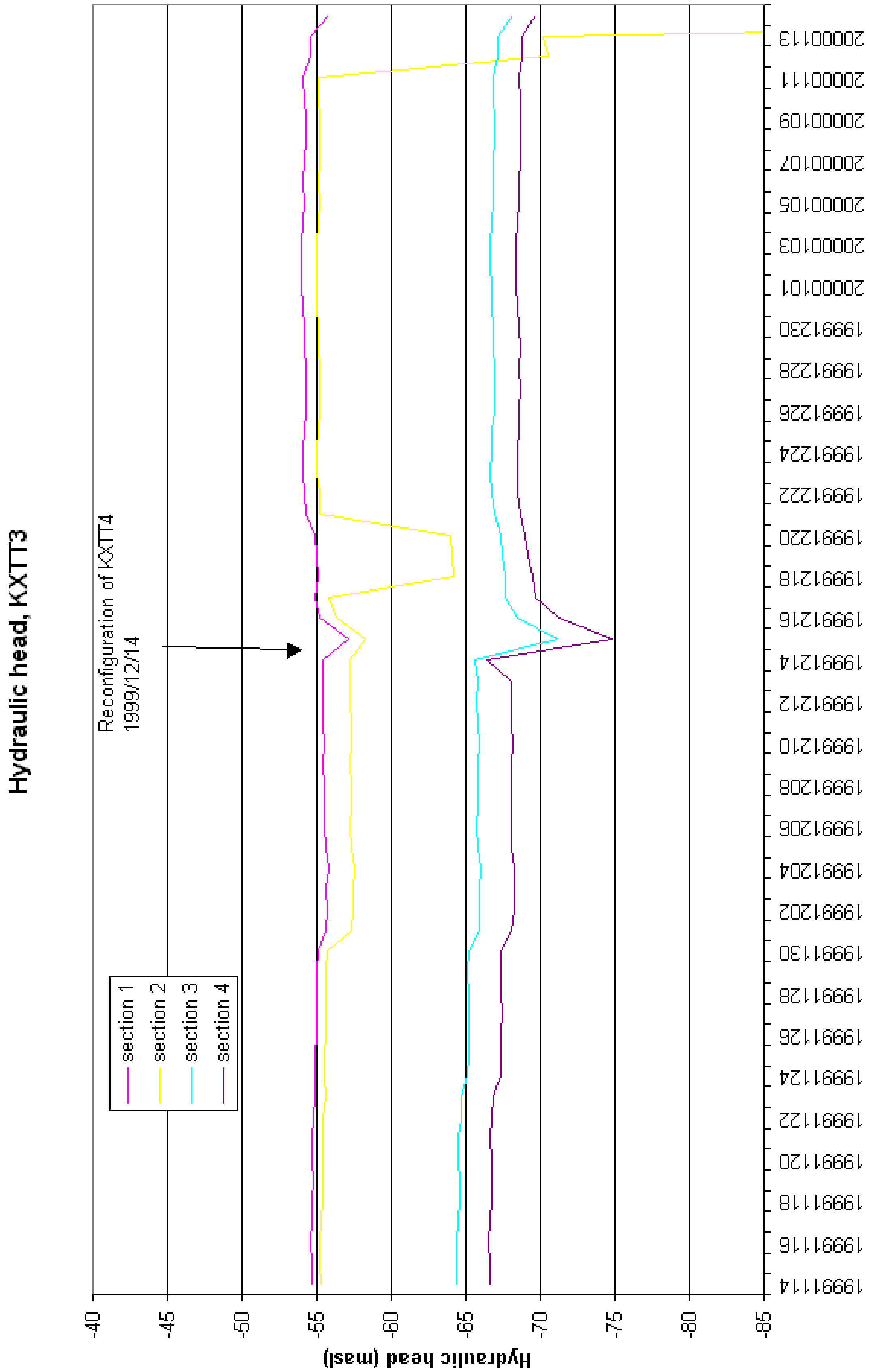
Hydraulic head, KXTT3
Reconfiguration of KXTT4
1999/12/14
section 1
section 2
section 3
section 4
Hydraulic head (masl)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
19991114
19991116
19991118
19991120
19991122
19991124
19991126
19991128
19991130
19991202
19991204
19991206
19991208
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19991218
