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Äspö Hard Rock Laboratory

Hydro Monitoring Program

Report for 2007

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GEOSIGMA Uppsala

September 2008

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Abstract

The Äspö island is situated close to the nuclear power plant of Simpevarp in south-eastern Sweden. As part of the pre-investigations preceding excavation of the Äspö Hard Rock Laboratory, registrations of the groundwater levels and electrical conductivity in packed-off borehole sections and levels in open boreholes started in 1987. The investigations are still ongoing and are planned to continue for a long period of time. As the tunnel excavation went on from the autumn 1990 and onwards, new boreholes were drilled in the tunnel and instrumented to enable groundwater pressure monitoring in packed-off sections. In addition, other hydro-related measurements such as water flow in the tunnel, electrical conductivity of tunnel water and inflow and outflow of water through tunnel pipes have been performed. This report is a summary of the monitoring during 2007.

In order to allow for comparison with factors that may influence the groundwater level/pressure and flow, meteorological data are also presented in the report.

From the end of 1991, the disturbance from the tunnel is the dominating factor influencing groundwater levels in the area. In one chapter, activities that may have an influence on the ground water situation are listed and briefly discussed.

Sammanfattning

Äspö ligger nära Oskarshamns kärnkraftverk i sydöstra Sverige. Som en del av förundersökningarna inför anläggningen av Äspölaboratoriet påbörjades 1987 registrering av grundvattennivå och elektrisk konduktivitet i avmanschetterade borrhålssektioner och nivå i öppna borrhål. Nivåmätningarna pågår fortfarande och planeras fortgå under lång tid framöver. Från hösten 1990, under det att tunneln drevs, borrades nya hål i tunneln som instrumenterades för att möjliggöra mätningar av grundvattentrycket i avmanschetterade sektioner. Därtill har andra hydrorelaterade mätningar gjorts i tunneln såsom: vattenflöde i tunneln, grundvattnets elektriska ledningsförmåga samt in- och utflöde av vatten i tunnelledningar. Denna rapport sammanfattar mätningar som gjorts under 2007.

För att kunna relatera förändringar till faktorer som kan påverka grundvattnets nivå/tryck och flöde presenteras även meteorologiska data i rapporten.

Från och med 1991, ett år efter det att tunneldrivningen startade, är störningen från tunneldrivningen den faktor som har störst påverkan på grundvattenytan i området. I ett kapitel redovisas och diskuteras översiktligt sådana aktiviteter som kan påverka grundvattnet.

Executive Summary

The construction of the Äspö Hard Rock Laboratory started in October 1990. The laboratory consists of an extensive tunnel system excavated down to a depth of 460 m below the ground surface. A 3.6 km long entrance tunnel to the laboratory, starting at the ground surface close to the nuclear power plant on the Simpevarp peninsula, has been excavated. Vertical shafts, connecting the laboratory with the ground surface of Äspö, were also drilled.

Extensive pre-investigations (e.g. aerial and ground geophysical surveys, mapping of solid rocks and borehole investigations) have been performed on Äspö and four adjacent areas: on the islands of Ävrö, Bockholmen and Mjälen east and south of Äspö and in the Laxemar area at the mainland west of Äspö. A large number of core and percussion boreholes have been drilled in these areas. One important part of the pre-investigations has been geohydrological borehole measurements, such as different types of hydraulic tests, hydrochemical investigations, tracer tests and groundwater level registrations.

The objectives of the geohydrological investigations are 1) to document the groundwater conditions before, during and after excavating the laboratory tunnel system, 2) to obtain a data set of hydraulic, transport and chemical parameters and 3) to meet the regulations imposed by the water rights court. The obtained parameters are essential in order to improve predictions of transient processes, e.g. predictions of groundwater level changes, which is one consequence of the tunnel excavation.

The groundwater level registrations were initiated in 1987, before the start of the tunnel excavation. The results of these registrations have consecutively been presented in annual reports (Nyberg, et al, 1991-2007). Earlier reports only comprised data collected in surface boreholes but as from the annual report for 1995, data collected from measurements in the tunnel were also included. The present paper is the annual report covering the year 2007. The following data have been collected:

1. Groundwater level data in surface boreholes
2. Groundwater pressure in tunnel boreholes
3. Water flow in tunnel
4. Water flow in tunnel pipes
5. Electrical conductivity of tunnel water
6. Temperature, humidity and pressure of tunnel air
6. Precipitation
7. Air temperature
8. Potential evaporation

The meteorological data are collected at the SMHI (Swedish Meteorological and Hydrological Institute) meteorological stations situated as close as possible to the investigation area. From 2006 the station used is a SMHI-station, Norra Äspö, situated at the northern part of Äspö.

During 2007, there were 137 boreholes involved in the hydro-monitoring program within the five investigation areas and in the tunnel. Most of the boreholes are equipped with one or several rubber packers, which isolate up to ten borehole sections.

In the tunnel, 25 gauging boxes equipped with a v-notch weir are installed for flow measurements. Electrical conductivity of tunnel water has been measured at eleven locations. Water flow out of the tunnel in the discharge pipe is measured at 0/700 m tunnel length.

During the spring of 1991, the tunnel excavation began to affect the groundwater level in many surface boreholes. During 1992 and 1993 the effect of the tunnel is evident in all sub-areas except at Laxemar. In the areas on Äspö located near the tunnel spiral, the drainage caused by the tunnel has resulted in dramatic effects in many boreholes. In some borehole sections, the level has declined as much as 100 metres. Since 1994 the levels have gradually stabilised and during the last years the level decline in most boreholes has been within some metre. During 2007, the level changes were relatively small, within ±1 m in most boreholes. Even if the changes are rather small, the long-term overall picture is that a small decrease is still ongoing in many boreholes on the Äspö island as a result of the excavation of the Äspö HRL. During certain periods this decrease may be balanced by meteorological conditions resulting in increasing groundwater levels.

In many tunnel boreholes, the pressure was still decreasing (about 10-100 kPa) during 2007, but there were also a large number of sections, mainly in the deeper part of the tunnel, with increasing pressure. Due to a lot of activities in the tunnel during the year (e.g. blasting of a new tunnel, drilling, packer expansion and releases, opening, closing and pumping different boreholes), it is difficult to say whether the pressure changes are "natural" or due to the activities.

The flow in most gauging boxes has decreased if one compares the mean flow for the period October – December for the latest thirteen years. A few exceptions from this, especially in the deepest parts of the tunnel system, can be related to various activities. During the comparison period October – December, 1702 m^3/d was pumped out from the tunnel during 2007, which is approximately 16 m^3/d more than during the same period year 2006.

The total amount of precipitation during 2007 was 558 mm (Norra Äspö), which is 5 mm more than the mean for the comparison period 1961-90 (Oskarshamn). Large amounts were measured in June and July while the precipitation in April was only 15 mm.

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1 Introduction

Since October 1990, construction work for the Äspö Hard Rock Laboratory, situated a few kilometres north of the nuclear power plant of Simpevarp in south-eastern Sweden (Figure 1-1), are in progress. The laboratory is situated at a depth of up to 460 m below the ground surface of the small island of Äspö. The entrance tunnel, starting at the ground surface on the mainland close to the nuclear power plant, has a length of about 3.6 km. Three vertical shafts (one elevator and two ventilation shafts), which connect the laboratory with the ground surface of Äspö, have been excavated. A large number of surface boreholes have been drilled on Äspö and on the adjacent islands of Ävrö, Bockholmen and Mjälen and in the Laxemar area on the mainland west of Äspö (Figure 1-2).

The groundwater level investigations in surface boreholes performed to this date have been described in several progress reports. The groundwater level registrations are ongoing since 1987. The measurements have continued during the entire period of tunnel excavation and will go on for a long period afterwards. The registrations are presented in annual reports (Nyberg et al, 1991-2007). The first report, however, contained groundwater level data from three years: 1987-89 (Nyberg et al, 1991). As from the report for 1995, tunnel data are also included. The present paper is the annual report covering the year 2007. The following data have been collected:

1) groundwater level in surface boreholes

2) groundwater pressure in tunnel boreholes

3) water flow in tunnel

4) water flow in tunnel pipes

5) electrical conductivity of tunnel water

6) temperature, humidity and pressure of tunnel air

Background data considered necessary for interpreting changes of groundwater levels are also presented in the report. This includes:

7) precipitation from northern Äspö

8) air temperature from northern Äspö

9) potential evapotranspiration from northern Äspö

Figure 1-1 Location of the Äspö Hard Rock Laboratory area and of the stations used to collect background data. Gladhammar, Målilla and Oskarshamn are SMHI´s meteorological stations used in the report.

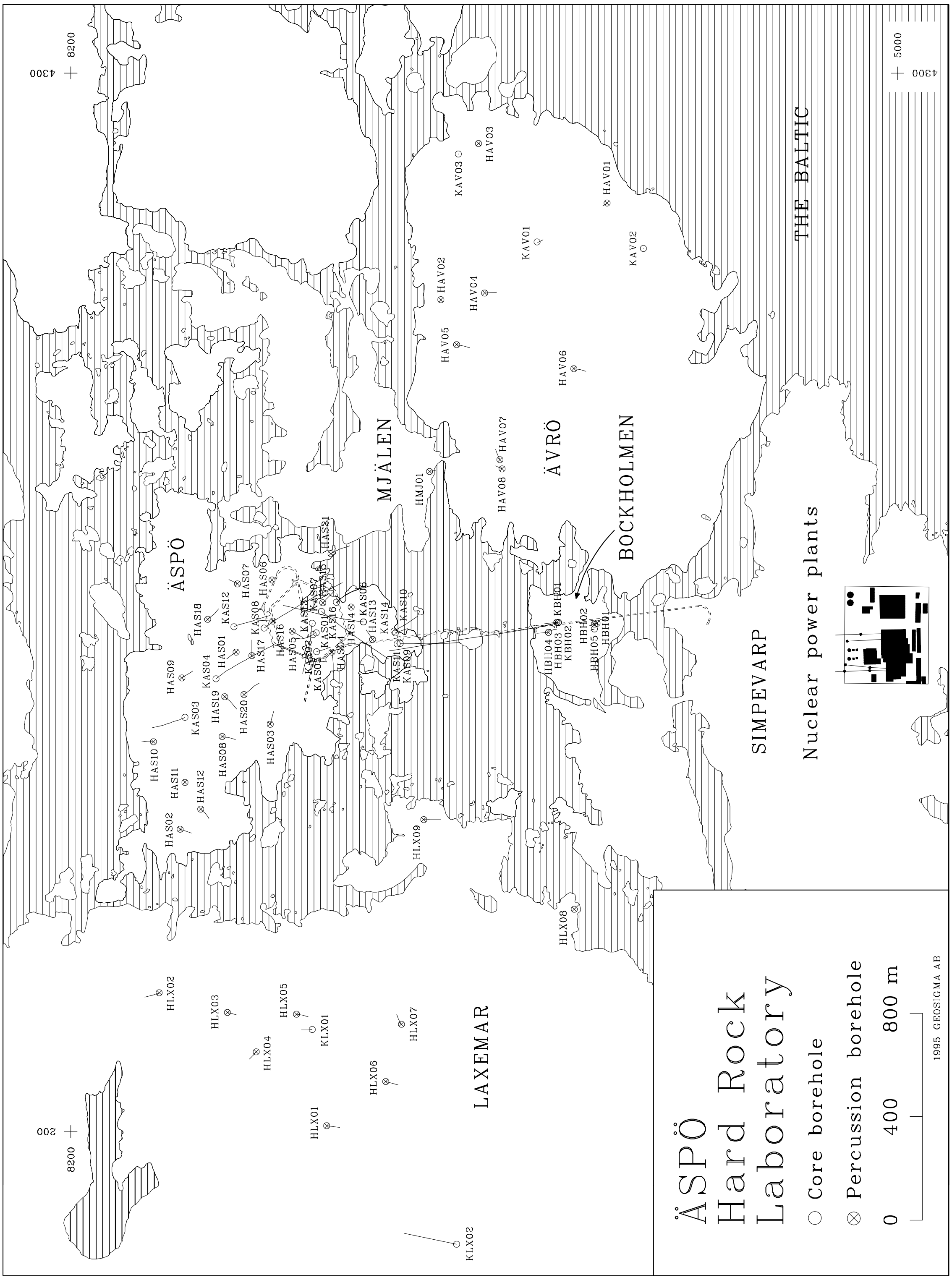

Figure 1-2 The investigation area with borehole locations.

