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Data for calibration and validation of numerical models at SFR Nuclear Waste Repository

Forsmark, Sweden

Carl-Lennart Axelsson

Golder Associates AB

December 1997

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Keywords: Forsmark, SFR, Groundwater data, Model calibration

SUMMARY

The final repository for low and intermediate radioactive waste, SFR, is located below the Baltic offshore of the nuclear power plant at Forsmark. The current operating permit for SKB stipulates that the safety assessment is updated at least every ten year. In response, SKB has started the SAFE project which aims at submitting a complete revised safety analyses before or during the year 2000. The current report is part of the far-field analyses in SAFE and provides information that can be used in a revised hydrogeological modelling of the facility.

Information have been collected mainly during the construction phase of SFR, 1983 - 88, and the operation phase from 1988. The specific information that is available for the construction phase is; pressure responses in different bore holes when pumping in one bore hole, groundwater pressure in sections of bore holes, inflow to different parts of the SFR, and groundwater chemistry and isotope analyses in sections of bore holes. During the operation phase, the following information is available; ground-water pressure in sections of bore holes, inflow to different parts of the SFR facility, and groundwater chemistry and isotope analyses in sections of bore holes.

The important issues in the groundwater modelling for the performance assessment study of SFR is the amount of water that flows through the storage caverns and the silo together with the possible retention and adsorption in the rock mass, i.e. the flow paths from the repository parts. Thus, the most important type of information is the inflow measurements made in different parts of SFR. The groundwater chemistry may be used to understand the flow pattern and mixing of water with various origin such as fresh groundwater, saline rock/fracture groundwater and Baltic Sea water, especially to predict breakthrough time for the Baltic Sea water at different bore hole sections in fracture zones.

The report discusses especially the availability and evolution of inflow and chemical data within different parts of the SFR facility. Estimated errors in the flow measurements are also discussed. It is recommended that the inflow measurements to be used in the groundwater flow modelling is inflow to the BMA storage cavern, inflow to the other storage caverns and nearby tunnel systems, total inflow to the silo and total inflow to SFR. A steady state model should be calibrated on the latest measurement values, with the given accuracy for the respective stations.

The chemistry data can be used to calibrate time for breakthrough of Baltic Sea water in the groundwater flow modelling. The construction work started in autumn 1983 and the underground excavations were completed by May - June 1986. The first breakthrough occurred in a bore hole in Zone 8 about 10 - 22 months after completion. The second breakthrough occurred in a bore hole in Zone 3 about 67 - 72 months after completion.

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1 BACKGROUND

The final repository for low and intermediate radioactive waste, SFR, is located below the Baltic offshore of the nuclear power plant at Forsmark. Pre-investigations from platforms at sea for the siting of the facility was started in 1980, and the actual construction work was ongoing from the autumn 1983 until June 1986. During this period a number of various geo-scientific investigations were performed and used to build a conceptual model of the fracture system around SFR. The conceptual model formed the basis for hydraulic modeling that gave input to a performance assessment study of the SFR facility, which was reported by SKB in September 1987 (SKB, 1987). The application for a permit was accepted by the authorities with some restrictions, as for instance the incorporation of a control program, and the facility was taken in operation in April 1988. An updated performance assessment study, based on the experience from three years of operation, was reported by SKB in May 1993 (SKB, 1993). A brief review of the conceptual model and the control program was performed by Axelsson et al. (1995). One of the findings was that there were uncertainties in the official conceptual model of the fracture system and that there existed other possible interpretations.

The current operating permit for SKB stipulates that the safety assessment is updated at least every ten year. In response, SKB has started the SAFE project which aims at submitting a complete revised safety analyses before or during the year 2000. The current report is part of the far-field analyses in SAFE and provides information that can be used in a revised hydrogeological modelling of the facility.

2 SHORT HISTORY OF SFR

Pre-investigations for the SFR facility started in 1980. Five bore holes (Kb1-5) were drilled from a platform at sea and tested hydraulically and groundwater samples were taken during the summer and autumn 1981. The construction of the SFR facility started in the autumn 1983 and was finalised in May/June 1986. During this period various parts of SFR, like access tunnels, rock caverns and silo, were blasted. The operation of SFR started in April 1988.

Intense measurements were made during the construction, and a measurement program started in January 1985. Most measurements concerned groundwater pressure, but some inflow measurements were also made. The measurement program can be devided into measurements during construction and measurements during operation, i.e. the ongoing control programme. The measurements made during the construction phase are influenced by the activities within SFR. This is especially shown by the decrease of the groundwater head from about +500 m (mean sea level) to some "steady state" value, depending on the location of the measurement point (Appendix A). It is seen that the major pressure drop takes place during the construction phase.

3 SCOPE OF WORK AND EXECUTION

The scope of work for the present study is to create a set of different types of data, that can be used to calibrate and validate numerical groundwater flow models.

The work is based on the findings of the former review by Axelsson et al. (1995). This report is based on material collected during the construction of the SFR facility up to 1988 and thereafter on the control program for SFR presented in yearly reports up to 1992. In the present study, this information has been updated with new information from the following SFR yearly reports between 1993 and 1996.

- SFR - Kontrollprogram för driftskedet. Årsrapport för 1993 (Anläggningar PM 12-94, A4324/SQ-653, 1994-04-28)
- SFR - Kontrollprogram för driftskedet. Årsrapport för 1994 (Anläggningar PM 95/13, A4324/SQ-653, 1995-04-28)
- SFR-1 - Kontrollprogram för driftskedet. Årsrapport för 1995 (Anläggningar PM 96/12, SQ-653, 1996-04-19)
- SFR-1 Kontrollprogram för driftskedet. Årsrapport för 1996 (Anläggningar PM 97/20, SQ-653, 1997-03-26)

4 AVAILABLE INFORMATION

Information have been collected mainly during the construction phase (1983 - 88) and the operation phase (from 1988) of SFR. The specific information that can be used to calibrate and validate numerical models are as follows:

Construction phase

- Pressure responses at different bore holes when pumping in one bore hole at 11 interference tests (Axelsson et al., 1995 and Axelsson and Hansen, 1997).
- Groundwater pressure (not corrected) in sections in 22 bore holes (Axelsson et al., 1995, Appendix A).
- Inflow to different parts of the SFR facility (Axelsson et al., 1995, Appendix A).
- Groundwater chemistry in sections in 11 bore holes and isotope analyses in sections in 5 bore holes (Axelsson et al., 1995, Appendix A).

Operation phase - Control program

- Groundwater pressure (corrected) in sections in 12 bore holes (Axelsson et al., 1995, Appendix B).
- Inflow to different parts of the SFR facility (Axelsson et al., 1995, Appendix B).
- Groundwater chemistry in one section in 4 bore holes (campaign measurements in all available bore holes,13 and 17, in 1992 and 1995) and isotope analyses (1992 and 1995) in sections in 13 and 17 bore holes respectively (Axelsson et al., 1995, Appendix B).

The measured groundwater pressure is converted to groundwater head in a local co-ordinate system, which is related to the RAK RH70 co-ordinate system by the formula (according to SKB):

$$Z_{RH70} = Z_{Local} - 500 \text{ (m)}$$

The evolution of the local groundwater head from the early construction phase is shown in Appendix A for some chosen bore hole sections. The mean sea level in the local co-ordinate system is about +500 m. The measured groundwater pressure data were not corrected during the construction phase. During the operation phase, the pressure data are corrected for drift in 0-point and amplification. This cause a difference in head for a given bore hole section between data collected before and after August 1988 (start of the control program). From August 1988 to December 1989 both corrected and not corrected pressure data are available. The largest difference amounts to 3 - 3.5 m in HK1 (Singö zone). For most of the bore hole sections the correction amounts to about 0 - 0.5 m (Axelsson et al., 1995).

5 CHOISE OF DATA

5.1 PHILOSOPHY

The important issues in the groundwater modelling for the performance assessment study of SFR is the amount of water that flows through the storage caverns and the silo together with the possible retention and adsorption in the rock mass, i.e. the flow paths from the repository parts. Thus, the most important type of information is the inflow measurements made in different parts of SFR. The groundwater chemistry may be used to understand the flow pattern and mixing of water with various origin, such as fresh groundwater, saline rock/fracture groundwater and Baltic Sea water, especially to predict breakthrough time for the Baltic Sea water at different bore hole sections in fracture zones.

Pressure responses in different bore holes at the performed interference tests could be used for calibration and validation. However, this information is rather subjective and is better used in building the conceptual model of the hydrogeological system.

The groundwater pressure measurements are only point measurements within a narrow section of a bore hole and can vary over short distances. The groundwater pressure decreases towards the tunnels, rock caverns and the silo in the SFR facility, which drains the rock. The pressure distribution around the facility depends on the hydraulic properties and the connectivity of the fracture system. Some examples of the pressure distribution within the SFR facility is given in Appendix A. Most of the groundwater pressure data gathered at the SFR site appear either to be irrelevant for the modelling problem or too uncertain. Due to the probable difference in scale between the point measurements of hydraulic head and the scale of the modelling approaches, a calibration/validation against head measurements can only be recommended for some proper spatial averages of these measurements.

The pressure measurements are therefore rather used subjectively, together with information on hydraulic conductivity and chemistry, for the interpretation of major conductive fracture zones in building the conceptual model than in the calibration and validation of models. However, the models should predict the overall pressure conditions within the rock mass and main fracture zones around the SFR facility.

Given the complex history of the SFR site and the heterogeneity of the structural and hydrogeological conditions, the above points imply that only a subset of the measured data are likely to be useful for calibration and validation of numerical models. The data most suitable appear to be:

- the inflow to different parts of the SFR facility, perhaps divided into a few distinct stages of the repository construction, and

- the time for breakthrough of salt-water from the Baltic Sea in different fracture zones.

5.2 INFLOW DATA

5.2.1 Measurements

Some measurements of inflow to different parts of the SFR facility and estimates of total inflow were made during the construction of SFR (Axelsson et al., 1995, Appendix D:1-3).

Within the present control program, inflow is measured four times per year at 11 places within the SFR facility. Each measurement station represent the inflow to a specific part of SFR (Figure 1). Inflow measurements are made at the following stations with the associated part of SFR:

01A	Walls and roof of cavern BMA
01B	Floor of cavern BMA
31B	Rock caverns (BMA, BLA, BTF), rock cavern tunnel (BST), central tunnel (CT), maintenance building (UB), minor tunnels (DB, 3VB, EB and part of ST)
05A	Loading building (IB), parts of building tunnel (BT) and minor tunnel (ST)
05B	NE part of loading building (IB)
06	NE half of silo roof
07	SW half of silo roof
V11-18	Silo wall
G19-30	Silo bottom
08	Operation tunnel (DT), building tunnel (BT), transverse tunnel (TT), Silo tunnel (STT) and a minor tunnel (2VB)
32B	Operation tunnel (DT), building tunnel (BT), transverse tunnel (TT), Silo tunnel (STT) and a minor tunnel (2VB), lower building tunnel (NBT), minor tunnels (SBT, SDT, FS), water storage basin (NDB), Silo (S), loading building (IB), parts of building tunnel (BT) and minor tunnel (ST)

The total groundwater inflow to SFR is composed of the measured flows at the stations 31B and 32B. The measurement program with a description of the measurement stations and measurement techniques is described in Axelsson et al. (1995, Appendix B).

5.2.2 Results

All basic measurements and calculations of flow are presented in Appendix B. Since the regular measurements (4 times per year) started in 1992, there has been a slightly decreasing trend in all inflow measurements (Figure 2 and Figure 3). The total inflow to SFR has decreased from a mean value in 1992 of 565 l/min to 483 l/min in 1996, which is a about 15%. The inflow to the entrance tunnels (DT, BT, TT, STT and 2VB), measured at the Thompson weir, has decreased during the same period from 419 to 375 l/min (11%). The major source of water is the Singö zone, but the tunnels also cross the zones 3, 6 and 9 and the schistosity through the silo. The inflow to the loading building and minor tunnel parts (IB, BT, ST) has decreased from 10.6 to 6.0 l/min (43%). The total inflow to the silo has decreased with about 25% from 2.1 to 1.6 l/min. The main cause is a reduction in inflow at the silo walls and silo top of 0.3 and 0.2 l/min respectively. The inflow at the silo bottom has almost ceased. The inflow to the middle active waste cavern BMA has decreased with about 21% from 11.8 to 9.3 l/min. The inflow to the other storage caverns (BLA and BTF) and surrounding tunnels has decreased from 98.2 to 83.6 l/min (15%).