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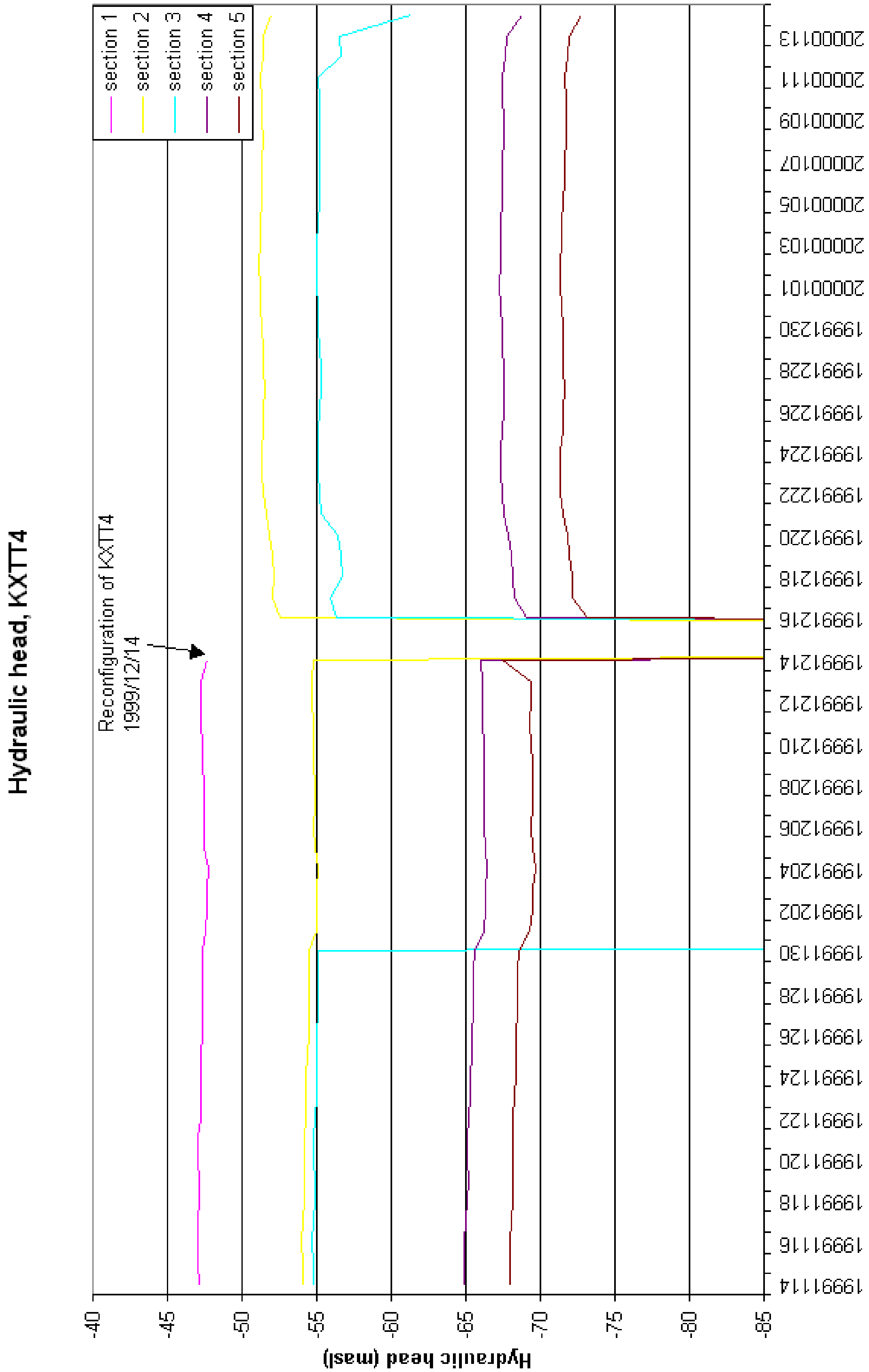

Hydraulic head, KXTT4
Reconfiguration of KXTT4
1999/12/14
section 1
section 2
section 3
section 4
section 5
Hydraulic head (masl)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
19991114
19991116
19991118
19991120
19991122
19991124
19991126
19991128