2 Boreholes

2.1 Surface boreholes

The locations of the boreholes are shown in Figure 1-2. The extent of the monitoring program for surface boreholes during 2007 is shown in Table 3-3.

Table 2-1 presents borehole deviation (inclination and bearing), borehole length, elevation of the top of casing, length of casing and the date for completion of drilling for each surface borehole.

The height above ground for the top of casing is normally less than half a meter, typically about 30 cm.

Table 2-1 Borehole deviation, length, elevation of top of casing, length of casing and date for the completion of drilling.

Borehole	Inclination at ground (°)	Bearing * at ground (°)	Borehole length (m)	Elevation ** at top of casing (m.a.s.l)	Length of casing (m)	Drilling completed
HAS01	-60.7	327	100.0	6.38	1.2	870807
HAS02	-55.4	198	93.0	2.11	1.6	870801
HAS03	-55.6	108	100.0	2.36	1.6	870803
HAS04	-61.2	257	201.0	6.26	1.4	870804
HAS05	-58.1	207	100.0	6.31	1.4	870806
HAS06	-88.1	261	100.0	4.80	1.0	870806
HAS07	-61.5	30	100.0	3.76	2.0	870801
HAS08	-58.0	189	125.0	6.62	1.5	880319
HAS09	-59.3	150	125.0	7.84	1.5	880320
HAS10	-60.6	2	125.0	6.35	1.5	880322
HAS11	-89.3	356	125.0	5.59	1.5	880323
HAS12	-59.9	222	125.0	2.88	1.5	880325
HAS13	-60.3	60	100.0	2.05	3.0	881211
HAS14	-88.0	255	100.0	1.67	1.5	890117
HAS15	-60	136	120.0	4.19		890419
HAS16	-60	5	120.0	4.36		890415
HAS17	-60	90	120.0	7.89		890417
HAS18	-62.2	147	150.0	7.54	6.0	900319
HAS19	-57.3	220	150.0	8.97	6.0	900313
HAS20	-60.5	142	150.0	6.24	6.0	900319
HAS21	-60.0	151	148.0	3.04	3.0	911106
HAV01	-88.6	334	175.0	9.27		860813
HAV02	-89.1	137	163.0	6.08		860821
HAV03	-88.0	160	134.2	9.17		860824
HAV04	-60.1	180	100.0	7.97	0.4	870724
HAV05	-54.5	191	100.0	6.83	1.0	870728
HAV06	-59.5	190	100.0	12.39	1.2	870730
HAV07	-56.2	66	100.0	4.14	4.0	870728
HAV08	-61.9	28	63.0	7.05		870909
HBH01	-58.5	352	50.6	4.71	3.0	910220
HBH02	-47.5	346	32.4	4.68	3.0	910221
HBH03	-58.2	356	100.0	5.92	1.2	910306

Borehole	Inclination at ground (°)	Bearing * at ground (°)	Borehole length (m)	Elevation ** at top of casing (m.a.s.l)	Length of casing (m)	Drilling completed
HBH04	-59.7	356	90.4	5.52	5.1	920506
HBH05	-45	347	22.0	2.97	6.7	920601
HLX01	-59.4	190	100.63	8.87	3.0	871021
HLX02	-59.3	339	132.0	9.01	0.6	871027
HLX03	-63.1	200	100.0	10.43	1.4	871104
HLX04	-65.2	316	125.0	10.33	1.2	871106
HLX05	-59.9	188	100.0	15.68	0.6	871105
HLX06	-58.6	195	100.0	15.45	1.0	871030
HLX07	-60.8	62	100.0	8.58	1.0	871103
HLX08	-47.8	134	40.0	2.19	6.0	911114
HLX09	-61.3	178	151.0	3.28	3.0	911121
HMJ01	-60.0	182	46.0	1.39	6.0	911030
KAS01	-85	330	101.00	8.18	1.00	871029
KAS02	-84.5	331	924.04	7.68	1.05	871221
KAS03	-82.9	339	1002.26	8.79	1.11	880407
KAS04	-59.9	141	480.98	11.66	100.70	880501
KAS05	-84.9	164	549.60	8.68	1.05	890226
KAS06	-59.6	8	602.94	5.16	1.30	890128
KAS07	-59.1	218	603.88	4.58	1.15	890105
KAS08	-59.0	146	601.49	7.66	100.00	881223
KAS09	-59.9	182	450.62	4.08	100.65	891121
KAS10	-60	162	99.93	3.72	2.50	891023
KAS11	-88.7	35	248.90	4.22	6.00	900220
KAS12	-69.9	162	380.48	4.83	6.00	900319
KAS13	-62.2	281	406.95	3.84	6.00	900313
KAS14	-61.3	149	211.85	3.35	6.00	900511
KAS16	-84.5	139	548.46	3.66	6.00	920902
KAV01	-89.2	237	502.00			770516
			746.60			861116
			757.31	14.07	68.04	040110
KAV02	-89.5	39	97.10	7.52	12.40	770531
KAV03	-89.4	146	248.40	8.71	2.80	861005
KBH02	-45.0	348	706.35	5.50	5.50	900517
KLX01	-85.3	1	702.11		0-101.30	880205
			1077.99	16.74	268.3-700	900804
KLX02	-85.0	9	1700.50	18.37	202.95	921129

* Degrees (0-360) measured clockwise in local system ÄSPÖ96. Magnetic bearing is obtained by subtracting 11.8°.

** Measured in local system ÄSPÖ96. Elevation in RT90-RHB70 is obtained by adding 0.03 m.

The borehole diameters are presented in Table 2-2. Most boreholes are enlarged in the uppermost part to allow for the installation of casing. All core boreholes except four are "telescope drilled"; i.e. the diameter of the upper part is larger than below. Exceptions are KAS01 and KAS10, where drilling was unsuccessful, and KAV02 and KAV03, which were not telescope drilled. Normally, the enlarged part has a length of approximately 100 m. All telescope drilled core boreholes have an enlargement (approximately 1 m long) where the diameter changes to make room for a funnel-shaped pipe, which gives a smooth transition between the two borehole diameters.

Table 2-2 Borehole diameters.

Borehole	Length of borehole from (m)	to (m)	Nominal diameter (mm)
HAS01	0.00	100.00	115
HAS02	0.00	93.00	115
HAS03	0.00	100.00	115
HAS04	0.00	201.00	115
HAS05	0.00	100.00	115
HAS06	0.00	100.00	115
HAS07	0.00	100.00	115
HAS08	0.00	125.00	115
HAS09	0.00	125.00	115
HAS10	0.00	125.00	115
HAS11	0.00	125.00	115
HAS12	0.00	125.00	115
HAS13	0.00	100.00	115
HAS14	0.00	100.00	115
HAS15	0.00	120.00	115
HAS16	0.00	120.00	115
HAS17	0.00	120.00	115
HAS18	0.00	6.00	250
	6.00	150.00	162
HAS19	0.00	6.00	250
	6.00	150.00	158
HAS20	0.00	6.00	250
	6.00	150.00	152
HAS21	0.00	148.00	115
HAV01	0.00	175.00	110
HAV02	0.00	163.00	110
HAV03	0.00	134.20	110
HAV04	0.00	100.00	115
HAV05	0.00	100.00	115
HAV06	0.00	100.00	115
HAV07	0.00	100.00	115
HAV08	0.00	63.00	76
HBH01	0.00	50.60	115
HBH02	0.00	32.40	115
HBH03	0.00	100.00	115
HBH04	0.00	90.40	115
HBH05	0.00	22.00	115
HLX01	0.00	100.63	115
HLX02	0.00	132.00	115
HLX03	0.00	100.00	115
HLX04	0.00	125.00	115
HLX05	0.00	100.00	115
HLX06	0.00	100.00	115
HLX07	0.00	100.00	115
HLX08	0.00	40.00	115
HLX09	0.00	151.00	115
HMJ01	0.00	46.00	115
KAS01	0.00	95.85	115
	95.85	101.00	115
KAS02	0.00	93.35	155
	93.35	924.04	56
KAS03	0.00	1.11	?
	1.11	100.80	164
	100.80	1002.26	56
KAS04	0.00	100.70	155
	100.70	480.98	56
KAS05	0.00	150.00	164
	150.00	549.60	76
KAS06	0.00	100.00	164
	100.00	602.94	56
KAS07	0.00	100.00	164
	100.00	603.88	56
KAS08	0.00	100.00	164
	100.00	601.49	56
KAS09	0.00	100.65	167
	100.65	450.62	56
KAS10	0.00	99.93	56
KAS11	0.00	40.40	160
	40.40	248.90	56
KAS12	0.00	100.05	167
	100.05	380.48	56
KAS13	0.00	100.20	162
	100.2	104.35	56
	104.35	257.45	76
	257.45	406.95	56
KAS14	0.00	100.44	164
	101.40	211.85	56
KAS16	0.00	100.00	164
	100.00	548.46	56
KAV01	0.04	68.74	200
	68.74	68.84	165
	68.84	70.04	76
	70.04	757.31	56
KAV02	0.00	97.10	56
KAV03	0.00	248.40	56
KBH02	0.00	101.50	165
	101.50	706.35	56
KLX01	0.00	1.00	?
	1.00	101.30	155
	101.30	702.11	76
	702.11	1077.99	56
KLX02	0.40	3.00	304
	3.00	200.80	215
	200.80	201.00	165
	201.00	202.95	92
	202.95	1700.50	76

2.2 Tunnel Boreholes

The borehole deviation (inclination and bearing), borehole length, borehole diameter, elevation of the starting point at the tunnel wall, length of casing and the date for completion of drilling for tunnel boreholes are presented in Table 2-3. Only those boreholes that have been monitored within the HMS during 2007 are listed.

Many boreholes are enlarged in the outermost (closest to the tunnel) 2 - 2.5 metres to enable installation of casing. Except for HA1283B and KA3065A03, which were lengthened with a smaller diameter, the diameter inside the casing enlargement does not change. During 2007, over-core drilling has been performed in boreholes KA3065A03, KXTT3 and KXTT4.

Table 2-3 Borehole deviation, length, minimum diameter, elevation at tunnel wall, length of casing and date for the completion of drilling.