5.2.3 Uncertainties

The errors in connection to the flow measurements have been discussed by Axelsson et al. (1995). The estimated errors for the different measurement stations are as follows:

01A + 01B	ca. 1 l/min (1 cm)
31B	ca. 20 l/min (1 cm + variation in area)
08	ca. 10-20 l/min (1-2 mm) (various changes to the Thompson weir has been made; new construction winter 1991-92, new measurement ruler July 1994)
05A+ 05B	ca. 0.5 l/min (1 cm)
06 + 07	ca. 0.01-0.02 l/min (10%)
V11-18	ca. 0.1-0.2 l/min (10%)
G19-30	ca. 0.0001-0.0002 l/min (10%)
32B	ca. 20 l/min (1 cm + variation in area)

The estimated error in the measurements of groundwater inflow is in the order of 10% (Axelsson et al., 1995). This is crucial especially when measuring the major integrated inflows at the stations (basins) in the maintenance building (UB) and the lower building tunnel (NBT), which constitutes the total inflow to SFR. The integrated flow in the operation tunnel (DT), building tunnel (BT), transverse tunnel (TT) and some minor tunnels is measured with a Thompson weir at the station 08. This is the second largest measured inflow, next to that measured in the basin NBT, and is probably more accurate than those measured in the basins NBT and UB. Due to the relatively large errors in the flow measurements in the basin NBT, the difference in measured flows at the basin NBT and the Thompson weir gives a poor estimate of the groundwater inflow in the tunnel system (NBT, SBT, SDT and FS) between those two stations. This is illustrated by the fact that the difference in measured inflow in the basin NBT and at the Thompson weir is very small (some l/min) and even negative at two measurement dates (Appendix B).

5.3 CHEMISTRY DATA

Representative results from groundwater samples taken during the pre-investigation phase are shown in Table 1. The water samples from interpreted major fracture zones show a higher content of chloride, calcium and potassium than the rock mass and the Baltic.

Table 1 *Representative values of chloride, calcium and potassium in bore holes Kb1-5 drilled from the sea during the pre-investigation phase (results from Hagconsult, 1982).*

Borehole	Length From (m)	To (m)	Depth From (m a.s.l.)	To (m a.s.l.)	Interpreted zone	Date	Cl (mg/l)	Ca (mg/l)	K (mg/l)
Kb1	61	64	439	436	-	1981-07-25	3020	640	7.5
	70	73	430	427	-	1981-07-30	3100	647	9.3
Kb2	55	58	452.4	449.8	-	1981-08-20	1440	339	4.7
	73	76	436.8	434.2	-	1981-08-20	1375	296	5.1
Kb3	71	80	438.5	430.7	-	1981-09-14	4310	825	14
Kb4	141	159	380.4	365.2	H2	1981-10-06	3640	650	13
Kb5	85	88	438.8	436.6	-	1981-10-29	2700	620	7.7
	136	139	402.1	399.9	H2	1981-10-29	4360	870	11
	178	181	371.8	369.7	8	1981-11-19	3720	896	9

In the control program, water samples for chemical analysis are taken twice a year in four bore holes; HK1:P1, HK7a:P1, HK8:P1 and HK10:P1 (Figure 4, Figure 5 and Figure 6). However, the water sampling has been reduced to once a year from 1997. A comparison has been made of the evolution of chloride, calcium and potassium in the bore holes with the Baltic water. The analyses of water samples taken during the construction phase are also included. The bore holes penetrate different fracture zones and the evolution of the chemistry reflects how the groundwater flow in the fracture zones react on the drainage of the rock due to the SFR facility. The evolution of salinity (chloride) in the different bore holes (fracture zones) can be explained as follows.

HK1 - Singö zone: The bore hole penetrates the conductive Singö zone, which shows a stable composition with a week decrease in salinity (Figure 7). This can be explained by the disturbance of the tunnel either by a very small contribution of fresh groundwater or by a somewhat bigger contribution of Baltic Sea water or both. The increased tritium content indicate that the contribution of Baltic Sea water increases. However, the amount of potassium and calcium shows that the water is affected by ion exchange reactions with the rock. The contribution of Baltic Sea water can be estimated to about 25 to 75%.

HK7a - Zone H2: The bore hole penetrates the conductive zone H2 below the facility. The salinity was increased during the construction phase due to the inflow of deeper, more saline, groundwater (Figure 8). After 1989 the salinity is decreasing very slowly. This is probably due to the fact that the Baltic Sea water has started to intrude Zone H2 via Zone 8 (see below), which is indicated by an increase in tritium content. The amount of Baltic Sea water is however low, < 25%.

HK8 - Zone 8: The bore hole penetrates the conductive Zone 8, which is in contact with Zone H2. The intrusion of saline Baltic Sea water occurred already during the late construction phase (Figure 9). This is shown by a chloride, calcium and potassium content similar to the Baltic Sea water. The salinity has been stable and equal to the Baltic Sea water since the early operation phase. The tritium content indicates a 50 to 75% mixing of Baltic Sea water.

HK10 - Zone 3: The bore hole penetrates the conductive Zone 3. The salinity decreased during the construction phase to a steady state condition in the beginning of the operation phase in 1988 (Figure 10). This condition is stable until January - June 1992, when the chloride, calcium and potassium content suddenly becomes equal to the Baltic Sea water. This can be explained by the fact that the Baltic Sea water has intruded the rock down to the level of HK10, and that no mixing with deeper groundwater with higher salinity takes place. The quotient of sodium to calcium as well as the tritium content indicates a mixing of 75 to 100% of Baltic Sea water. The late intrusion of Baltic Sea water is in good agreement with a lesser hydraulic conductivity in the vertical direction than in the horizontal direction in Zone 3. When pumping the bore hole HK9 no pressure drop was registered in bore hole HK10 at a vertical distance of 35 - 70 m and vice versa, which indicates a low vertical hydraulic conductivity. However, when pumping bore hole SH3 about 230 m from HK9 and HK10 both bore holes registered a pressure drop.

6 RECOMMENDATIONS

The inflow measurements that are recommended to be used in the groundwater flow modelling is inflow to the storage cavern for intermediate radioactive waste (BMA), inflow to the other storage caverns and nearby tunnel systems (BLA, BTF, BST, CT, DB, UB, 3VB, EB and ST), total inflow to the silo and total inflow to SFR. A steady state model should be calibrated on the latest measurement values, with the given accuracy for the respective stations.

The chemistry data can be used to calibrate time for breakthrough of Baltic Sea water in the groundwater flow modelling. The construction work started in autumn 1983 and the underground excavations were completed by May - June 1986. The first breakthrough occurred in bore hole HK08 in Zone 8 between 15th August 1987 and 11th August 1988, i.e. about 10 - 22 months after completion. The second breakthrough occurred in bore hole HK10 in Zone 3 between 10th January and 29th June 1992, i.e. about 67 - 72 months after completion.

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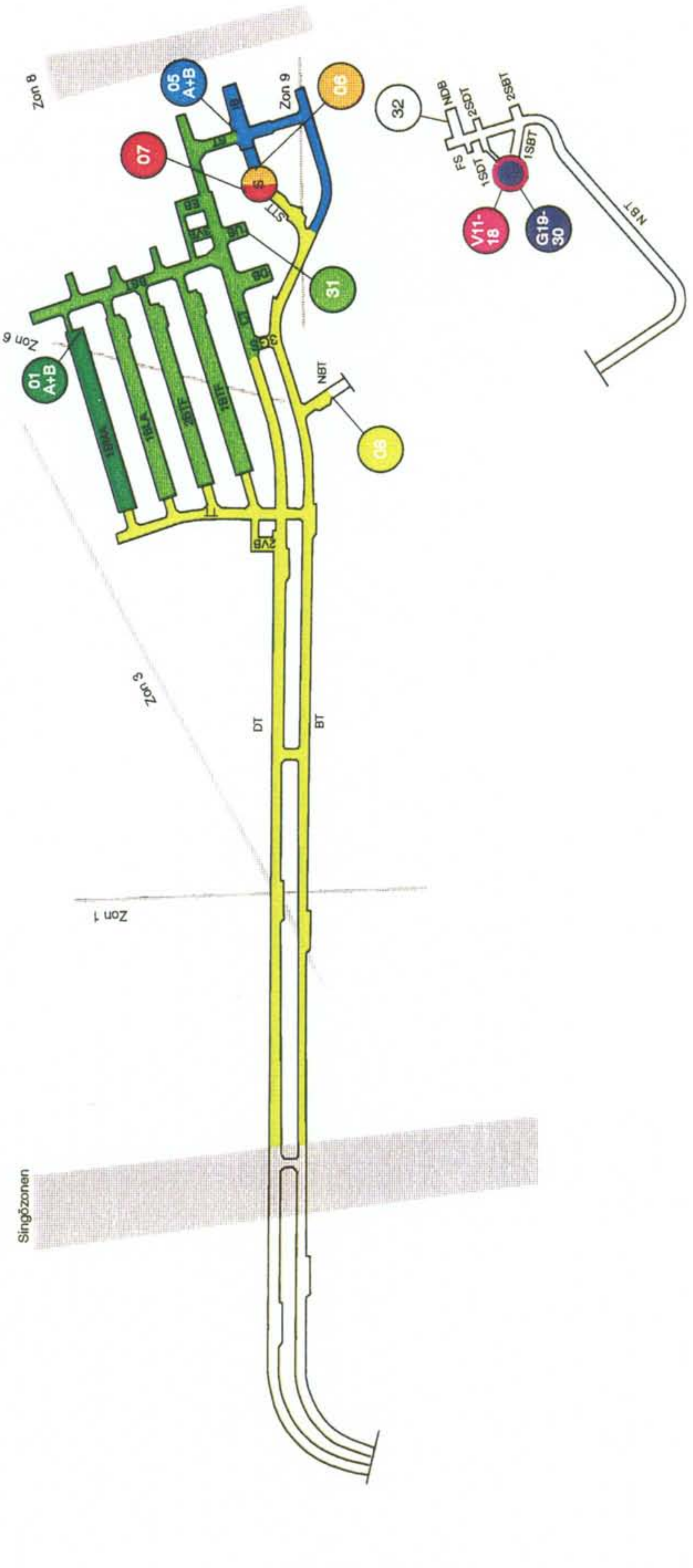


Figure 1 *Measurement stations for groundwater inflow with associated parts of SFR (modified from Vattenfall Energisystem AB, 1991, Appendix 1).*