19991130
19991202
19991204
19991206
19991208
19991210
19991212
19991214
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19991220
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20000103
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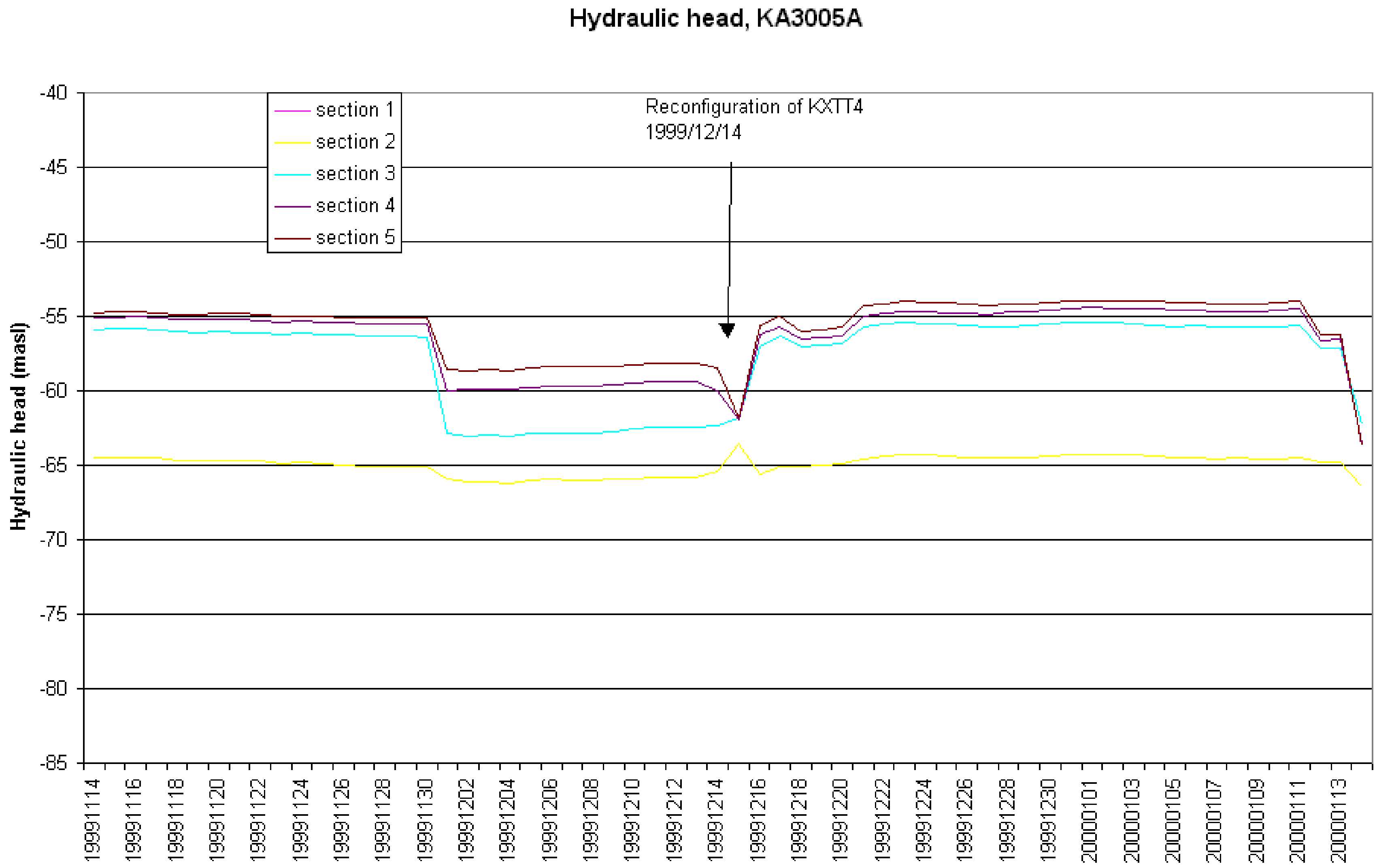
Hydraulic head, KA3005A
Hydraulic head (masl)
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