Borehole	Inclination at top of b.h. (°)	Bearing * at top of b.h. (°)	Borehole length (m)	Minimum diameter (mm)	Elevation** at tunnel wall (m.a.s.l.)	Length of casing (m)	Drilling completed
HA1273A	10.7	351.3	30.0	57	-174.23	2.00	920423
HA1278A	4.3	304.8	29.0	57	-175.68	2.00	920910
HA1279A	2.8	311.6	24.0	57	-175.65	2.00	920910
HA1283B	-8.0	352.7	35.5	57	-176.55	2.00	920415
			40.2	51			
HA1327B	-0.5	140.0	29.5	57	-182.81	2.00	920911
HA1330B	-0.5	100.0	32.5	57	-182.99	No c.	920911
HD0025A	7.0	88.7	15.0	57	-416.70	No c?	941111
KA1061A	0.6	349.6	208.5	56	-144.93	2.00	920123
KA1131B	-12.9	0.5	203.1	56	-155.30	2.00	920212
KA1751A	5.2	274.2	149.91	56	-237.56	2.00	930504
KA1754A	-26.2	299.9	159.88	56	-237.84	2.00	930519
KA1755A	-19.9	339.4	320.58	56	-237.80	2.42	940406
KA2048B	-10.6	190.9	184.45	56	-275.43	2.00	930216
KA2050A	-53.5	55.3	211.57	56	-275.79	2.50	931102
KA2162B	-15.2	272.2	288.1	56	-289.87	2.50	930401
KA2511A	-33.3	234.8	293.0	56	-335.88	2.50	930905
KA2563A	-42.5	237.2	363.43	56	-340.79	2.05	960924
KA2598A	-32.2	292.6	300.77	56	-342.39	No c?	930928
KA2858A	-4.3	287.0	59.7	56	-379.38	2.50	950115
KA2862A	-8.0	15.9	15.98	56	-379.54	2.50	950125
KA3005A	-4.5	299.1	58.11	56	-399.86	2.50	941205
KA3010A	-4.7	99.5	60.66	56	-399.87	2.50	941208
KA3065A02	-5.1	59.8	69.95	76	-408.25	2.55	990422

Borehole	Inclination at top of b.h. (º)	Bearing * at top of b.h. (º)	Borehole length (m)	Minimum diameter (mm)	Elevation** at tunnel wall (m.a.s.l.)	Length of casing (m)	Drilling completed
KA3065A03	-4.5	55.8	9.20	300	-408.09	2.34	
			10.40	196			000206
			11.35	36			011003
			0 - 12.11	300			070503
KA3067A	-4.7	98.4	40.05	56	-408.59	2.50	941211
KA3068A	2.8	113.8	16.85	86	-408.38	No c?	940603
KA3105A	-4.7	102.5	68.95	56	-413.68	2.50	941215
KA3110A	-5.4	238.3	26.83	56	-413.71	2.50	941217
KA3385A	-4.1	176.2	34.18	56	-445.99	No c.	950110
KA3386A01	-1.9	219.9	65.11	76	-446.11	2.51	020615
KA3510A	-30.1	255.3	150.06	76	-448.70	2.35	960909
KA3539G	-80.5	274.2	30.01	76	-449.19	No c.	980513
KA3542G01	-44.9	188.7	30.04	76	-449.07	No c.	980603
KA3542G02	-44.2	6.3	30.01	76	-449.07	No c.	980605
KA3543A01	-0.8	234.1	2.06	56	-446.80	No c.	001005
KA3543I01	70.5	195.5	2.06	56	-444.08	No c.	001011
KA3544G01	-90.0	0.0	12.0	76	-448.95	No c.	980325
KA3546G01	-89.8	194.0	12.0	76	-448.89	No c.	980324
KA3548A01	-3.1	188.3	30.0	76	-446.58	2.5	980628
KA3548D01	2.7	52.6	2.06	56	-445.87	No c.	001006
KA3548G01	-89.7	75.7	12.01	76	-449.00	No c.	980323
KA3550G01	-89.2	249.0	12.03	76	-448.77	No c.	980322
KA3550G05	-89.2	25.0	3.0	56	-448.96	No c.	001030
KA3551G05	-89.9	356.1	3.1	56	-448.91	No c.	001027
KA3552A01	-2.8	233.6	2.06	56	-446.62	No c.	000928
KA3552G01	-89.5	130.6	12.01	76	-448.77	No c.	980321
KA3552H01	58.2	267.7	2.1	56	-443.98	No c.	001012
KA3553B01	-37.7	8.1	2.02	56	-446.55	No c.	001004
KA3554G01	-45.0	188.2	30.01	76	-448.83	No c.	980607
KA3554G02	-45.0	8.2	30.01	76	-448.82	No c.	980606
KA3557G	-81.5	271.2	30.04	76	-448.85	No c.	980512
KA3563A01	-7.7	233.8	2.06	56	-447.06	No c.	000922
KA3563D01	2.5	53.7	2.01	56	-446.15	No c.	000925
KA3563G	-79.9	277.9	30.0	76	-448.69	No c.	980507
KA3563I01	73.0	235.9	2.15	56	-443.64	No c.	001011
KA3566C01	3.5	232.3	2.1	56	-445.56	No c.	000920
KA3566G01	-44.9	188.8	30.01	76	-448.57	No c.	980609
KA3566G02	-43.8	7.7	30.01	76	-448.57	No c.	980610
KA3568D01	-2.3	54.4	2.3	56	-445.83	No c.	000925
KA3572G01	-89.6	225.0	12.0	76	-448.51	No c.	980320
KA3573A	-2.1	188.3	40.07	76	-446.07	2.65	970911
KA3573C01	34.9	232.3	2.05	56	-445.13	No c.	000926
KA3574D01	12.6	55.5	2.05	56	-445.12	No c.	000926
KA3574G01	-89.2	249.0	12.0	76	-448.33	No c.	980428
KA3576G01	-89.2	213.7	12.01	76	-448.27	No c.	980426

Borehole	Inclination at top of b.h. (°)	Bearing * at top of b.h. (°)	Borehole length (m)	Minimum diameter (mm)	Elevation** at tunnel wall (m.a.s.l.)	Length of casing (m)	Drilling completed
KA3578C01	-5.4	232.4	2.09	56	-445.34	No c.	000928
KA3578G01	-89.0	252.7	12.58	76	-448.38	No c.	980319
KA3578H01	59.1	266.7	1.9	56	-443.38	No c.	001002
KA3579D01	-1.0	54.2	2.0	56	-445.43	No c.	000922
KA3579G	-89.4	296.6	22.65	76	-448.37	No c.	971008
KA3584G01	-89.2	212.5	12.0	76	-448.25	No c.	980319
KA3588C01	-4.0	232.8	2.04	56	-445.44	No c.	000926
KA3588D01	-1.8	55.0	1.9	56	-445.24	No c.	000925
KA3588I01	65.6	5.2	1.96	56	-443.34	No c.	001019
KA3590G01	-44.4	186.7	30.06	76	-448.06	No c.	980623
KA3590G02	-43.8	7.9	30.05	76	-448.08	No c.	980616
KA3592C01	4.4	233.8	2.1	56	-445.25	No c.	000926
KA3593G	-79.8	275.2	30.02	76	-448.07	No c.	980504
KA3597D01	3.1	53.5	2.22	56	-445.10	No c.	001004
KA3597H01	55.1	248.8	2.06	56	-443.18	No c.	001005
KA3600F	-1.7	248.4	50.1	76	-445.58	2.65	970924
KF0051A01	29.9	310.3	11.70	76	-451.38	2.50	980527
KF0069A01	-1.8	28.9	70.09	76	-454.82	2.54	020521
KG0021A01	17.7	220.1	48.82	76	-445.15	2.50	980708
KG0048A01	14.0	222.4	54.69	76	-444.49	2.42	980804
KI0010B01	-0.5	229.8	100.64	76	-446.01	2.77	070421
KI0014B01	-0.6	229.8	100.27	76	-447.56	2.81	070618
KI0016B01	-0.5	229.8	100.24	76	-446.06	2.79	070608
KI0023B	-20.7	214.6	200.71	76	-447.69	2.65	971120
KI0025F	-20.2	187.1	193.8	76	-448.23	2.50	970425
KI0025F02	-25.5	200.0	204.18	76	-448.53	2.65	980825
KI0025F03	-29.8	206.9	141.72	76	-448.08	2.50	990813
KXTT1	-45.6	61.5	28.76	56	-392.12	2.50	950518
KXTT2	-44.5	61.2	18.3	56	-392.42	2.50	950522
KXTT3	-37.0	44.4	17.43	56	-391.07	2.50	950606
			14.73	300			070607
			17.43	56			950606
KXTT4	-36.5	60.0	49.31	56	-391.10	2.50	950616
			13.60	300			070816
			49.31	56			950616
KXTT5	-14.9	47.7	25.85	76	-390.30	2.55	990505
SA3045A	-10.5	132.2	20.7	57	-405.42	No c?	940227

* Degrees (0-360) measured clockwise in local system ÄSPÖ96. Magnetic bearing is obtained by subtracting 11.8°.

** Measured in local system ÄSPÖ96. Elevation in RT90-RHB70 is obtained by adding 0.03 m.

3 Measurements methods

3.1 Data collection

All data are collected by means of different types of pressure transducers connected to different types of logger units or by manual levelling.

In the tunnel, pressure in borehole sections are measured either via a hydraulic multiplexer or by individual transducers for each section connected directly to a Borre logger, a Datascan unit, a Datataker logger or a PLC. The hydraulic multiplexer holds a pressure transducer connected to a Borre logger of a type that can operate the magnetic valves on the multiplexer.

Below follows a summary of the units that are used.

BorreR is a logger with a 16 bits A/D converter. This logger communicates with a measurement station either by radio or via the power line. Used at the ground only.

BorreT is a logger with a 16 bits A/D converter communicating with a measurement station in a Borre data network. This logger, which can operate magnetic valves on a hydraulic multiplexer, is used in the tunnel only.

Datascan has a 16 bits A/D converter. This unit has no data storing facility and is connected directly to a measurement station. It is used in the tunnel only.

DataTaker is a data logger connected on-line to a measurement station by means of radio or network. The logger has 42 channels and is used in the tunnel only.

A **PLC** (Programmable Logic Controller) consists of several parts; a CPU, a power unit, digital and analog inputs/outputs. It is connected to a measurement station and is only used for the tunnel boreholes included in the LTDE experiment.

The logger types used for different boreholes on the surface are presented in Table 3-1.

In Table 3-2, the data-collecting units used for pressure measurements in different borehole sections in the tunnel are presented.

Table 3-1 Monitoring equipment in surface boreholes.

Borehole	Section	Equipment	from	To
HAS01	1	BorreR	91-09	
HAS02	1	Manually	970320	
HAS03	1	Manually	981018	
HAS05	1	Manually	970320	
HAS06	1	BorreR	91-09	
HAS07	1	BorreR	970218	
HAS08	1	Manually	970130	
HAS09	1	Manually	970320	
HAS10	1	Manually	970320	
HAS11	1	Manually	060504	
HAS12	1	Manually	970320	
HAS13	1	BorreR	91-09	
HAS14	1	Manually	970320	
HAS15	1	Manually	041002	
HAS16	1	BorreR	91-09	
HAS17	1	Manually	050419	
HAS18	1	Manually	970227	
HAS19	1	Manually	050419	
HAS20	1	Manually	970130	
HAS21	1	BorreR	970130	
HAV01	1	Manually	000917	

Borehole	Section	Equipment	from	To
HAV03	1	Manually	000917	
HAV04	1	Manually	000917	
HAV08	1	Manually	060504	
HBH01	1	Manually	040101	
HBH02	1	Manually	040101	
HBH04	1	Manually	050530	
	2	Manually	91-03	
HLX03	1	Manually	000917	
HLX04	1	Manually	970129	
HLX05	1	Manually	050530	
KAS03	1-6	BorreR	91-09	
KAS04	1	Manually	970320	
KAS07	1	Manually	970220	
KAS09	1-5	BorreR	91-09	
KAS10	1	BorreR	91-09	
KAS11	1	Manually	970320	
KAS14	1	Manually	970320	
KAS16	1	Manually	92-10	
	2-4	Manually	041002	
KBH02	3-6	Manually	050530	

Note - Data not relevant for 2007 is to be found in earlier annual reports.

Table 3-2 Monitoring equipment in tunnel boreholes.