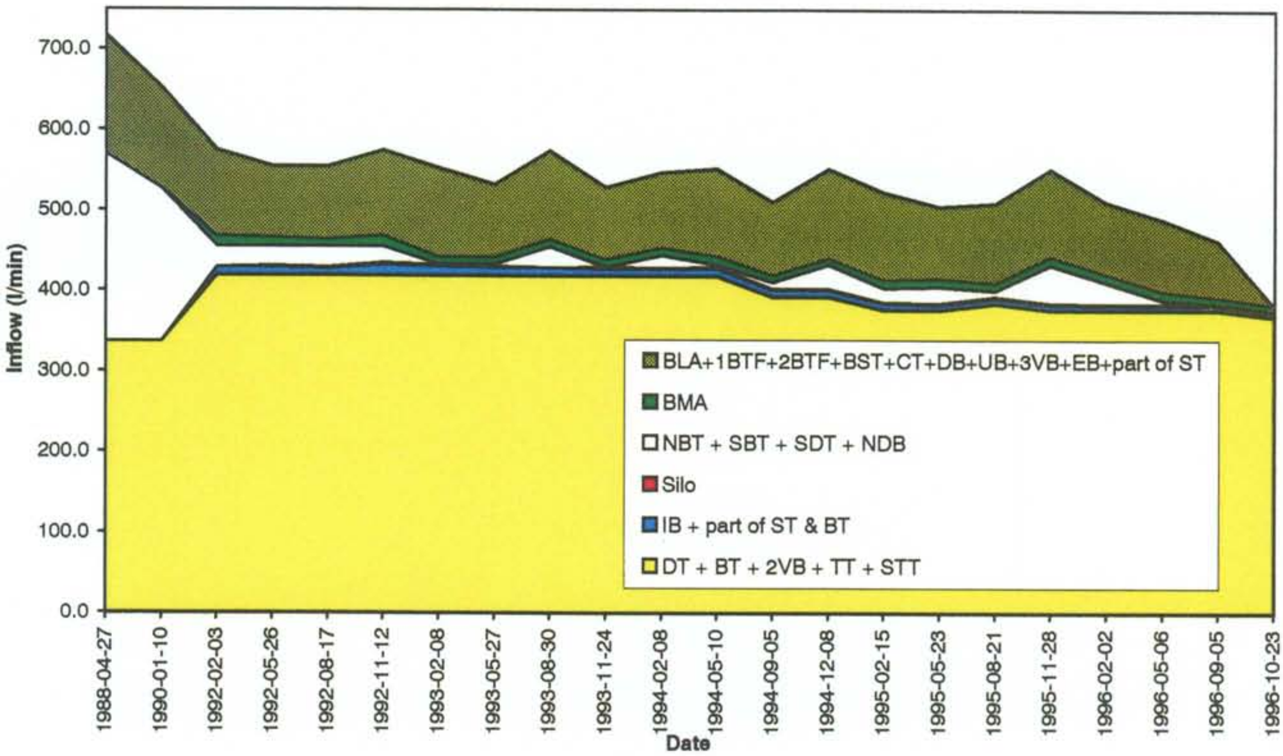


Figure 2 *Groundwater inflow to different parts of SFR.*

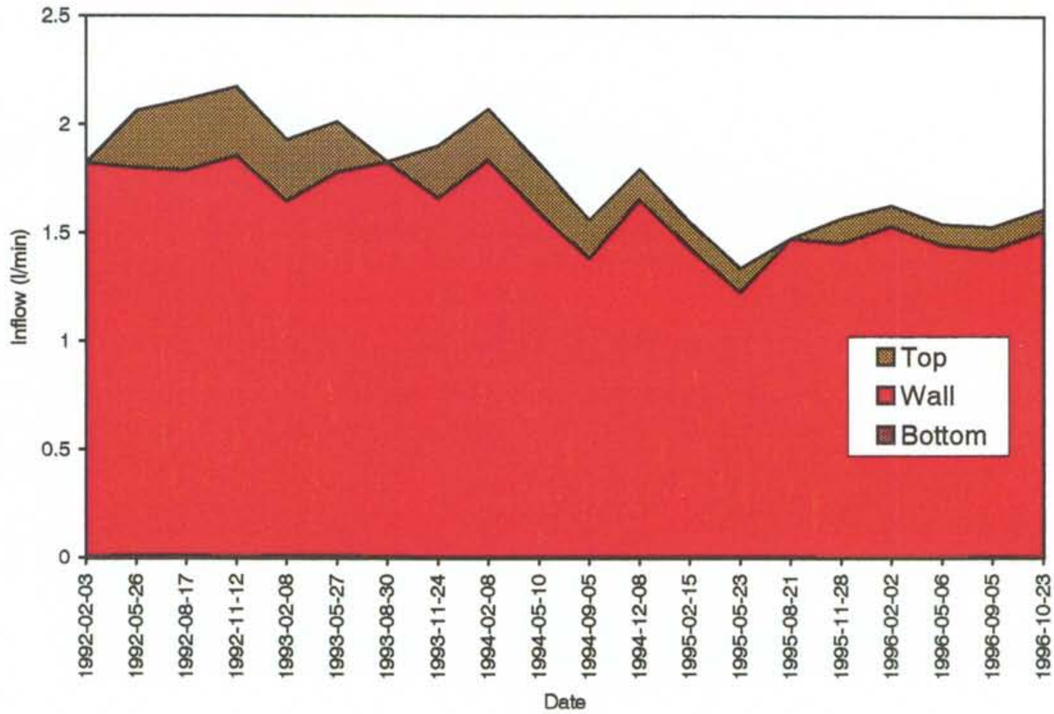


Figure 3 *Groundwater inflow to different parts of the silo.*

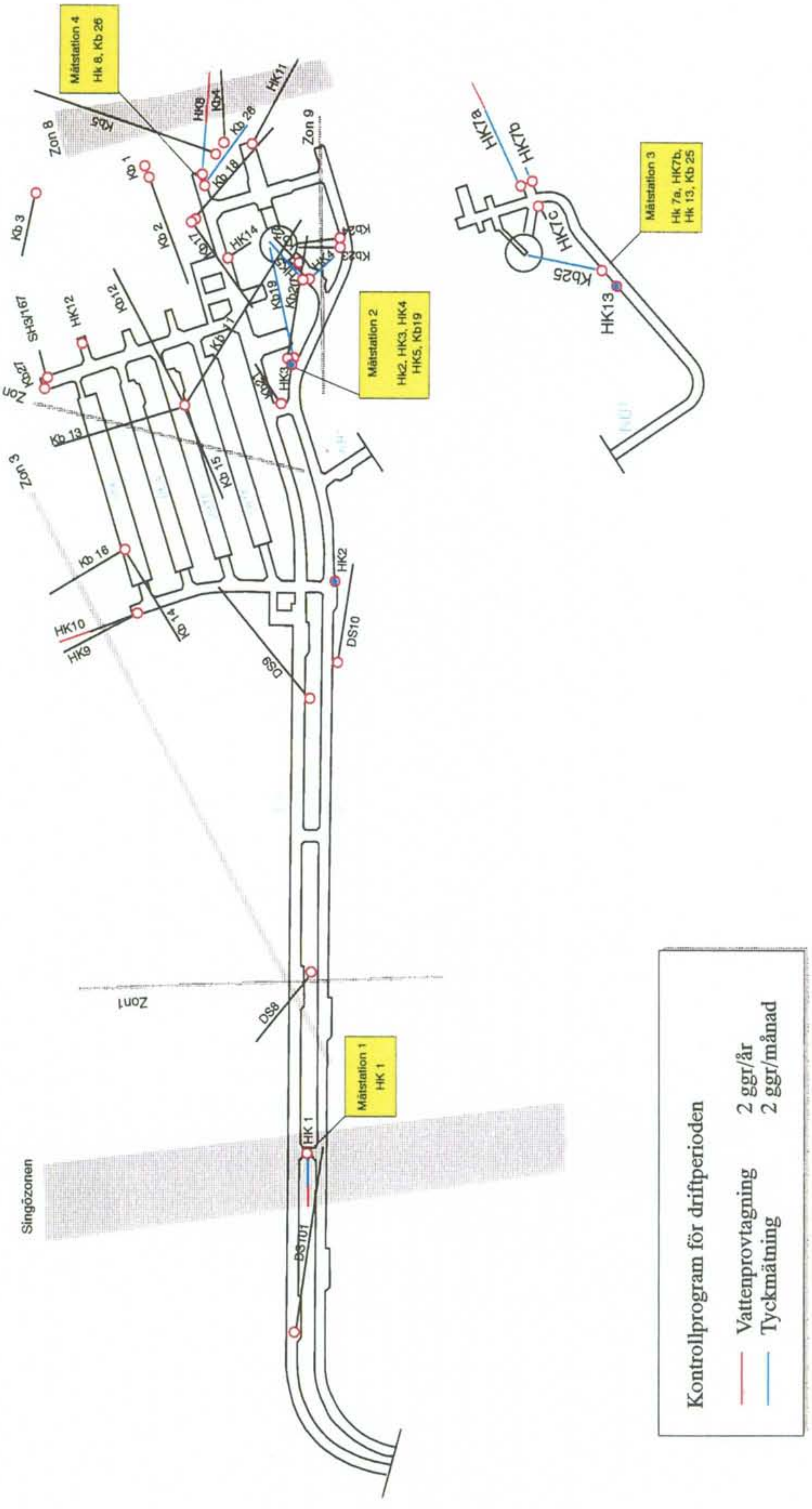


Figure 4 *Bore holes for measurement of groundwater pressure and water sampling at SFR1 (modified from Carlsson et al., 1987).*

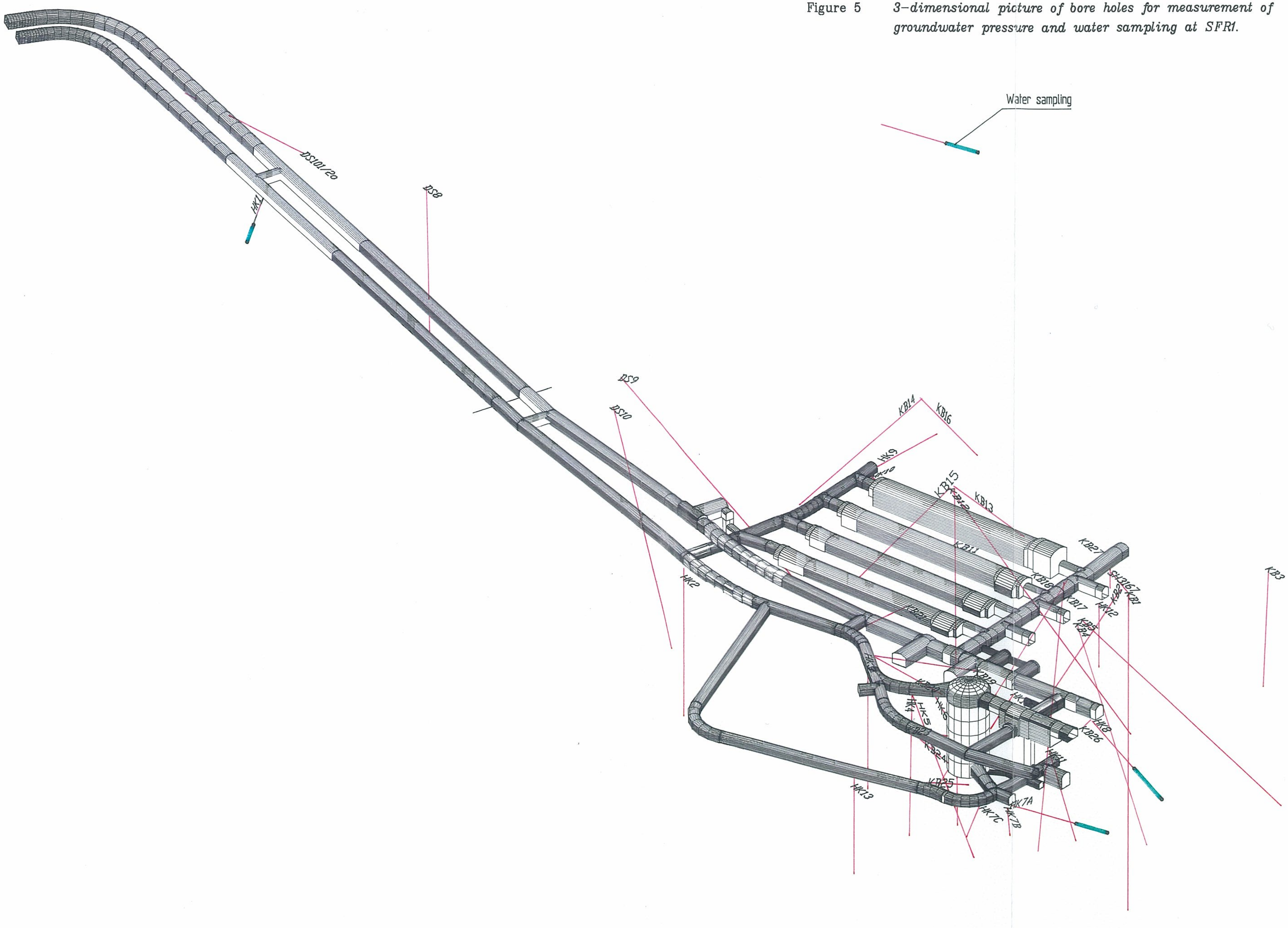


Figure 5 *3-dimensional picture of bore holes for measurement of groundwater pressure and water sampling at SFR1.*