section 1
section 2
section 3
section 4
section 5
Reconfiguration of KXTT4
1999/12/14
19991114
19991116
19991118
19991120
19991122
19991124
19991126
19991128
19991130
19991202
19991204
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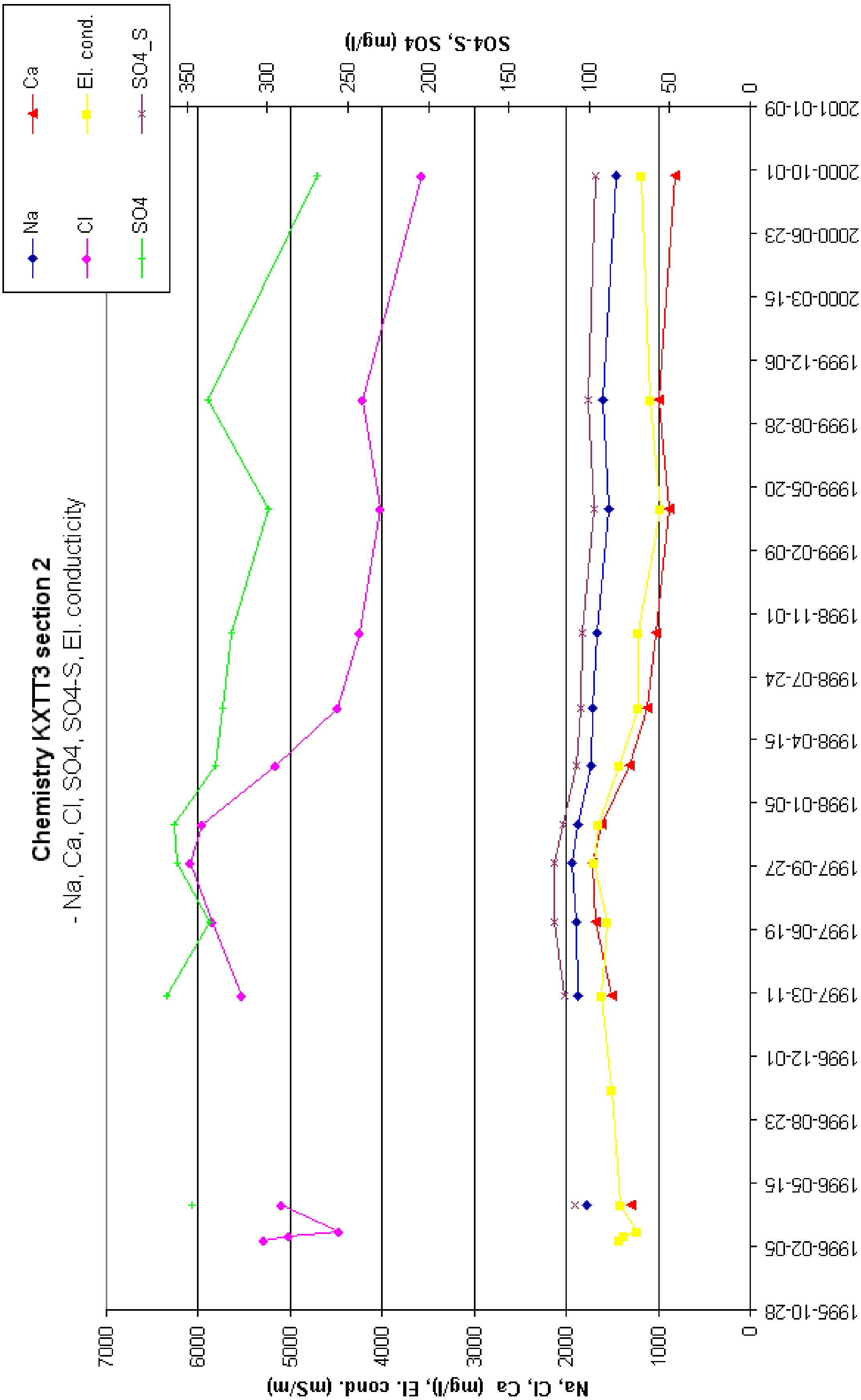
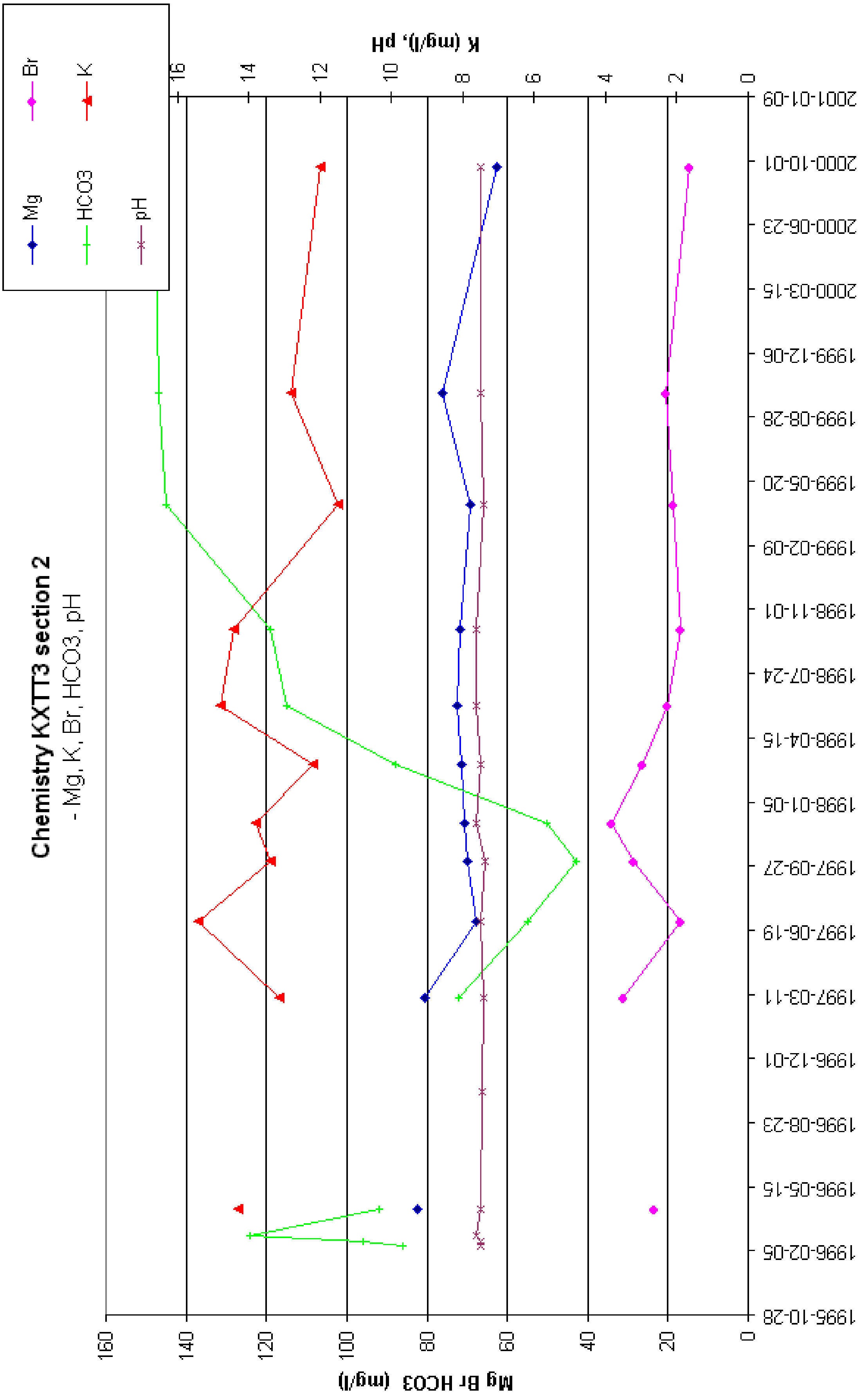
Appendix 5 – Chemistry of section 2 in KXTT3




Chemistry KXTT3 section 2
- Mg, K, Br, HCO3, pH
Mg
HCO3
pH
Br
K
Mg Br HCO3 (mg/l)
K (mg/l), pH
0
20
40
60
80
100
120
140
160
0
2
4
6
8
10
12
14
16
1995-10-28
1996-02-05
1996-05-15
1996-08-23
1996-12-01
1997-03-11
1997-06-19
1997-09-27
1998-01-05
1998-04-15
1998-07-24
1998-11-01
1999-02-09
1999-05-20
1999-08-28
1999-12-06
2000-03-15
2000-06-23
2000-10-01
2001-01-09