Borehole	Sect. no	Equipment	Date from	Date to
HA1273A	1	HM*+BorreT		
HA1278A	1	HM+BorreT		
HA1279A	1	HM+BorreT		
HA1283B	1	HM+BorreT		
HA1327B	1	HM+BorreT		
HA1330B	1	HM+BorreT		
HD0025A	1	Datascan	990602	
KA1061A	1	HM+BorreT		
KA1131B	1	HM+BorreT		
KA1751A	1-3	HM+BorreT	940426	071106
	1-3	DataTaker	071106	
KA1754A	1-2	HM+BorreT	941025	071106
	1-2	DataTaker	071106	
KA1755A	1-4	HM+BorreT	940503	071106
	1-4	DataTaker	071106	
KA2048B	1-4	HM+BorreT		080123
	1-4	DataTaker	080206	
KA2050A	1-3	HM+BorreT		080123
	1-3	DataTaker	080206	
KA2162B	1-4	HM+BorreT		080123
	1-4	DataTaker	080206	
KA2511A	1-6	Datascan	970701	
	7-8	Datascan	990316	
KA2563A	1-5	Datascan	961120	
KA2598A	1	Datascan	990512	
KA2858A	2	Datascan	011024	
KA2862A	1	Datascan	011024	
KA3005A	2-5	Datascan	011024	
KA3010A	2	Datascan	011024	
KA3065A02	1-4	PLC	040121	071227
	1-4	DataTaker	080117	

Borehole	Sect. no	Equipment	Date from	Date to
KA3065A03	1-5	PLC	040121	070507
	1	PLC	070523	071227
	1	DataTaker	080123	
KA3067A	1-4	PLC	040121	071227
	1-4	DataTaker	080117	
KA3068A	1	PLC	040121	071227
	1	DataTaker	080116	
KA3105A	1-5	Datataker	061128	
KA3110A	1-2	Datataker	061128	
KA3385A	1-2	Datascan	970701	
KA3386A01	1	Datascan	030415	
KA3510A	1-3	Datascan	981027	
	4-5	Datascan	010518	
KA3539G	1-4	Datascan	030508	
KA3542G01	1-5	Datascan	030508	
KA3542G02	1-5	Datascan	030508	
KA3543A01	1	Datascan	030508	
KA3543I01	1	Datascan	030508	
KA3544G01	1-3	Datascan	030508	
KA3546G01	1-3	Datascan	030508	
KA3548A01	1-4	Datascan	030508	
KA3548D01	1	Datascan	030508	
KA3548G01	1-2	Datascan	030508	
KA3550G01	1-3	Datascan	030508	
KA3550G05	1	Datascan	030508	
KA3551G05	1	Datascan	030508	
KA3552A01	1	Datascan	030508	
KA3552G01	1-3	Datascan	030508	
KA3552H01	1	Datascan	030508	
KA3553B01	1	Datascan	030508	
KA3554G01	1-5	Datascan	030508	

Borehole	Sect. no	Equipment	Date from	to
KA3554G02	1-5	Datascan	030508	
KA3557G	1-2	Datascan	030508	
KA3563A01	1	Datascan	011219	
KA3563D01	1	Datascan	011219	
KA3563G	1-4	Datascan	011219	
KA3563I01	1	Datascan	010921	
KA3566C01	1	Datascan	011114	
KA3566G01	1-5	Datascan	011217	
KA3566G02	1-5	Datascan	011217	
KA3568D01	1	Datascan	010926	
KA3572G01	1-2	Datascan	011217	
KA3573A	1-5	Datascan	011217	
KA3573C01	1	Datascan	011219	
KA3574D01	1	Datascan	011219	
KA3574G01	1-3	Datascan	011217	
KA3576G01	1-3	Datascan	010918	
KA3578C01	1	Datascan	011106	
KA3578G01	1-2	Datascan	010918	
KA3578H01	1	Datascan	011219	
KA3579D01	1	Datascan	010920	
KA3579G	1-3	Datascan	011217	
KA3584G01	1-2	Datascan	010918	
KA3588C01	1	Datascan	011101	
KA3588D01	1	Datascan	011219	
KA3588I01	1	Datascan	011101	
KA3590G01	1-3	Datascan	011217	
KA3590G02	1-4	Datascan	011217	
KA3592C01	1	Datascan	011219	
KA3593G	1-4	Datascan	011015	
KA3597D01	1	Datascan	010918	
KA3597H01	1	Datascan	011015	
KA3600F	1-4	Datascan	011015	
KF0051A01	1-4	Datascan	980612	
KF0069A01	1	Datascan	030417	
KG0021A01	1-5	Datascan	010530	
KG0048A01	1-5	Datascan	010529	
KI0010B01	1	Datascan	070329	071108
KI0014B01	1	Datascan	070329	071029
KI0016B01	1	Datascan	070329	070904
KI0023B	1-9	Datascan	980216	
KI0025F	1-6	Datascan	970710	
KI0025F02	1-10	Datascan	981027	
KI0025F03	1-9	Datascan	991013	
KXTT1	1-4	Datascan	011024	
KXTT2	1-5	Datascan	011024	
KXTT3	3	Datascan	051027	070328
	4-5	Datascan	051027	070412
KXTT4	3	Datascan	051027	070328
	4-5	Datascan	051027	070412
KXTT5	1-4	Datascan	011024	
SA3045A	1-3	PLC	040121	071227
	1-3	DataTaker	080117	

* HM=Hydraulic Multiplexer
Note - Data not relevant for 2007 is to be found in earlier annual reports.

3.2 Groundwater level measurements in surface boreholes

3.2.1 Monitoring in surface boreholes

In Table 3-3, lengths along the borehole to top and bottom of each section as well as elevation of the top of section are presented. If no end date is given, the borehole was equipped in the same way at the end of 2007. However, the period when some of the boreholes were open to enable re-instrumentation (summer 1991) is not included in the table.

Table 3-3 Monitored sections in surface boreholes.

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of section* at top (masl)	at middle (masl)
HAS01	1	1988-08-01		0	100	6.38	-37.41
HAS02	1	1995-08-25		0	93	2.11	-36.87
HAS03	1	1997-02-05		0	100	2.36	-39.41
HAS05	1	1993-03-31		0	100	6.31	-36.70
HAS06	1	2003-09-23		0	100	4.80	-45.12
HAS07	1	1997-02-18		0	100	3.76	-41.45
HAS08	1	1997-01-30		0	125	6.62	-48.20
HAS09	1	1995-08-14		0	125	7.84	-47.69
HAS10	1	1995-08-14		0	125	6.35	-49.32
HAS11	1	2003-05-21		0	125	5.59	-56.81
HAS12	1	1995-08-15		0	125	2.88	-52.78
HAS13	1	*2003-05-21*		0	100	2.05	-42.01
HAS14	1	1995-08-14		0	100	1.67	-48.30
HAS15	1	2001-05-15		0	120	4.19	-47.77
HAS16	1	*2003-09-23*		0	120	4.36	-47.60
HAS17	1	2005-04-19		0	120	7.89	-44.07
HAS18	1	1997-02-27		0	150	7.54	-59.72
HAS19	1	2005-04-19		0	150	8.97	-55.65
HAS20	1	2003-07-03		0	150	6.24	-57.68
HAS21	1	1997-01-30		0	148	3.04	-60.98
HAV01	1	*2000-09-17*		0	175	9.27	-77.88
HAV03	1	*2000-09-17*		0	134	9.17	-57.78
HAV04	1	*2000-09-17*		0	100	7.97	-35.77
HAV08	1	1987-09-05		0	63	7.05	-20.77
HBH01	1	2003-09-17		0	50.6	4.71	-17.16
HBH02	1	2003-09-17		0	32.4	4.68	-7.35
HBH04	1	1991-04-04		31	90.4	-21.28	-46.69
	2	1991-04-04		0	30	5.52	-7.45
HLX03	1	*2000-09-17*		0	100	10.43	-35.06
HLX04	1	1997-01-29		0	125	10.33	-48.06
HLX05	1	1997-01-29		0	100	15.68	-28.54
KAS03	1	2005-07-04		0	1002	8.79	-488.49
KAS04	1	1993-06-04		0	480.98	11.66	-193.58
KAS07	1	1997-02-20		0	603.88	4.58	-253.44
KAS09	1	1990-04-09		261	450	-220.08	-301.03
	2	1990-04-09		241	260	-202.93	-211.08
	3	1990-04-09		151	240	-125.97	-163.99
	4	1990-04-09		116	150	-96.01	-110.58
	5	1990-04-09		0	115	4.08	-45.66
KAS10	1	1989-10-23		0	99.93	3.72	-39.55
KAS11	1	1995-10-23		0	248.9	4.22	-120.21
KAS14	1	1995-10-24		0	211.85	3.35	-87.81
KAS16	1	1992-10-20		466	548.46	-452.88	-492.38
	2	1992-10-20		390	465	-379.57	-415.81
	3	1992-10-20		121	389	-116.36	-248.21
	4	1992-10-20		0	120	3.66	-55.96
KBH02	*3*	*1991-09-19*		261	326	-109.42	-117.31
	4	*1991-09-19*		151	260	-79.60	-95.08
	5	*1991-09-19*		106	150	-61.29	-71.08
	6	*1991-09-19*		0	105	5.50	-29.95

Note - Data not relevant for 2007 is to be found in earlier annual reports.
* Measured in local system ÄSPÖ96. Elevation in RT90-RHB70 is obtained by adding 0.03 m.
Italics= This information is either uncertain or not available in the Sicada database.

3.2.2 Absolute pressure in borehole sections

Sometimes it is of interest to determine the absolute pressure at the top of a packed off section. This value can be calculated if the vertical distance from top of section to the water level in the tube connecting the section with the ground surface and the density of water in the tube are known.

The altitude at top of section is presented in Table 3-3.

Density

The density of the tube water is determined in the following way. When all packers in a core borehole are installed and inflated, water is flushed from all sections to the ground surface through the tubes. When at least two tube volumes have been discharged, a water sample from each tube is collected. The electrical conductivity of the sample is measured. On approximately 75 samples from 1988 and 1989, the density was laboratory-determined. The electrical conductivity of the samples ranged from 60 to 3400 mS/m. From these measurements a first order equation is set up, by means of the least square method (by Ann-Chatrin Nilsson, KTH, 1990, personal communication), which gives the density from the electrical conductivity (see note in Table 3-4). This equation is then used to calculate the density of any sample. The deviation from the straight line for a single value is at most 1.5 kg/m^3, but normally less then 0.5 kg/m^3.

A more difficult problem is to determine whether the water sample is representative for the water in the tube or not. For example, water with a different density than the sample might have entered into a part of the tube when the flushing was interrupted. Taking also this into account, the maximum error in the density is estimated to be ±10 kg/m^3, corresponding to ±1 m per 100 m water column.

Calculated density values in the tubes and measured electrical conductivity values are found in Table 3-4. Measurements of the electrical conductivity in water samples were performed only in the core boreholes on Äspö, in KBH02 and in KLX01, beginning in 1988.

The values may differ from undisturbed values in the section. For example, if the sample was taken immediately after inflation of the packers, the electrical conductivity in the section may not have reached its natural value.

It can be mentioned that the electrical conductivity of the sea water east of Ävrö in August and September 1986 was 1180 and 1170 mS/m, respectively.

Table 3-4 Electrical conductivity and calculated density (at 25° C) of water in tubes between section and the ground surface.

Borehole	Sec.	Valid from	Electrical conduct. (mS/m)	Density (kg/m^3)
KAS03	1	2006-10-03	193	998
	1	2007-09-27	274	999
KAS09	1	1990-04-07	1600	1005
	2	1990-04-07	1600	1005
	3	1990-04-07	1600	1005
	4	2006-09-28	994	1002
	4	2007-10-08	925	1002
	5	1990-04-07	1600	1005
KAS16	1	1992-10-20	1450	1004
	2	1992-10-20	1350	1004
	3	1992-10-20	800	1001
	4	1992-10-20	750	1001
KBH02	3	1992-05-14	970	1002
	4	1992-05-14	1090	1002
	5	1992-05-14	870	1001
	6	1992-05-14	530	1000

Density (kg/m^3) = 997.3 + 0.00467 × Electrical conductivity (mS/m).
Note - Data not relevant for 2007 is to be found in earlier annual reports.