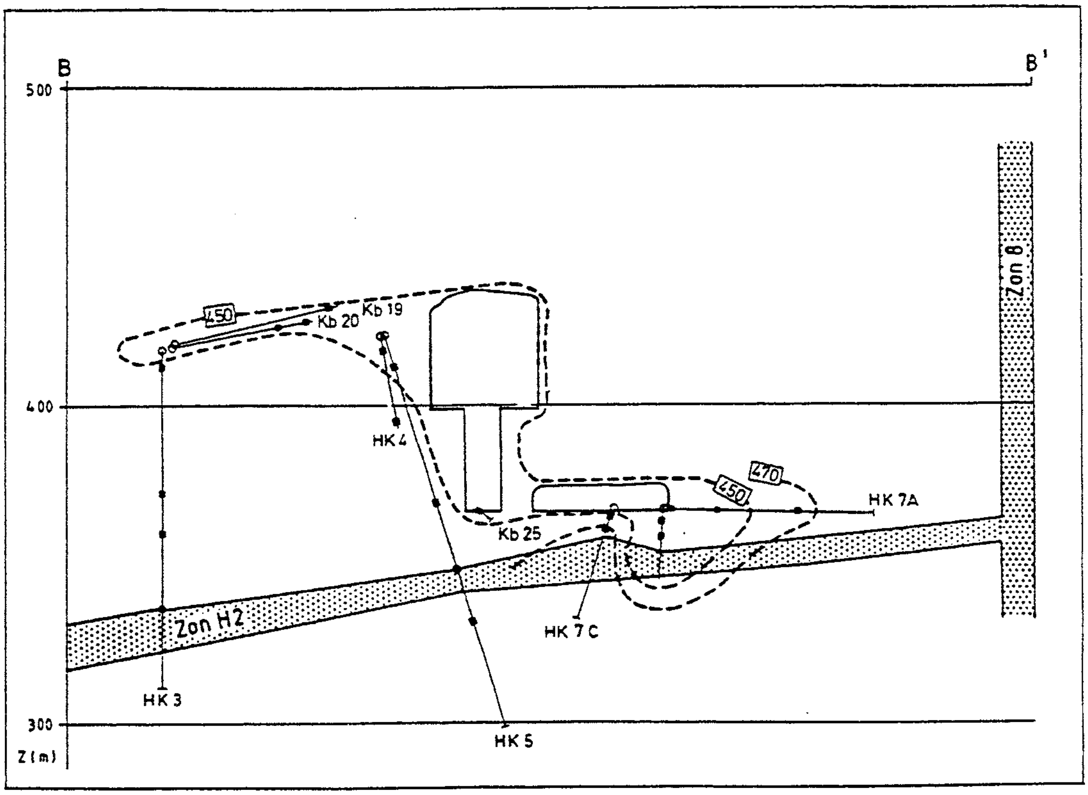


Figure 6 *Bore holes for measurement of groundwater pressure and water sampling at SFR1 in a NE-SW section through the silo (Carlsson et al., 1987).*

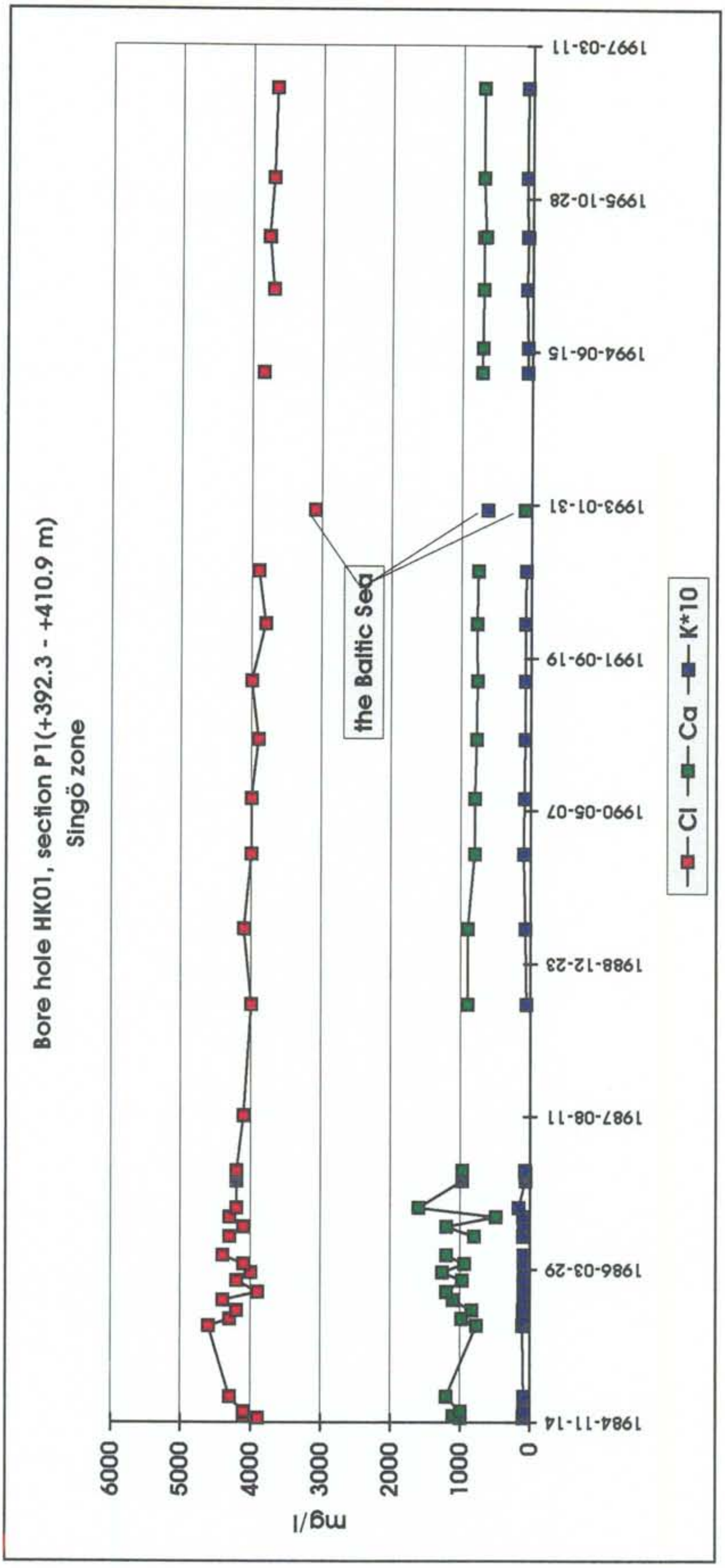


Figure 7 *Chloride, calcium and potassium content in bore hole HK01 in the Singö zone.*

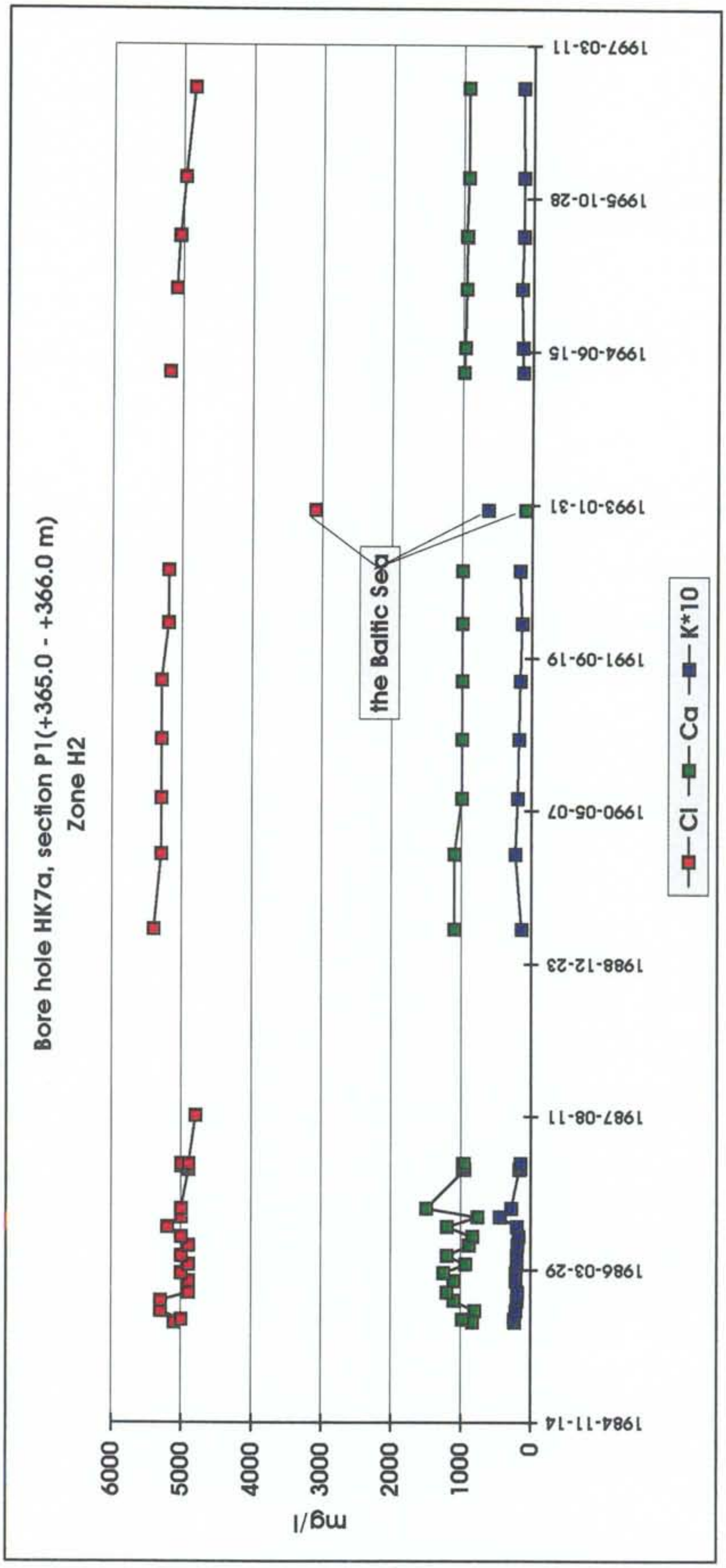


Figure 8 *Chloride, calcium and potassium content in bore hole HK7a in Zone H2.*

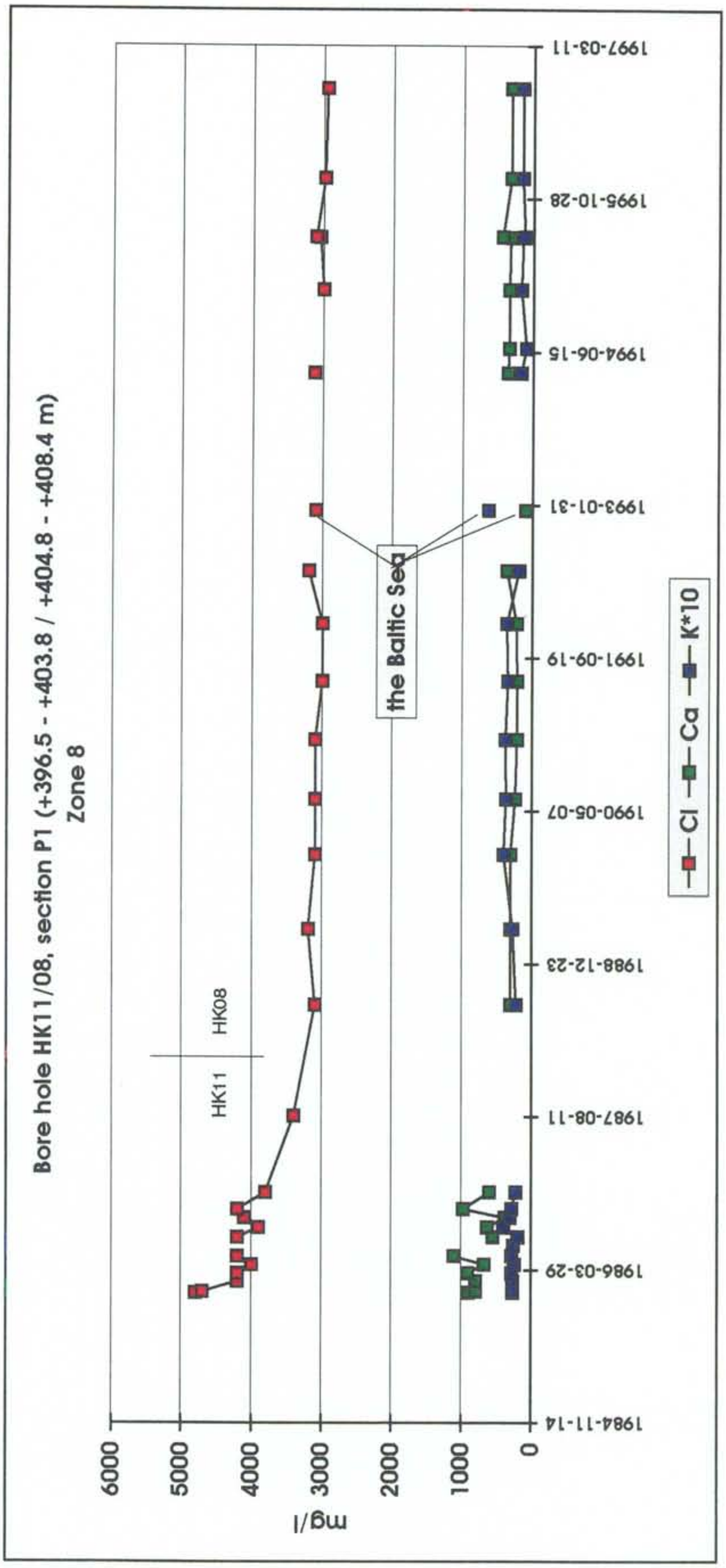


Figure 9 *Chloride, calcium and potassium content in bore hole HK11 and HK08 in Zone 8.*