3.2.3 Calibration method

To calibrate the registrations from the data loggers, manual levelling of all sections is made, normally once every month.

The logger data is converted to water levels by means of a linear calibration equation (if the pressure transducer is of the absolute type, subtracting the air pressure is also necessary). Converted logger data are compared with manual levellings that are corrected to account for borehole deviation. If the two differs, calibration constants are changed and the procedure is repeated until an acceptable fit is achieved.

3.3 Groundwater pressure in tunnel boreholes

3.3.1 Monitoring in tunnel boreholes

In Table 3-5 the length along the boreholes to top and bottom of each section and the elevation at the middle of section is presented. To enable calculations of absolute pressure at the middle of section, the level of the pressure transducer is also given.

Table 3-5 Monitored sections in tunnel boreholes.

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of * SecTop (masl)	SecMid (masl)	Transducer (masl)
HA1273A	1	1992-03-12		0.0	23.0	-174.23	-172.10	*-163.34*
HA1278A	1	1992-09-10		0.0	29.0	-175.68	-174.59	*-163.34*
HA1279A	1	1992-09-10		0.0	24.0	-175.65	-175.06	*-163.34*
HA1283B	1	1992-04-15		0.0	40.2	-176.55	-179.35	*-163.34*
HA1327B	1	1992-09-11		0.0	29.5	-182.81	-182.93	*-163.34*
HA1330B	1	1992-09-11		6.0	32.5	-183.04	-183.15	*-163.34*
HD0025A	1	*1999-06-02*		0.0	15.0	-416.70	-415.79	-416.42
KA1061A	1	1992-01-14		0.0	208.5	-144.93	-144.01	*-163.34*
KA1131B	1	1992-02-02		0.0	203.1	-155.30	-178.88	*-163.34*
KA1751A	1	1994-04-21	*2007-11-06*	99.0	150.0	-246.10	-248.20	*-224.28*
	2	1994-04-21	*2007-11-06*	56.0	98.0	-242.50	-244.23	*-224.28*
	3	1994-04-21	*2007-11-06*	6.0	55.0	-238.10	-240.25	*-224.28*
	1	*2007-11-06*		99.0	150.0	-246.10	-248.20	?
	2	*2007-11-06*		56.0	98.0	-242.50	-244.23	?
	3	*2007-11-06*		6.0	55.0	-238.10	-240.25	?
KA1754A	1	1994-04-21	*2007-11-06*	75.0	159.87	-270.76	-289.21	*-224.28*
	2	1994-04-21	*2007-11-06*	6.0	74.0	-240.49	-255.48	*-224.28*
	1	*2007-11-06*		75.0	159.87	-270.76	-289.21	?
	2	*2007-11-06*		6.0	74.0	-240.49	-255.48	?
KA1755A	1	1994-05-03	*2007-11-06*	231.0	320.58	-318.23	-334.61	*-224.28*
	2	1994-05-03	*2007-11-06*	161.0	230.0	-293.11	-305.47	*-224.28*
	3	1994-05-03	*2007-11-06*	88.0	160.0	-267.53	-279.92	*-224.28*
	4	1994-05-03	*2007-11-06*	6.0	87.0	-239.83	-253.50	*-224.28*
	1	*2007-11-06*		231.0	320.58	-318.23	-334.61	?
	2	*2007-11-06*		161.0	230.0	-293.11	-305.47	?
	3	*2007-11-06*		88.0	160.0	-267.53	-279.92	?
	4	*2007-11-06*		6.0	87.0	-239.83	-253.50	?
KA2048B	1	1994-12-12		149.5	184.45	-302.36	-305.35	*-289.19*
	2	1994-12-12		100.0	148.5	-293.69	-297.97	*-289.19*
	3	1994-12-12		50.5	99.0	-284.73	-289.16	*-289.19*
	4	1994-12-12		5.0	49.5	-276.35	-280.46	*-289.19*
KA2050A	1	1994-04-14		155.0	211.57	-400.25	-422.84	*-289.19*
	2	1994-04-14		102.0	154.0	-357.81	-378.65	*-289.19*
	3	1994-04-14		6.0	101.0	-280.61	-318.81	*-289.19*
KA2162B	1	1994-04-15		201.5	288.1	-342.47	-353.24	*-289.19*
	2	1994-04-15		143.0	200.5	-327.48	-334.87	*-289.19*
	3	1994-04-15		80.5	142.0	-311.17	-319.19	*-289.19*
	4	1994-04-15		40.0	79.5	-300.49	-305.70	*-289.19*
KA2511A	1	1999-03-16		239.0	293.0	-467.14	-481.94	-335.20
	2	1999-03-16		171.0	238.0	-429.93	-448.25	-335.20
	3	1999-03-16		139.0	170.0	-412.40	-420.90	-335.20
	4	1999-03-16		111.0	138.0	-397.01	-404.44	-335.20
	5	1999-03-16		103.0	110.0	-392.62	-394.54	-335.20
	6	1999-03-16		96.0	102.0	-388.77	-390.42	-335.20
	7	1999-03-16		65.0	95.0	-371.67	-379.95	-335.20
	8	1999-03-16		6.0	64.0	-339.17	-355.13	-335.43

Borehole	Section	Section installed		Borehole length		Elevation of *		
	no	from	to	from	to	SecTop	SecMid	Transducer
				(m)	(m)	(masl)	(masl)	(masl)
KA2563A	1	1999-03-15		242.0	246.0	-501.36	-502.65	-335.43
	2	1999-03-15		236.0	241.0	-497.48	-499.10	-335.43
	3	1999-03-15		206.0	208.0	-478.00	-478.65	-335.43
	4	1999-03-15		187.0	190.0	-465.58	-466.56	-335.43
	5	1999-03-15		146.0	186.0	-438.64	-451.81	-335.43
KA2598A	1	1999-05-12		0.0	300.77	-342.39	-421.96	-334.69
KA2858A	2	1995-02-23		39.77	40.77	-382.34	-382.37	-399.00
KA2862A	1	2002-03-22		0.0	15.98	-379.54	-380.66	-399.00
KA3005A	2	1995-12-07		46.78	50.03	-403.52	-403.64	-399.67
	3	1995-12-07		44.78	45.78	-403.37	-403.41	-399.67
	4	1995-12-07		39.03	43.78	-402.94	-403.12	-399.67
	5	1995-12-07		6.53	38.03	-400.38	-401.64	-399.67
KA3010A	2	1995-02-23		8.56	15.06	-400.58	-400.86	-399.67
KA3065A02	1	2000-09-05		21.0	69.95	-410.06	-412.42	*-407.89*
	2	2000-09-05		14.0	20.0	-409.46	-409.72	*-407.89*
	3	2000-09-05		7.5	13.0	-408.90	-409.14	*-407.89*
	4	2000-09-05		4.0	6.5	-408.59	-408.71	*-407.89*
KA3065A03	1	2002-06-28	*2007-04-17*	10.74	11.23	-408.90	-408.92	*-408.19*
	2	2002-06-28	*2007-04-17*	10.39	10.73	-408.89	-408.90	*-407.89*
	3	2002-06-28	*2007-04-17*	8.98	10.23	-408.80	-408.85	*-407.89*
	4	2002-06-28	*2007-04-17*	4.26	7.98	-408.43	-408.57	*-407.89*
	5	2002-06-28	*2007-04-17*	0.0	3.26	-408.09	-408.22	*-407.89*
	1	*2007-05-04*		*0.0*	*12.11*	*-408.09*	*-408.57*	*?*
KA3067A	1	1995-02-28		34.55	40.05	-411.50	-411.74	*-407.59*
	2	1995-02-28		30.55	33.55	-411.16	-411.29	*-407.59*
	3	1995-02-28		28.05	29.55	-410.95	-411.01	*-407.59*
	4	1995-02-28		6.55	27.05	-409.14	-410.00	*-407.59*
KA3068A	1	2001-11-22		0.0	16.85	-408.38	-407.97	*-407.59*
KA3105A	1	1995-03-01		53.01	68.95	-418.09	-418.81	-413.14
	2	1995-03-01		25.51	52.01	-415.78	-416.87	-413.14
	3	1995-03-01		22.15	24.51	-415.54	-415.62	-413.14
	4	1995-03-01		17.01	19.51	-415.09	-415.19	-413.14
	5	1995-03-01		6.51	16.01	-414.21	-414.61	-413.14
KA3110A	1	1995-02-23		20.05	26.83	-415.61	-415.94	-413.14
	2	1995-02-23		6.55	19.05	-414.32	-414.91	-413.14
KA3385A	1	1995-03-02		32.05	34.18	-448.30	-448.37	-445.94
	2	1995-03-02		7.05	31.05	-446.49	-447.36	-445.94
KA3386A01	*1*	*2006-01-30*		*2.12*	*65.11*	*-446.18*	*-447.31*	-446.08
KA3510A	1	2001-05-08		125.0	150.06	-511.24	-517.48	-447.96
	2	2001-05-08		110.0	124.0	-503.77	-507.26	-447.96
	3	2001-05-08		75.0	109.0	-486.30	-494.79	-447.96
	4	2001-05-08		51.0	74.0	-474.28	-480.04	-447.54
	5	2001-05-08		4.5	50.0	-450.96	-462.38	-447.54
KA3539G	1	2002-12-02		18.6	30.0	-467.53	-473.16	-446.93
	2	2002-12-02		15.85	17.6	-464.82	-465.68	-446.71
	3	2002-12-02		10.0	14.85	-459.05	-461.44	-446.50
	4	2002-12-02		4.0	9.0	-453.14	-455.60	-446.29

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of * SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3542G01	1	2002-11-13		27.0	30.0	-468.15	-469.21	-446.92
	2	2002-11-13		21.3	26.0	-464.12	-465.78	-446.71
	3	2002-11-13		18.6	20.3	-462.22	-462.82	-446.50
	4	2002-11-13		10.5	17.6	-456.49	-459.00	-446.29
	5	2002-11-13		3.5	9.5	-451.55	-453.67	-446.07
KA3542G02	1	2002-11-20		28.2	30.01	-468.73	-469.36	-446.92
	2	2002-11-20		25.6	27.2	-466.92	-467.48	-446.71
	3	2002-11-20		21.5	24.6	-464.06	-465.14	-446.50
	4	2002-11-20		9.0	20.5	-455.35	-459.36	-446.29
	5	2002-11-20		2.8	8.0	-451.02	-452.84	-446.07
KA3543A01	1	2002-01-30		0.65	2.06	-446.81	-446.82	-445.42
KA3543I01	1	2002-01-30		0.65	2.06	-443.47	-442.81	-445.64
KA3544G01	1	2002-11-12		11.65	12.0	-460.60	-460.78	-446.07
	2	2002-11-12		8.9	10.65	-457.85	-458.73	-445.86
	3	2002-11-12		3.5	7.7	-452.45	-454.55	-445.65
KA3546G01	1	2002-11-07		9.3	12.0	-458.19	-459.54	-446.92
	2	2002-11-07		6.75	8.3	-455.64	-456.42	-446.71
	3	2002-11-07		1.5	5.75	-450.39	-452.52	-446.50
KA3548A01	1	2002-11-28		21.5	30.0	-447.74	-447.97	-446.92
	2	2002-11-28		11.75	20.5	-447.21	-447.45	-446.70
	3	2002-11-28		8.8	10.75	-447.05	-447.11	-446.49
	4	2002-11-28		3.0	7.8	-446.74	-446.87	-446.28
KA3548D01	1	2002-01-30		0.65	2.06	-445.83	-445.80	-445.43
KA3548G01	1	2002-01-29		6.0	12.0	-455.00	-458.00	-445.85
	2	2002-01-29		2.0	5.0	-451.00	-452.50	-445.64
KA3550G01	1	2002-11-06		8.3	12.03	-457.07	-458.93	-445.85
	2	2002-11-06		2.0	7.3	-450.77	-453.42	-445.64
	3	2002-11-06		1.8	4.2	-450.57	-451.77	-445.43
KA3550G05	1	2002-01-29		1.5	3.0	-450.46	-451.21	-446.07
KA3551G05	1	2002-01-29		1.5	3.1	-450.41	-451.21	-446.28
KA3552A01	1	2002-01-30		0.65	2.06	-446.65	-446.69	-445.64
KA3552G01	1	*2003-04-27*		7.05	12.01	-455.82	-458.30	-446.92
	2	*2003-04-27*		4.35	6.05	-453.12	-453.97	-446.70
	3	*2003-04-27*		1.5	3.35	-450.27	-451.20	-446.49
KA3552H01	1	*2003-04-27*		0.0	2.1	-443.98	-443.09	-445.63
KA3553B01	1	2002-01-30		0.65	2.02	-446.95	-447.37	-445.43
KA3554G01	1	2002-11-27		25.15	30.01	-466.63	-468.35	-446.92
	2	2002-11-27		22.6	24.15	-464.82	-465.37	-446.70
	3	2002-11-27		14.0	21.6	-458.74	-461.43	-446.49
	4	2002-11-27		5.0	13.0	-452.37	-455.20	-446.28
	5	2002-11-27		1.5	4.0	-449.90	-450.78	-446.07
KA3554G02	1	2002-11-25		22.0	30.01	-464.37	-467.21	-446.92
	2	2002-11-25		15.9	21.0	-460.06	-461.86	-446.70
	3	2002-11-25		13.2	14.9	-458.15	-458.75	-446.50
	4	2002-11-25		10.5	12.2	-456.24	-456.84	-446.28
	5	2002-11-25		1.5	9.5	-449.88	-452.71	-446.07
KA3557G	1	2002-01-29		15.0	30.04	-463.68	-471.12	-446.92
	2	2002-01-29		1.5	14.0	-450.33	-456.51	-446.70
KA3563A01	1	2001-04-02		0.65	2.06	-447.15	-447.24	-445.49
KA3563D01	1	2001-04-02		0.65	2.0	-446.13	-446.10	-445.49

Borehole	Section	Section installed		Borehole length		Elevation of *		
	no	from	to	from	to	SecTop	SecMid	Transducer
				(m)	(m)	(masl)	(masl)	(masl)
KA3563G	1	2001-03-27		15.0	30.0	-463.46	-470.85	-445.93
	2	2001-03-27		10.0	13.0	-458.54	-460.02	-445.72
	3	2001-03-27		4.0	8.0	-452.63	-454.60	-445.94
	4	2001-03-27		1.5	3.0	-450.17	-450.91	-445.72
KA3563I01	1	2001-04-03		0.65	2.15	-443.02	-442.30	-445.70
KA3566C01	1	2001-04-02		0.65	2.1	-445.52	-445.48	-445.92
KA3566G01	1	2001-03-20		23.5	30.01	-465.14	-467.44	-447.00
	2	2001-03-20		20.0	21.5	-462.68	-463.20	-446.78
	3	2001-03-20		12.0	18.0	-457.03	-459.15	-446.57
	4	2001-03-20		7.3	10.0	-453.72	-454.67	-446.36
	5	2001-03-20		1.5	6.3	-449.62	-451.32	-446.14
KA3566G02	1	2001-03-20		19.0	30.01	-461.72	-465.53	-446.56
	2	2001-03-20		16.0	18.0	-459.64	-460.34	-446.35
	3	2001-03-20		12.0	14.0	-456.87	-457.57	-446.14
	4	2001-03-20		8.0	11.0	-454.11	-455.14	-445.93
	5	2001-03-20		1.5	6.0	-449.61	-451.16	-445.71
KA3568D01	1	2001-04-02		0.65	2.3	-445.86	-445.89	-445.49
KA3572G01	1	2001-03-21		7.3	12.0	-455.81	-458.16	-446.99
	2	2001-03-21		2.7	5.3	-451.21	-452.51	-446.78
KA3573A	1	2001-03-29		26.0	40.07	-447.03	-447.29	-446.35
	2	2001-03-29		21.0	24.0	-446.84	-446.90	-446.14
	3	2001-03-29		14.5	19.0	-446.60	-446.68	-445.93
	4	2001-03-29		10.5	12.5	-446.45	-446.49	-445.71
	5	2001-03-29		3.4	8.5	-446.19	-446.28	-445.50
KA3573C01	1	2001-04-02		0.65	2.05	-444.76	-444.36	-445.71
KA3574D01	1	2001-04-02		0.65	2.05	-444.98	-444.83	-445.92
KA3574G01	1	2001-03-07		8.0	12.0	-456.33	-458.33	-446.99
	2	2001-03-07		5.1	7.0	-453.43	-454.38	-446.78
	3	2001-03-07		1.8	4.1	-450.13	-451.28	-446.56
KA3576G01	1	2001-03-07		*7.87*	*12.01*	*-456.14*	*-458.21*	-446.56
	2	2001-03-07		*3.87*	*5.87*	*-452.14*	*-453.14*	-446.34
	3	2001-03-07		*1.37*	*2.87*	*-449.64*	*-450.39*	-446.13
KA3578C01	1	2001-04-03		0.65	2.09	-445.40	-445.47	-445.49
KA3578G01	1	2001-03-08		6.5	12.58	-454.88	-457.92	-446.98
	2	2001-03-08		4.3	5.5	-452.68	-453.28	-446.77
KA3578H01	1	2001-04-03		0.65	1.9	-442.82	-442.28	-445.70
KA3579D01	1	2001-04-03		0.65	2.0	-445.44	-445.45	-445.91
KA3579G	1	2001-03-08		14.7	22.65	-463.07	-467.04	-446.56
	2	2001-03-08		12.5	13.7	-460.87	-461.47	-446.35
	3	2001-03-08		2.5	11.5	-450.87	-455.37	-446.13
KA3584G01	1	2001-03-19		7.0	12.0	-455.25	-457.75	-446.98
	2	2001-03-19		1.4	5.0	-449.65	-451.45	-446.77
KA3588C01	1	2001-04-03		0.65	2.04	-445.49	-445.54	-445.49
KA3588D01	1	2001-04-03		0.65	1.9	-445.26	-445.28	-445.70
KA3588I01	1	2001-04-03		0.65	1.96	-442.75	-442.15	-445.91
KA3590G01	1	2001-02-28		16.0	*30.06*	-459.26	*-464.18*	-446.98
	2	2001-02-28		*7.0*	*15.0*	*-452.96*	*-455.76*	-446.78
	3	2001-02-28		*1.5*	*6.0*	*-449.11*	*-450.69*	-446.56

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of * SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3590G02	1	2001-03-06		*25.65*	*30.05*	*-465.84*	*-467.36*	-446.98
	2	2001-03-06		*15.35*	*23.65*	*-458.71*	*-461.58*	-446.77
	3	2001-03-06		*12.05*	*13.35*	*-456.42*	*-456.87*	-446.55
	4	2001-03-06		*1.65*	*10.05*	*-449.22*	*-452.13*	-446.34
KA3592C01	1	2001-04-03		0.63	2.1	-445.20	-445.15	-445.49
KA3593G	1	2001-02-27		25.2	30.02	-472.88	-475.25	-446.98
	2	2001-02-27		23.5	24.2	-471.21	-471.55	-446.76
	3	2001-02-27		9.0	22.5	-456.93	-463.58	-446.55
	4	2001-02-27		3.0	7.0	-451.03	-452.99	-446.34
KA3597D01	1	2001-04-03		0.65	2.22	-445.06	-445.02	-445.70
KA3597H01	1	2001-04-03		0.65	2.06	-442.64	-442.07	-445.91
KA3600F	1	2001-03-28		43.0	50.1	-446.86	-446.96	-446.98
	2	2001-03-28		40.5	42.0	-446.79	-446.81	-446.76
	3	2001-03-28		20.0	39.5	-446.18	-446.47	-446.55
	4	2001-03-28		3.4	18.0	-445.69	-445.91	-446.34
KF0051A01	1	*2006-04-19*		*10.55*	*11.7*	*-446.12*	*-445.84*	*-452.23*
	2	*2006-04-19*		*8.85*	*9.55*	*-446.97*	*-446.80*	*-452.23*
	3	*2006-04-19*		*6.26*	*7.85*	*-448.26*	*-447.87*	*-452.23*
	4	*2006-04-19*		*4.66*	*5.26*	*-449.06*	*-448.91*	*-452.23*
KF0069A01	1	2002-05-21		0.0	70.09	-454.82	-455.97	?
KG0021A01	1	2001-05-30		42.5	48.81	-432.25	-431.29	-447.00
	2	2001-05-30		37.0	41.5	-433.92	-433.24	-446.79
	3	2001-05-30		35.0	36.0	-434.53	-434.38	-446.58
	4	2001-05-30		19.0	34.0	-439.39	-437.11	-446.36
	5	2001-05-30		5.0	18.0	-443.64	-441.67	-446.15
KG0048A01	1	2001-05-29		49.0	54.69	-432.63	-431.95	-447.00
	2	2001-05-29		34.8	48.0	-436.07	-434.47	-446.79
	3	2001-05-29		32.8	33.8	-436.55	-436.43	-446.58
	4	2001-05-29		13.0	31.8	-441.34	-439.07	-446.36
	5	2001-05-29		5.0	12.0	-443.27	-442.43	-446.15
KI0010B01	1	*2007-05-29*	*2007-11-08*	*0.0*	*100.64*	*-446.01*	*-446.18*	*?*
KI0014B01	1	*2007-07-06*	*2007-10-29*	*0.0*	*100.27*	*-447.55*	*-447.82*	*?*
KI0016B01	1	*2007-06-15*	*2007-09-04*	*0.0*	*100.24*	*-446.06*	*-446.12*	*?*
KI0023B	1	1998-02-12		113.7	200.71	-488.30	-503.59	-448.21
	2	1998-02-12		111.25	112.7	-487.43	-487.69	-447.96
	3	1998-02-12		87.2	110.25	-478.84	-482.97	-447.96
	4	1998-02-12		84.75	86.2	-477.96	-478.22	-447.96
	5	1998-02-12		72.95	83.75	-473.73	-475.67	-447.96
	6	1998-02-12		70.95	71.95	-473.01	-473.19	-447.96
	7	1998-02-12		43.45	69.95	-463.15	-467.89	-447.96
	8	1998-02-12		41.45	42.45	-462.43	-462.61	-447.96
	9	1998-02-12		4.6	40.45	-449.32	-455.68	-447.96
KI0025F	1	1999-07-29		170.5	193.8	-502.58	-506.04	-448.21
	2	1999-07-29		165.5	169.5	-501.08	-501.68	-448.21
	3	1999-07-29		90.5	164.5	-478.18	-489.62	-448.21
	4	1999-07-29		87.5	89.5	-477.24	-477.55	-448.21
	5	1999-07-29		42.5	86.5	-462.70	-469.91	-448.21
	6	1999-07-29		5.0	41.5	-449.95	-456.23	-448.21