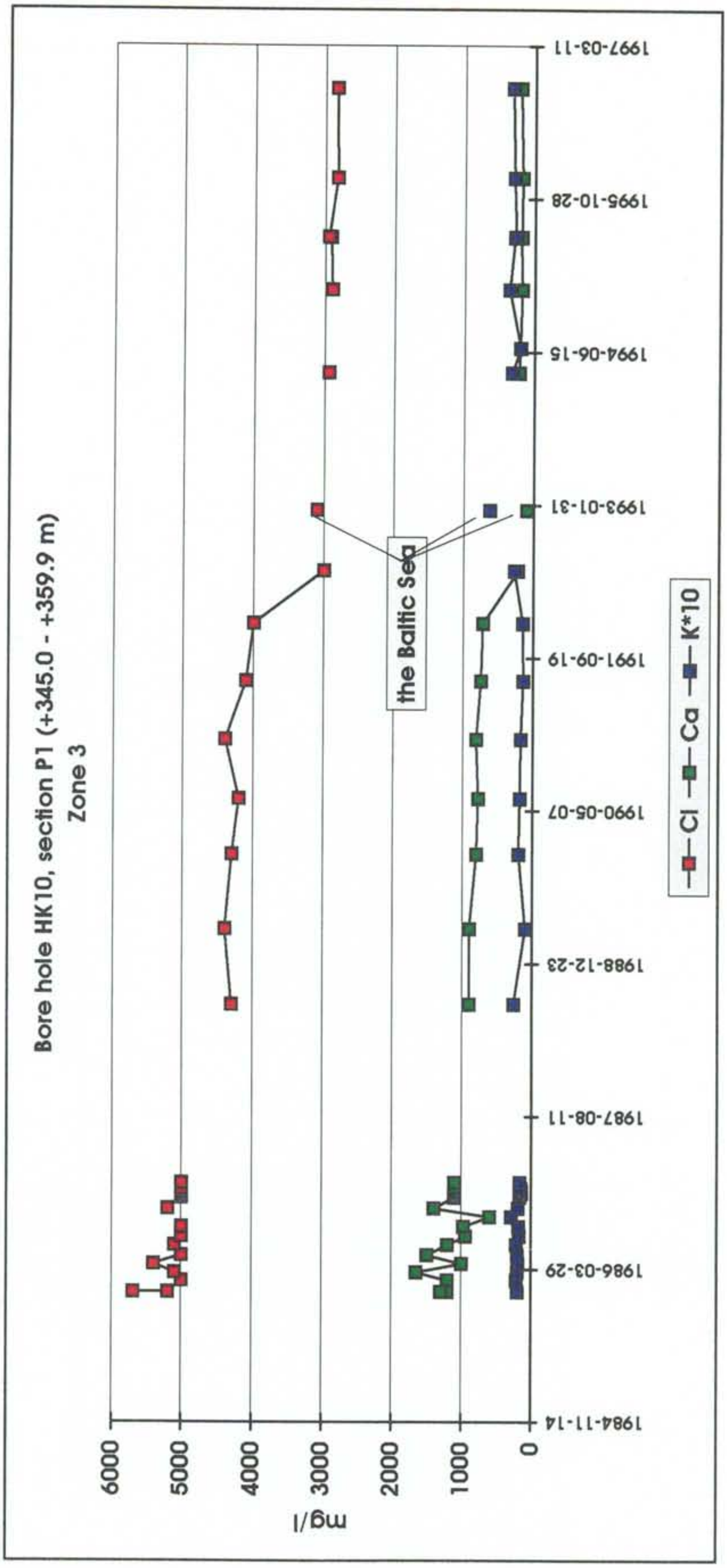


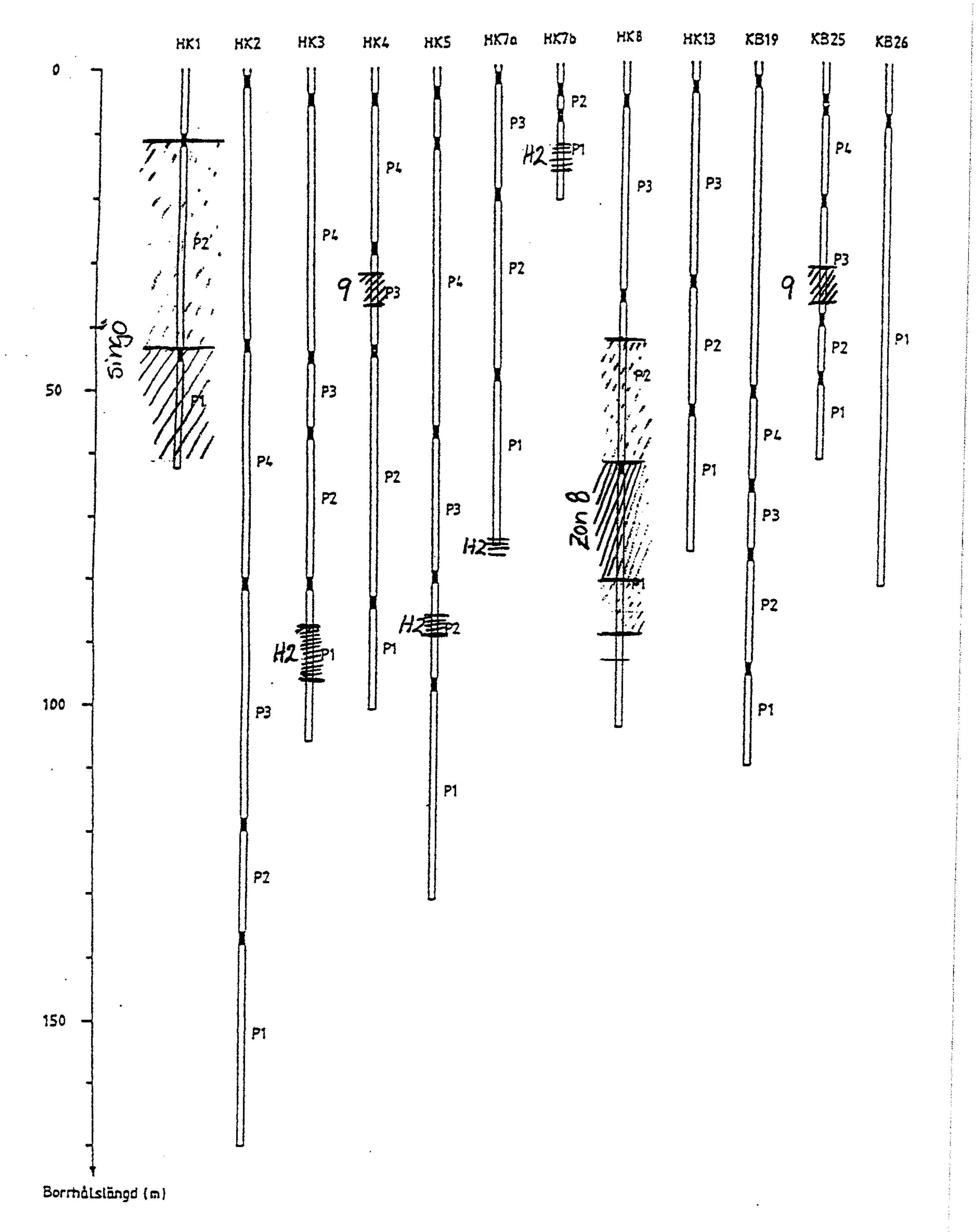
Figure 10 *Chloride, calcium and potassium content in bore hole HK10 in Zone 3.*

APPENDIX A

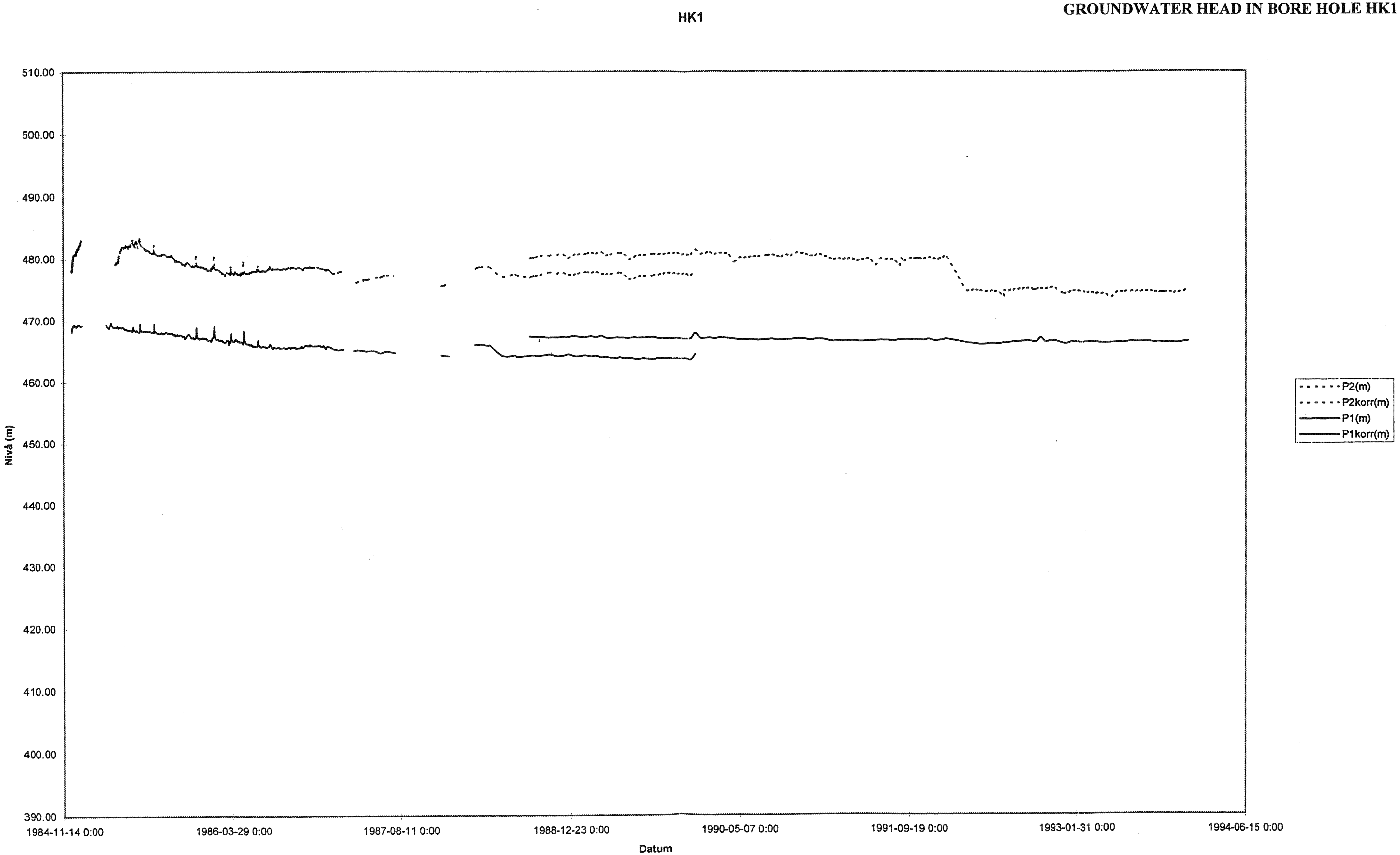
MEASUREMENTS OF GROUNDWATER HEAD AT SFR

Packer location, measurement sections and interpreted fracture zones in bore holes at SFR

(modified from SKB, 1990)

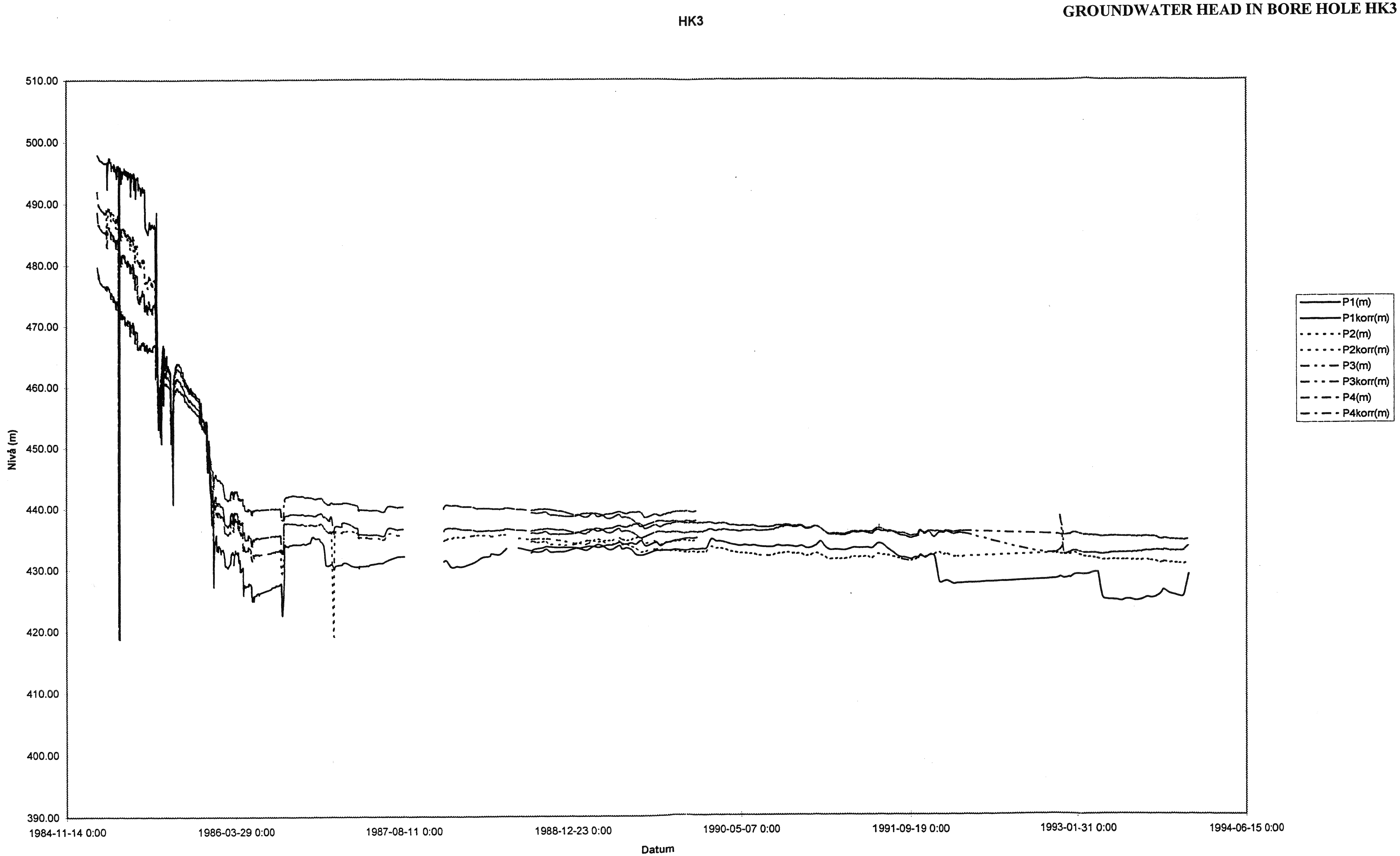


CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE HK1



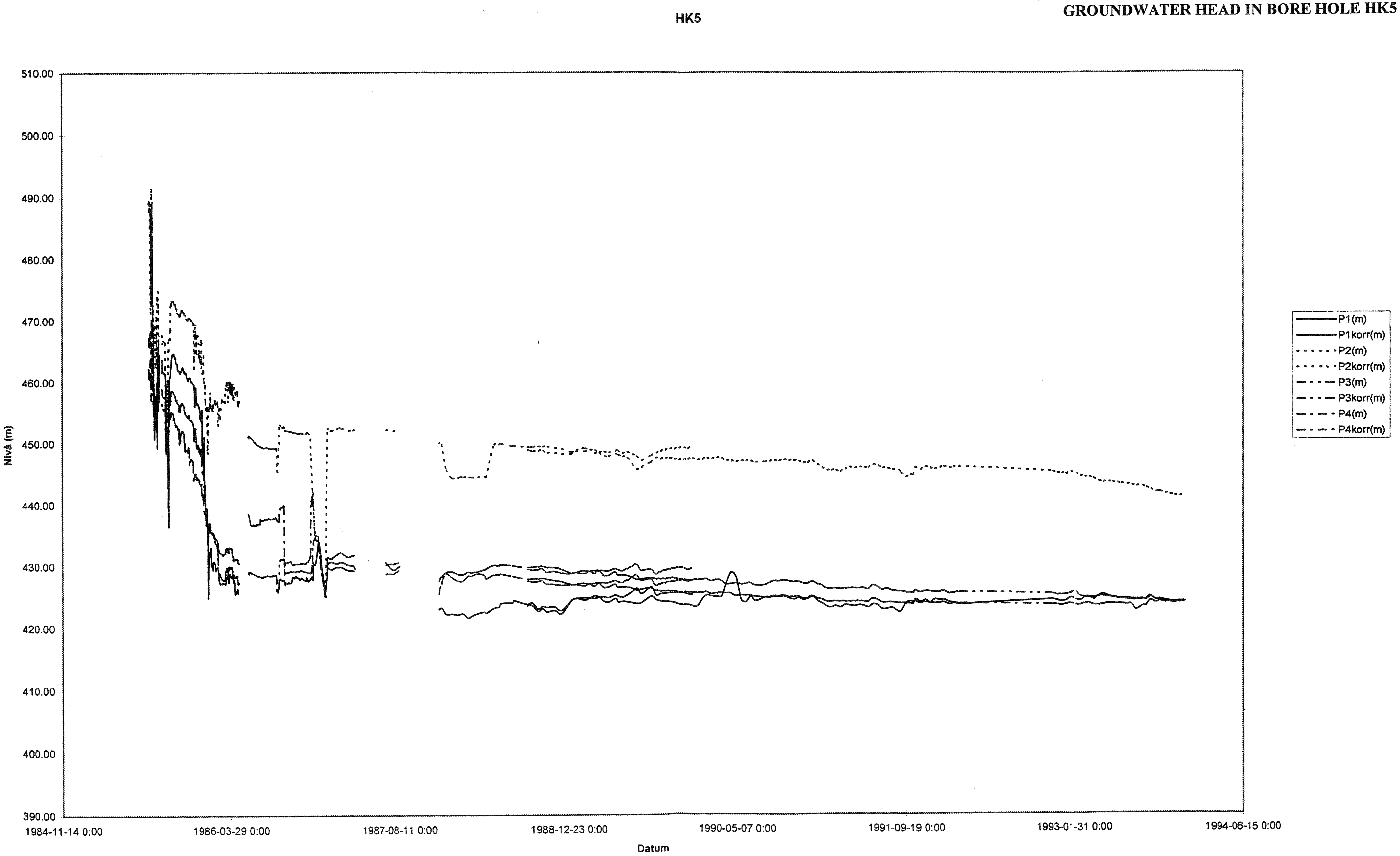
Appendix A:3

CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE HK3

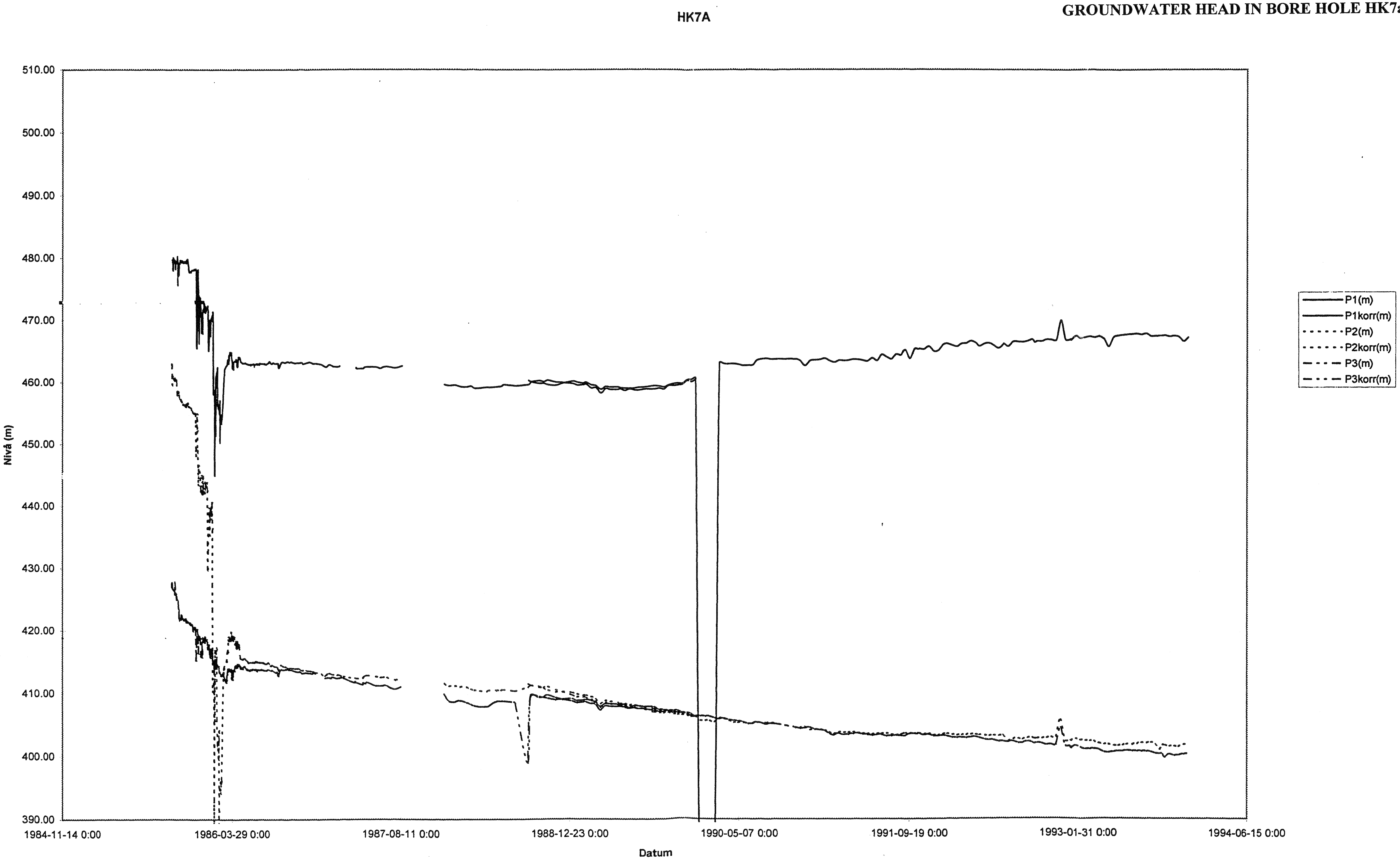


Appendix A:4

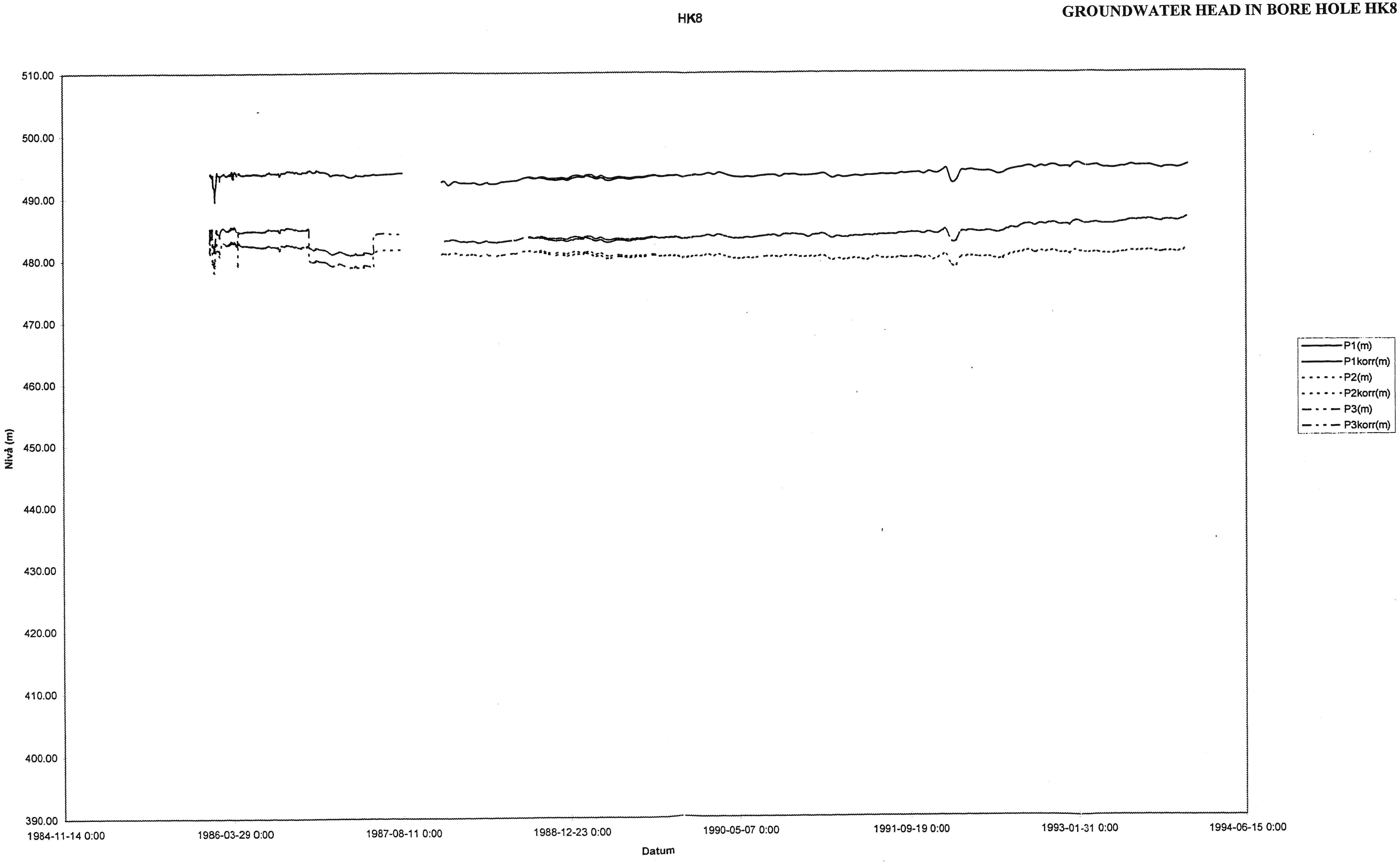
CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE HK5



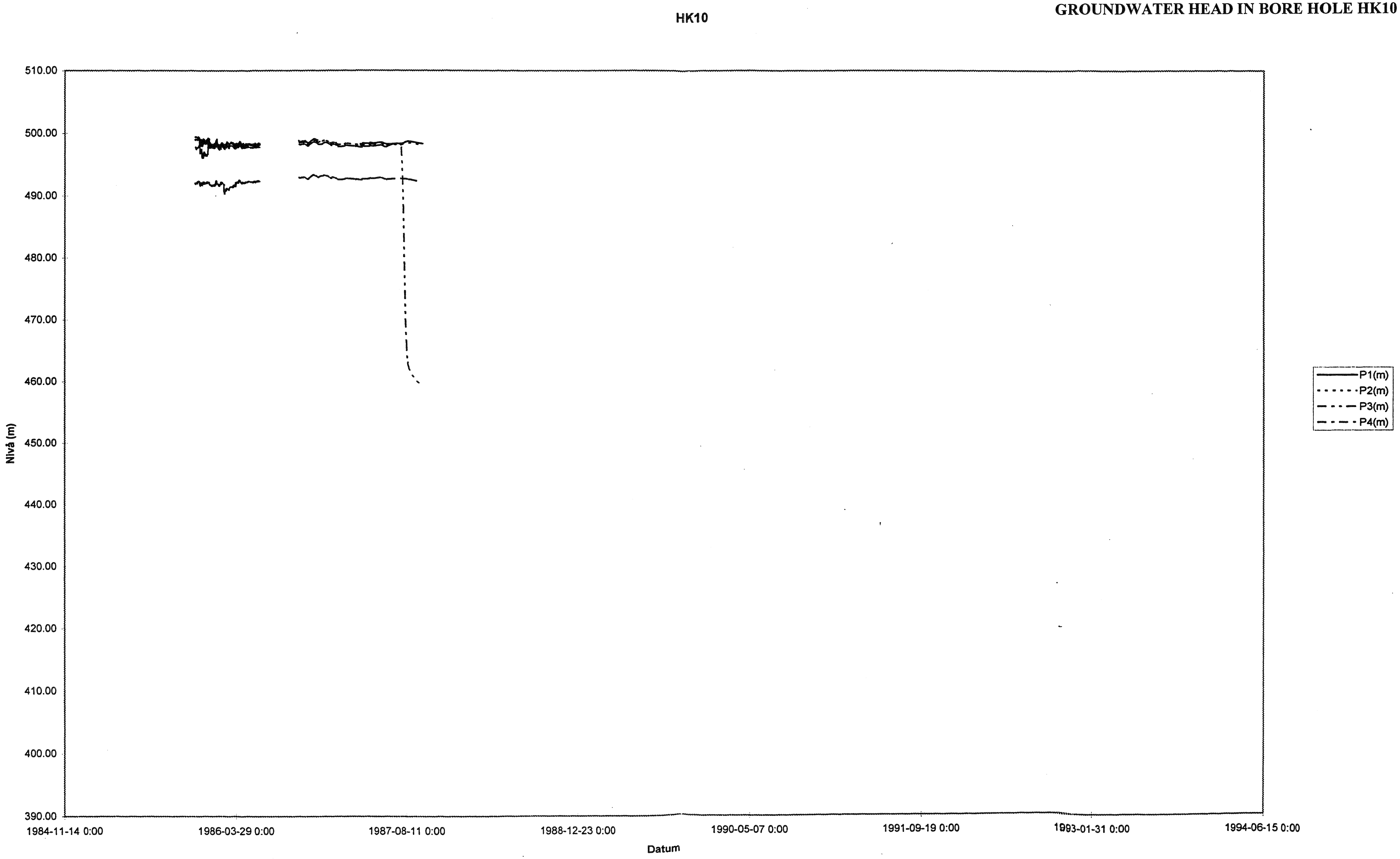
CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE HK7a