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of * SecTop (masl)	SecMid (masl)	Transducer (masl)
KI0025F02	1	2003-08-22		140.05	204.18	-506.37	-518.94	-447.35
	2	2003-08-22		135.1	139.05	-504.41	-505.20	-447.35
	3	2003-08-22		129.2	134.1	-502.07	-503.04	-447.35
	4	2003-08-22		100.25	128.2	-490.40	-496.07	-447.35
	5	2003-08-22		93.35	99.25	-487.58	-488.78	-447.35
	6	2003-08-22		78.25	92.35	-481.36	-484.26	-447.35
	7	2003-08-22		73.3	77.25	-479.31	-480.13	-447.35
	8	2003-08-22		64.0	72.3	-475.45	-477.18	-447.35
	9	2003-08-22		56.1	63.0	-472.17	-473.61	-447.35
	10	2003-08-22		3.4	55.1	-450.00	-460.97	-447.35
KI0025F03	1	2003-07-02		135.03	141.72	-513.20	-514.26	-447.96
	2	2003-07-02		129.03	134.03	-511.06	-512.25	-447.96
	3	2003-07-02		123.03	128.03	-508.20	-509.39	-447.96
	4	2003-07-02		93.53	122.03	-494.02	-500.89	-447.96
	5	2003-07-02		89.03	92.53	-491.84	-492.69	-447.96
	6	2003-07-02		75.03	88.03	-485.04	-488.20	-447.96
	7	2003-07-02		66.53	74.03	-480.89	-482.72	-447.96
	8	2003-07-02		59.53	65.53	-477.46	-478.93	-447.96
	9	2003-07-02		55.03	58.53	-475.26	-476.11	-447.96
KXTT1	1	1995-12-07		17.0	28.76	-404.27	-408.48	-399.00
	2	1995-12-07		15.0	16.0	-402.84	-403.20	-399.00
	3	1995-12-07		*7.5*	11.5	*-397.48*	-398.91	-399.00
	4	1995-12-07		3.0	*6.5*	-394.26	*-395.51*	-399.00
KXTT2	1	1995-12-06		16.55	18.3	-404.01	-404.63	-399.00
	2	1995-12-06		14.55	15.55	-402.61	-402.96	-399.00
	3	1995-12-06		11.55	13.55	-400.51	-401.21	-399.00
	4	1995-12-06		7.55	10.55	-397.72	-398.77	-399.00
	5	1995-12-06		3.05	6.55	-394.56	-395.79	-399.00
KXTT3	3	2005-10-26	*2007-04-12*	12.67	14.72	-398.68	-399.29	-399.67
	4	2005-10-26	*2007-04-12*	8.92	11.67	-396.43	-397.26	-399.67
	5	2005-10-26	*2007-04-12*	3.17	7.92	-392.98	-394.41	-399.67
KXTT4	3	2005-10-27	*2007-04-12*	11.67	13.68	-398.02	-368.62	-399.67
	4	2005-10-27	*2007-04-12*	8.42	10.67	-396.10	-396.76	-399.67
	5	2005-10-27	*2007-04-12*	3.17	7.42	-392.98	-394.24	-399.67
KXTT5	1	1999-12-14		10.81	*25.85*	-393.09	-395.05	-399.67
	2	1999-12-14		9.61	9.81	-392.78	-392.81	-399.67
	3	1999-12-14		6.11	8.61	-391.88	-392.20	-399.67
	4	1999-12-14		3.11	5.11	-391.10	-391.36	-399.67
SA3045A	1	2001-01-16		9.0	20.7	-407.05	-408.12	*-407.59*
	2	2001-01-16		6.0	8.0	-406.51	-406.69	*-407.59*
	3	2001-01-16		2.5	5.0	-405.87	-406.10	*-407.59*

Note - Data not relevant for 2007 is to be found in earlier annual reports.
* Measured in local system ÄSPÖ96. Elevation in RT90-RHB70 is obtained by adding 0.03 m.
Italics= This information is either uncertain or not available in the Sicada database.

3.4 Water flow in tunnel

3.4.1 Instrumentation

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

The tunnel sections, given as metres from the tunnel entrance, draining water to the various measurement ditches are listed in Table 3-6. The tunnel drainage system is illustrated in Figure 3-1. Normally, the gauging box is placed some 10 metres downward from the measurement ditch crossing the tunnel. Special arrangements are used to collect the water from the side tunnels containing the elevator and the ventilation shafts.

Table 3-6 Water flow measurements in tunnel segments.

Gauging box	Upper section (m)	Lower section (m)
MA0682G	0	682
MA1033G	682	1033
MA1232G	1033	1232
MA1372G	1232	1372
MA1584G	1372	1584
MA1659G	Water from the elevator shaft (TH: 0-213 m), from the ventilation shaft for incoming air (TV: 0-213 m) and from a sump inside the gate in the side tunnel at 1659 m.	
MA1745G	1584	1745
	Water from the side tunnel collected at MA1659G is not included.	
MA1883G	1745	1883
MA2028G	1883	2028
MA2178G	2028	2178
MA2357G	2178	2357
MA2496G	2357	2496
MA2587G	Water from the elevator shaft (TH: 220-333 m) and from a sump inside the gate in the side tunnel at 2587 m.	
MA2699G	2496	2699
	Water from the side tunnel collected at MA2587G is not included.	
MA2840G	2699	2840
MA2994G	2840	2994
MA3179G	2994	3179
MA3384G	Water from the elevator shaft (TH: 340-450 m), from the ventilation shaft for incoming air (TV: 220-450 m) and from the ventilation shaft for outgoing air (TW: 0-450 m)	
MA3411G	3179	3426
	Water from the side tunnel collected at MA3384G is not included.	
MA3426G	3426	3600
	Water from tunnel I and parts of tunnel J is included	

Gauging box	Upper section (m)	Lower section (m)
MA3515G	3515	3525
MA3525G	3525	3535
MA3535G	3535	3600
MF0061G	Water from tunnel F 0-61 m and parts of tunnel J	
MG0004G	Water from tunnel G	

Note – The water from MA3515G, MA3525G and MA3535G is collected in MA3426G.

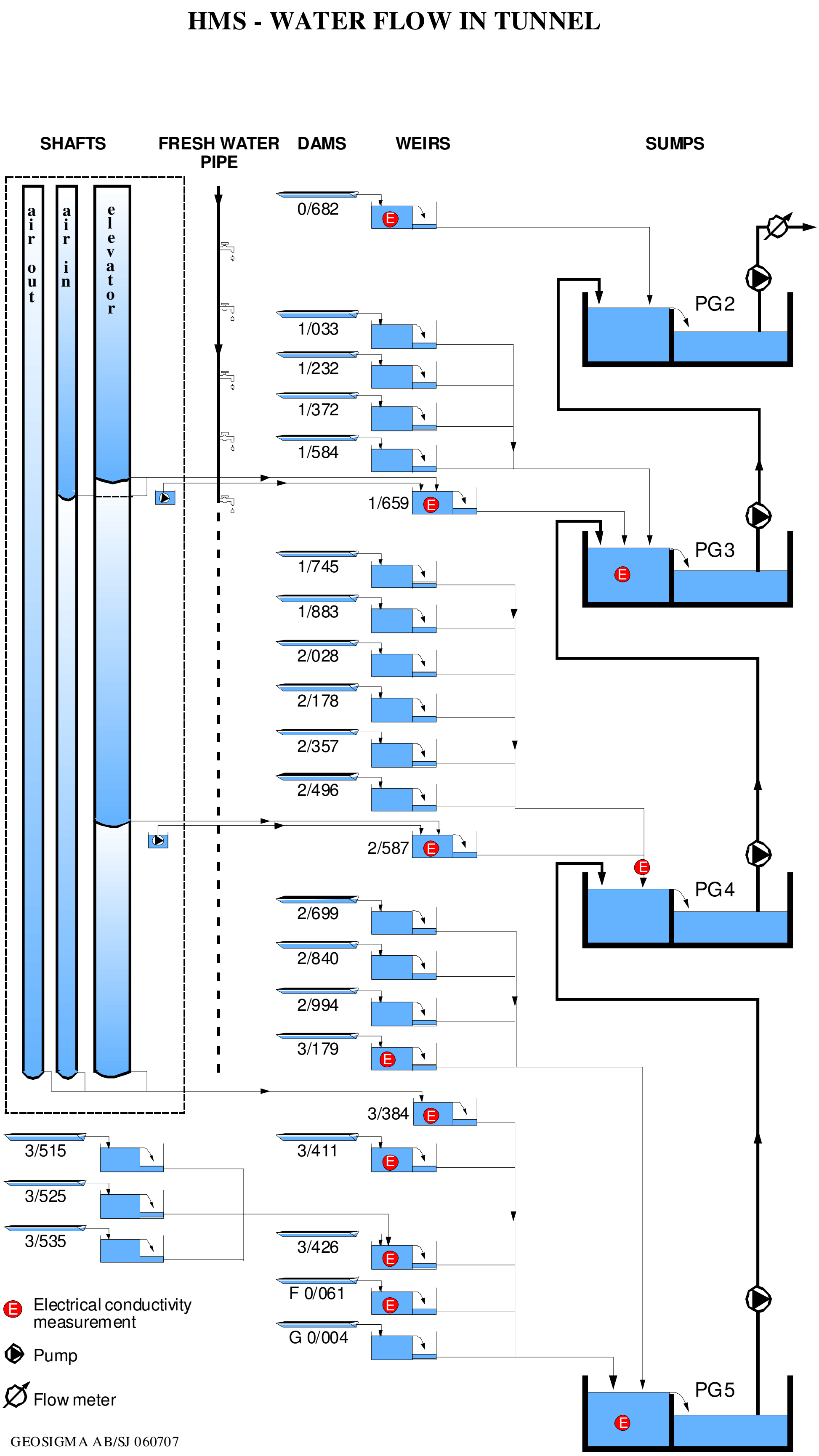

Figure 3-1 Schematic picture showing the tunnel drainage system.

3.4.2 Methodology

Water levels in the gauging boxes are used in the HMS to calculate flow rates by means of a discharge equation expressing flow rate as a function of the water level. Normally, the level is scanned every 10^{th} second but stored only once every hour unless the change since the latest stored value exceeds a pre-defined limit. The limit is usually set to 1 mm, but due to oscillating levels in some gauging boxes it has been necessary to increase this value to avoid sampling of too much data.

Initially, the discharge equation for a weir is determined. The flow rate is measured at four different levels on a ruler. The level indicator is then calibrated against the ruler by altering the level in the box. This two-step procedure is used to avoid a new determination of the discharge equation every time a level indicator has to be replaced and to make the discharge equation independent of changes in the calibration of the transducers.

The levels in the gauging boxes are manually read once every month to enable adjustments of the calibration constants for the level indicators. The discharge equations were checked through field measurements 2005 (see Wass et al. 2005).

3.4.3 Accuracy

If the flow rate does not differ too much from the flow interval for which the measurement points were selected to determine the calibration equation, the error is within approximately five percent.

However, maintenance of the v-notch weir is important. If there are obstacles or coatings on the weir, the relation between level and flow rate is disturbed.

3.5 Water flow in tunnel pipes

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

The flow in the pipe for pumped-out drainage water is measured with an acoustic "clamp-on" type flow meter. The sensor is situated approximately 700 m from the tunnel entrance. Until 1999-06-26, the flow of incoming consumption water was measured in the same way, but after a failure in the flow meter a decision was taken to not continue these measurements.

3.5.1 Methodology

The calibration constants given by the manufacturer do not provide the required accuracy. It is necessary to use material constants for different pipes and the errors caused by using the wrong constants are unknown. The pipes consist of different material layers, and might be coated on the inside. Therefore, due to these uncertainties, the flow meter is calibrated by measuring level changes in the uppermost pumping sump. (There are five sumps in the tunnel and the drainage water is pumped upwards from sump to sump until it is pumped out of the tunnel).