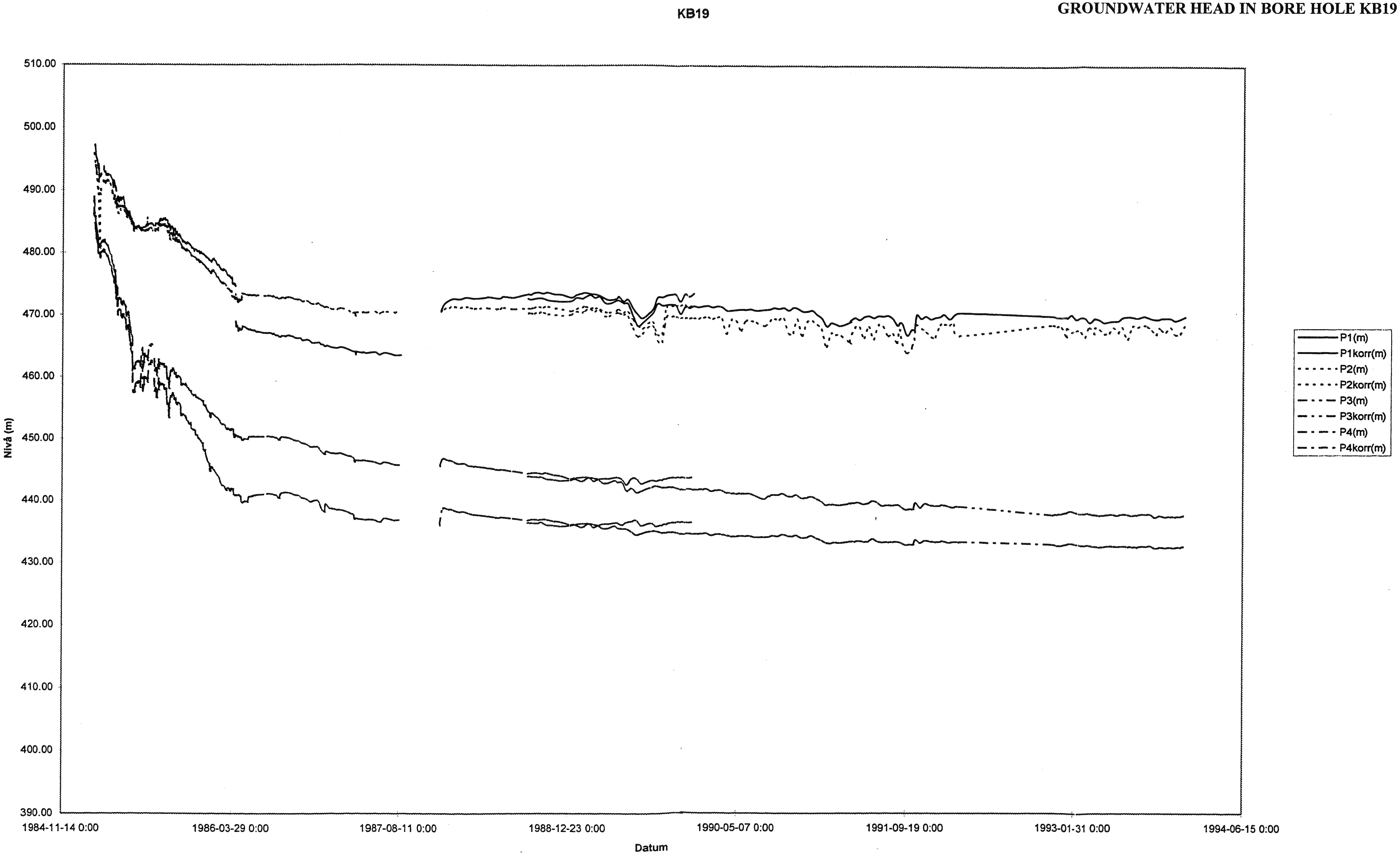
CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE HK8



CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE HK10



CONTROL PROGRAM - OPERATION PHASE
GROUNDWATER HEAD IN BORE HOLE KB19



APPENDIX B

MEASUREMENTS OF GROUNDWATER INFLOW AT SFR

Measurements of groundwater inflow at SFR

Created 1995-01-14 - 02-02 by Golder Associates AB, Carl-Lennart Axelsson
Updated 1997-10-21 - 22 by Golder Associates AB, Carl-Lennart Axelsson

Part	Rock BMA			Cavern BMA			Total BMA	BMA+BLA+BTF+BST+CT +DB+UB+3VB+EB+prt ST			DT+BT+2VB+TT+STT		IB+part of ST and BT			IB	Total	Silo top at IB			Silo top at STT			Silo top	Silo wall	Silo bottom	
Place	Well BMA			Well BMA				Basin UB			Thompson weir NBT		Basin i ST			Well i IB	IB+p ST&BT	Pumppit silo top			Pumppit silo top				Tubes SDT	Tubes SDT	Total Silo
Station	01A			01B			01A+01B	31B			08		05A			05B	05A+05B	06			07			06 + 07	V11-18	G19-30	
Area (m^2)	1							240			0.014		0.56														
Date	Raise (m)	Time (min)	Flow (l/min)	Time (dagar)	Volume (m^3)	Flow (l/min)	Flow (l/min)	Raise (m)	Time (min)	Flow (l/min)	Level (cm)	Flow (l/min)	Raise (m)	Time (min)	Flow (l/min)	Flow (l/min)	Flow (l/min)	Time (dagar)	Volume (m^3)	Flow (l/min)	Time (dagar)	Volume (m^3)	Flow (l/min)	Flow (l/min)	Flow (l/min)	Flow (l/min)	Flow (l/min)
1986-11-15							20																				2
1988-03-29											11	***337.1***															
1988-04-27								0.424	690	147.5																	
1990-01-10								0.22	420	125.7	11	***337.1***															
1992-02-03	0.13	10	13			No meas	13.0	0.06	120	120	12	**419.0**	0.19	10	10.6	No measur	10.6	No measurement						No meas	No mea	1.81	0.0071	No measure
1992-05-26	0.11	10	11	146	3	0.0143	11.0	0.05	120	100	12	**419.0**	0.18	10	10.1	0	10.1	109	19	0.12	109	22	0.14	0.26	1.79	0.0087	2.06
1992-08-17	0.09	10	9	83	1.5	0.0126	9.0	0.05	120	100	12	**419.0**	0.15	10	8.4	0	8.4	83	17	0.14	83	22	0.18	0.33	1.78	0.0096	2.11
1992-11-12	0.14	10	14	87	3	0.0239	14.0	0.06	120	120	12	**419.0**	0.24	10	13.4	0	13.4	87	18	0.14	87	22	0.18	0.32	1.85	0.0069	2.17
1993-02-08	0.09	10	9	88	3	0.0237	9.0	0.06	120	120	12	**419.0**	0.21	10	11.8	0	11.8	88	17	0.13	88	19	0.15	0.28	1.64	0.0084	1.93
1993-05-27	0.09	10	9	108	4.5	0.0289	9.0	0.15	360	100	12	**419.0**	0.18	10	10.1	0	10.1	108	14	0.09	108	22	0.14	0.23	1.77	0.0078	2.01
1993-08-30	0.1	10	10	95	3	0.0219	10.0	0.06	120	120	12	**419.0**	0.18	10	10.1	0	10.1	95	No measure		95	26	0.19	No mea	1.82	0.0045	No measure
1993-11-24	0.1	10	10	86	4.5	0.0363	10.0	0.05	120	100	12	**419.0**	0.16	10	9.0	0	9.0	86	15	0.12	86	15	0.12	0.24	1.66	0.0042	1.90
1994-02-08	0.1	10	10	76	4.5	0.0411	10.0	0.13	300	104	12	**419.0**	0.15	10	8.4	0	8.4	76	12	0.11	76	14	0.13	0.24	1.83	0.0024	2.07
1994-05-10	0.1	10	10	91	3	0.0229	10.0	0.06	120	120	12	**419.0**	0.17	10	9.5	0	9.5	91	15	0.11	91	15	0.11	0.23	1.59	0.0030	1.82
1994-09-05	0.09	10	9	118	3	0.0177	9.0	0.05	120	100	11.7	393.3	0.16	10	9.0	0	9.0	118	21	0.12	118	9	**0.05**	**0.18**	1.38	0.0030	1.56
1994-12-08	0.08	10	8	94	6	0.0443	8.0	0.06	120	120	11.7	393.3	0.15	10	8.4	0	8.4	94	15	0.11	94	4	**0.03**	**0.14**	1.65	0.0030	1.80
1995-02-15	0.1	10	10	69	3	0.0302	10.0	0.09	180	120	11.5	376.7	0.15	10	8.4	0	8.4	69	10	0.10	69	2	**0.02**	**0.12**	1.43	0.0018	1.55
1995-05-23	0.1	10	10	95	2	0.0146	10.0	0.05	120	100	11.5	376.7	0.14	10	7.8	0	7.8	95	15	0.11	95	0	**0.00**	**0.11**	1.22	0.0024	1.34
1995-08-21	0.1	10	10	91	2	0.0153	10.0	0.11	240	110	11.6	385.0	0.13	10	7.3	0	7.3		Not functioning			Not functioning			1.47	0.0021	1.47
1995-11-28	0.1	10	10	98	3	0.0213	10.0	0.06	120	120	11.5	376.7	0.13	10	7.3	0	7.3	98	15	0.11	98	1	**0.01**	**0.11**	1.45	0.0009	1.57
1996-02-02	0.1	10	10	66	3	0.0316	10.0	0.05	120	100	11.5	376.7	0.12	10	6.7	0	6.7	66	9	0.09	66	0	**0.00**	**0.09**	1.53	0.0012	1.62
1996-05-06	0.1	10	10	93	1.5	0.0112	10.0	0.05	120	100	11.5	376.7	0.12	10	6.7	0	6.7	93	13	0.10	93	0	**0.00**	**0.10**	1.44	0.0003	1.54
1996-09-05	0.09	10	9	122	4	0.0228	9.0	0.04	120	80	11.5	376.7	0.1	10	5.6	0	5.6	122	18	0.10	122	0	**0.00**	**0.10**	1.42	0.0021	1.53
1996-10-23	0.08	10	8	48	0	0.0000	8.0	No measurement			11.4	368.6	0.09	10	5.0	0	5.0	48	7	0.10	48	0	**0.00**	**0.10**	1.51	0.0009	1.61
Mean 1992	(l/min)		11.8			0.0169	11.8			110.0		419.0			10.6	0.0	10.6			0.14			0.17	0.30	1.81	0.0081	2.12
Mean 1996	(l/min)		9.3			0.0164	9.3			93.3		374.7			6.0	0.0	6.0			0.10			0.00	0.10	1.47	0.0011	1.57
Difference	(l/min)		-2.5			-0.0005	-2.5			-16.7		-44.3			-4.6	0.0	-4.6			-0.04			-0.17	-0.20	-0.33	-0.0070	-0.54
Difference	(%)		21.3%			3.2%	21.2%			15.2%		10.6%			43.4%	0.0%	43.4%			27.1%			100.0%	67.3%	18.4%	86.1%	25.6%
	BMA							**Caverns+BST+CT+DB+ UB+3VB+EB+part of ST**			**DT+BT+2VB+TT+STT**		**IB+part of ST and BT**					**Silo**									
	Zone 6							**Zone 6 + Schistosity**			**Singö + Zone 3, 6 & 9 + Schistosity**		**Zone 9 + Schistosity**					**Schistosity**									

Bold = uncertain values
Bold/italic = wrong values

DT+BT+2VB+TT+STT+ NBT+Silo+(IB+p ST&BT)																							
Basin NDB			Total SFR	*TEST*	*TEST*	**Part of total inflow to SFR**																	
32B			31B+32B	***NDB-Thomp-***	***UB-BMA***								Thompson	Well ST	Silo	NDB-Thomp-5-Silo	BMA	UB-BMA	Silo	Bottom	Wall	Top	
260				***IB,ST,BT-Silo***		*NDB*	*Thomp*	*IB+ST+BT*	*Silo*	*UB*	*BMA*		08	05A&B	6+7+V+G	32-8-5-(6+7+V+G)	01	31-01		G19-30	V11-18	06+07	
Raise	Time	Flow	Flow	Flow	Flow	*Flow*	*Flow*	*Flow*	*Flow*	*Flow*	*Flow*	Date	Flow	Flow	Flow	Flow	Flow	Flow	Date	Flow	Flow	Flow	
(m)	(min)	(l/min)	(l/min)	(l/min)	(l/min)	*(%)*	*(%)*	*(%)*	*(%)*	*(%)*	*(%)*		(l/min)	(l/min)	(l/min)	(l/min)	(l/min)	(l/min)		(l/min)	(l/min)	(l/min)	
			650						0.3		3.1	1986-11-15							1986-11-15				
												1988-03-29							1988-03-29				
1.82	830	**570.1**	**717.6**	233	147	79.4	47.0			20.6		1988-04-27	337.1			233.0		147.5	1988-04-27				
0.85	420	**526.2**	**651.9**	189	126	80.7	51.7			19.3		1990-01-10	337.1			189.1		125.7	1990-01-10				
0.21	120	455.0	575.0	25	107	79.1	72.9	1.9		20.9	2.3	1992-02-03	419.0	10.6		25.3	13.0	107.0	1992-02-03	0.0071	1.81		
0.21	120	455.0	555.0	24	89	82.0	75.5	1.8	0.4	18.0	2.0	1992-05-26	419.0	10.1	2.1	23.8	11.0	89.0	1992-05-26	0.0087	1.79	0.26	
0.21	120	455.0	555.0	25	91	82.0	75.5	1.5	0.4	18.0	1.6	1992-08-17	419.0	8.4	2.1	25.5	9.0	91.0	1992-08-17	0.0096	1.78	0.33	
0.21	120	455.0	575.0	20	106	79.1	72.9	2.3	0.4	20.9	2.4	1992-11-12	419.0	13.4	2.2	20.4	14.0	106.0	1992-11-12	0.0069	1.85	0.32	
0.2	120	**433.3**	**553.3**	**1**	111	**78.3**	**75.7**	2.1	0.3	21.7	1.6	1993-02-08	419.0	11.8	1.9	0.6	9.0	111.0	1993-02-08	0.0084	1.64	0.28	
0.6	360	**433.3**	**533.3**	**2**	91	**81.3**	**78.6**	1.9	0.4	18.8	1.7	1993-05-27	419.0	10.1	2.0	2.2	9.0	91.0	1993-05-27	0.0078	1.77	0.23	
0.21	120	455.0	575.0	24	110	79.1	72.9	1.8		20.9	1.7	1993-08-30	419.0	10.1		25.9	10.0	110.0	1993-08-30	0.0045	1.82		
0.18	120	***390.0***	***490.0***	***-40***	90	***79.6***	***85.5***	1.8	0.4	20.4	2.0	1993-11-24	419.0	9.0	1.9		10.0	90.0	1993-11-24	0.0042	1.66	0.24	
0.41	240	444.2	548.2	15	94	81.0	76.4	1.5	0.4	19.0	1.8	1994-02-08	419.0	8.4	2.1	14.7	10.0	94.0	1994-02-08	0.0024	1.83	0.24	
0.2	120	**433.3**	**553.3**	**3**	110	**78.3**	**75.7**	1.7	0.3	21.7	1.8	1994-05-10	419.0	9.5	1.8	3.0	10.0	110.0	1994-05-10	0.003	1.59	0.23	
0.19	120	**411.7**	**511.7**	**8**	91	**80.5**	**76.9**	1.8	0.3	19.5	1.8	1994-09-05	393.3	9.0	1.6	7.8	9.0	91.0	1994-09-05	0.003	1.38	0.18	
0.2	120	433.3	553.3	30	112	78.3	71.1	1.5	0.3	21.7	1.5	1994-12-08	393.3	8.4	1.8	29.8	8.0	112.0	1994-12-08	0.003	1.65	0.14	
0.28	180	404.4	524.4	18	110	77.1	71.8	1.6	0.3	22.9	1.9	1995-02-15	376.7	8.4	1.5	17.8	10.0	110.0	1995-02-15	0.0018	1.43	0.12	Update
0.375	240	406.3	506.3	20	90	80.2	74.4	1.5	0.3	19.8	2.0	1995-05-23	376.7	7.8	1.3	20.3	10.0	90.0	1995-05-23	0.0024	1.22	0.11	
0.37	240	**400.8**	**510.8**	**7**	100	**78.5**	**75.4**	1.4	0.3	21.5	2.0	1995-08-21	385.0	7.3	1.5	7.1	10.0	100.0	1995-08-21	0.0021	1.47	0.00	
0.2	120	433.3	553.3	48	110	78.3	68.1	1.3	0.3	21.7	1.8	1995-11-28	376.7	7.3	1.6	47.8	10.0	110.0	1995-11-28	0.0009	1.45	0.11	
0.19	120	411.7	511.7	27	90	80.5	73.6	1.3	0.3	19.5	2.0	1996-02-02	376.7	6.7	1.6	26.6	10.0	90.0	1996-02-02	0.0012	1.53	0.09	
0.18	120	**390.0**	**490.0**	**5**	90	**79.6**	**76.9**	1.4	0.3	20.4	2.0	1996-05-06	376.7	6.7	1.5	5.0	10.0	90.0	1996-05-06	0.0003	1.44	0.10	
0.17	120	***368.3***	***448.3***	***-16***	71	***82.2***	***84.0***	1.2	0.3	17.8	2.0	1996-09-05	376.7	5.6	1.5		9.0	71.0	1996-09-05	0.0021	1.42	0.10	
No measurement												1996-10-23	368.6	5.0	1.6		8.0		1996-10-23	0.0009	1.51	0.10	
		455.0	565.0										419.0	10.6	2.1	23.8	11.8	98.2		0.0081	1.81	0.30	
		390.0	483.3										374.7	6.0	1.6	15.8	9.3	83.6		0.0011	1.47	0.10	
		-65.0	-81.7										-44.3	-4.6	-0.5	-7.9	-2.5	-14.6		-0.0070	-0.33	-0.20	
		14.3%	14.5%										10.6%	43.4%	25.6%	33.5%	21.2%	14.9%		86.1%	18.4%	67.3%	
DB+BT+2VB+TT+STT+ NBT+Silo+ (IB + part of ST+BT) Singö + Zone 3, 6 & 9 + Schistosity			**SFR**										**DT+BT+ 2VB+TT+ STT**	**IB+part of ST and BT**	**Silo**	**NBT+SBT+SDT+ NDB + FS**	**BMA**	**BLA+BTF +BST+CT +DB+UB+ 3VB+EB+ part of ST**		**Silo Bottom**	**Silo Wall**	**Silo Top**	