The flow is measured at a location some 10 metres above the top sump. The pump in each sump is working at maximum capacity until the sump is emptied and starts again when the sump is filled to a certain level. This means that the flow rate is either zero or at the maximum capacity of the pump. The flow meter was calibrated 2005 by measuring level changes per time in the sump (Wass et al. 2005). By knowing the water surface area in the sump at different levels one can calculate the discharged water.

The flow meter measurements are very frequent, every five seconds for discharged water, but the values are stored every 30 minutes unless a certain change has taken place.

3.6 Electrical conductivity of tunnel water

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

Electrical conductivity is measured with a 4-electrode conductivity meter, consisting of a housing with an electronic unit and an integrated sensor. The manufacturer gives an inaccuracy of maximum 0.5 % of the measured value plus 0.5 % of the measurement range. This gives a maximum error of 20 mS/m for most of the sensors.

The meter is mounted either in a gauging box for flow measurements, on the common discharge pipe leading water from the gauging boxes to the pumping sumps, or in a sump.

In Table 3-7, the tunnel parts from which water originates at the different measurement points are listed. Length to section is given in metres from the tunnel entrance.

Table 3-7 Electrical conductivity of water in tunnel segments.

Measurement point	Upper section (m)	Lower section (m)
EA0682G	0	682
EA1584T	682	1584
	Water from the gauging box MA1659G is included (see below).	
EA1659B	Water from the elevator shaft (TH: 0-213 m), from the ventilation shaft for incoming air (TV: 0-220 m) and from a sump inside the gate in the side tunnel at 1659 m.	
EA2496T	1584	2496
	Water from the gauging box MA1659G (see above) is excluded and water from the gauging box MA2587G is included (see below).	
EA2587G	Water from the elevator shaft (TH: 220-333 m) and from a sump inside the gate in the side tunnel at 2587 m.	
EA3179G	2994	3179
EA3384G	Water from the elevator shaft (TH: 340-450 m), from the ventilation shaft for incoming air (TV: 220-450 m) and from the ventilation shaft for outgoing air (TW: 0-450 m).	
EA3411G	3179	3426
	Water from the gauging box MA3384G is excluded (see above).	
EA3426G	3426	3600
	Water from tunnel I and parts of tunnel J is included.	
EF0061G	Water from tunnel F 0-61 m and parts of tunnel J.	
EPG5	Water below section 2496 m, excluding the water from the gauging box MA2587G, including the water from the gauging box MA3384G (see above).	

3.6.1 Methodology

A value is measured and stored once every two hours in the HMS. The four gauging boxes MA3384G, MA3411G, MA3426G and MF0061G are all situated near the sump PG5 in the bottom part of the tunnel, and a single electrical conductivity meter is used periodically in the different boxes and the sump.

The conductivity meters were calibrated 2005 by measuring three buffer fluids having well-defined electrical conductivity (Wass et al. 2005).

3.6.2 Accuracy

No careful error calculations have been carried out, but from the annual calibrations the uncertainty can be estimated to be approximately ±5 % of measured values. This includes all types of errors, for example coatings on the sensor, drift in calibration constants, error in the electrical conductivity of the buffer solutions, etc.

3.7 Temperature, humidity and pressure of tunnel air

3.7.1 Instrumentation

Places in the tunnel where air temperature, air humidity and air pressure are measured are listed in Table 3-8.

Table 3-8 Monitored temperature, relative humidity and pressure of tunnel air.

Tunnel	Position	Parameters	Measured from	to
A	1198A	Temp & RH	2007-03-30	
A	1354B	Temp & RH	2007-03-30	
A	1624A	Temp & RH	2007-11-08	
A	2513A	Temp & RH	2006-11-10	
A	2714A	Temp & RH	2006-11-10	
A	3134A	Temp & RH	2006-11-28	
A	3134A	Air pressure	2007-03-30	
D	0042A	Temp & RH	2006-11-29	
E	0008A	Temp & RH	2006-11-10	
F	0070B	Temp & RH	2006-11-10	
G	0047A	Temp & RH	2006-11-10	
J	0015A	Temp & RH	2006-11-10	
J	0049A	Temp & RH	2006-11-10	
Q	0054B	Temp & RH	2006-11-10	
Incoming air	TV (above ground)	Temp & RH	2007-12-06	
Incoming air	TV (above ground)	Air pressure	2007-12-06	
Outgoing air	TW (above ground)	Temp & RH	2007-12-06	
Outgoing air	TW (above ground)	Air pressure	2007-12-06	

3.8 Meteorological data

From 2006 the station used to collect meteorological data is a SMHI-station, Norra Äspö, situated at the northern part of Äspö. Data are quality checked by SMHI.

3.8.1 Precipitation

Precipitation data were obtained from the Oskarshamn station (SMHI no 7616) throughout 2005. The station is a regular SMHI-station, where a precipitation gauge with a wind shield (SMHI-type) is emptied at 0700 hours every day. Precipitation amounts always refer to the day before emptying the gauge.

The most important error in point measurements of precipitation is due to the wind. The wind error varies with type of precipitation, wind speed and site, but always results in a deficiency of catch. The error due to evaporation from the gauge is largest during warm summer days with showers. The loss is estimated to some 1.5 mm/month (Gottschalk, 1982) as a mean, although much depending on meteorological factors. All types of errors cause precipitation to be underestimated. For the Oskarshamn station the total correction needed have been estimated to +18 % (Eriksson, 1980) for the annual precipitation amount. All precipitation values in this report are measured values, without any corrections.

A much more difficult problem when dealing with precipitation data is the poor areal representativity of precipitation measurements, especially during showery conditions in the summer.

3.8.2 Temperature

Daily mean temperature values were obtained from the Oskarshamn station throughout 2005. These are evaluated by SMHI as a weighted mean of temperatures measured at 0700, 1300 and 1900 hours and the maximum and minimum temperatures.

Temperature is easier to measure than precipitation, and the areal representativity is normally much better. Therefore, the Oskarshamn measurements some 25 km away can be regarded as good estimates of the temperature at Äspö, especially since both sites are near-coastal and at nearly the same altitude.

3.8.3 Potential Evapotranspiration

Potential evapotranspiration[1] is calculated with the Penman formula. The required meteorological data are available only at a few synoptical stations. Until the 31st of July, 1995, when the station at Ölands Norra Udde was closed, all presented values were means of potential evapotranspiration calculated for Gladhammar and Ölands Norra Udde. Furthermore, the observations of cloudiness, which are used to obtain incoming short-wave radiation in Penmans formula, were ended for Gladhammar on the 30th of June, 1995. Therefore, from the 31st of July 1995 up to 2005, the potential evapotranspiration was calculated with data from Gladhammar but with cloudiness from Målilla some 50 km west of the Simpevarp area. Since the cloudiness at Målilla is greater than at the near coastal station in Gladhammar, this will result in lower calculated potential evapotranspiration.

Ölands Norra Udde and Gladhammar are situated approximately 25 and 35 km, respectively, from the study site.

Although actual evapotranspiration can show a rather large areal variation in the local scale, the potential evapotranspiration, depending mainly upon meteorological factors, does not vary that much. For long periods the actual evapotranspiration is almost the same as the potential, but during the summer months it does not reach the potential rate. The difference between the two very much depends on vegetation, ground conditions and the wetness situation in an area.

[1] The theoretical evapotranspiration from a surface completely covered by a homogenous surface of green vegetation (crop) experiencing no lack of soil water.

4 Summary of activities influencing groundwater levels, pressure and flow

4.1 General

One main purpose of this report is to give an overview of the long-term effect of the tunnel excavations on the groundwater situation in the area. Therefore, activities that might influence the groundwater pressure, groundwater levels and groundwater inflow to the tunnel are presented. The character and magnitude of the disturbances are different for different activities. Some might influence the groundwater pressure/level in many surrounding boreholes while others have influence only in the borehole where the activity takes place.

During the spring of 1991, the tunnel excavation began to have a visible effect on the groundwater level in many surface boreholes, especially on Äspö and Bockholmen. Later on most boreholes, except those on Laxemar, were influenced by the tunnel activities. From late 1991, the disturbances from the tunnel had a dominating influence on the groundwater levels in the area. One particular activity affecting the groundwater levels in many boreholes on Äspö was the drilling of the first of two raise-drilled ventilation shafts to the tunnel at the end of October 1992. After this event, the groundwater levels continued to decline in many borehole sections, but nothing as spectacular as in the late 1992 has occurred. Since 1996, the levels in most surface boreholes seem to have stabilised and the changes during 2007 were relatively small, within some metre in most boreholes. In the tunnel, the pressure in many of the borehole sections decreased by about 10 - 100 kPa during 2007, but there were also a large number of sections, mainly in the deeper part of the tunnel, with increasing pressure during the year.

A large number of activities, which may or may not have influenced the groundwater level/pressure and inflow to the tunnel, have been carried out during 2007. Over 3000 entries during 2007 can be found in the activity table in the SKB database SICADA. One should also expect that there are activities influencing groundwater conditions that are missing in the database. Because of the great number of activities in the database, only a selection of activities is presented in the following tables.

The activities, obtained from the SKB database SICADA, are listed in Tables 4-1 - 4-6. The dates stated in the tables are the dates for the actual activity. However, the influence on groundwater levels/pressures may last 5-10 times the length of the activity.

4.2 Tunnel excavation and permanent reinforcement

These activities, presented in Table 4-1, may have a substantial influence on ground water levels and pressures.

Table 4-1 Tunnel excavation and permanent reinforcements.

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2006-10-15	2008-03-13	TASA	1760.00	1780.00	Bolting
2006-10-15	2008-03-17	TASA	2200.00	2220.00	Bolting
2007-01-08	2007-01-09	TASA	480.00	500.00	Additional scaling
2007-01-10	2007-01-16	TASA	460.00	480.00	Additional scaling
2007-01-17	2007-01-17	TASA	440.00	460.00	Additional scaling
2007-01-22	2007-01-24	TASA	420.00	440.00	Additional scaling
2007-01-25	2007-06-18	TASA	400.00	420.00	Additional scaling
2007-02-06	2007-06-13	TASA	380.00	400.00	Additional scaling
2007-02-12	2007-06-12	TASA	360.00	380.00	Additional scaling
2007-02-13	2007-06-04	TASA	340.00	360.00	Additional scaling
2007-02-14	2007-05-31	TASA	240.00	260.00	Additional scaling
2007-02-14	2007-05-31	TASA	260.00	280.00	Additional scaling
2007-02-14	2007-06-03	TASA	320.00	340.00	Additional scaling
2007-02-15	2007-05-30	TASA	220.00	240.00	Additional scaling
2007-02-21	2007-05-23	TASA	180.00	200.00	Additional scaling
2007-02-21	2007-05-28	TASA	200.00	220.00	Additional scaling
2007-02-26	2007-05-21	TASA	160.00	180.00	Additional scaling
2007-02-28	2007-05-08	TASA	140.00	160.00	Additional scaling
2007-02-28	2007-05-18	TASA	120.00	140.00	Additional scaling
2007-03-05	2007-04-24	TASA	80.00	100.00	Additional scaling
2007-03-05	2007-04-26	TASA	100.00	120.00	Additional scaling
2007-03-06	2007-04-18	TASA	60.00	80.00	Additional scaling
2007-03-06	2008-03-12	TASD	0.00	20.00	Bolting
2007-03-06	2008-03-12	TASA	3160.00	3180.00	Bolting
2007-03-07	2007-05-10	TASI	0.00	20.00	Additional scaling
2007-03-08	2007-04-16	TASA	40.00	60.00	Additional scaling
2007-03-10	2008-03-12	TASA	2460.00	2480.00	Bolting
2007-03-10	2008-03-12	TASA	3080.00	3100.00	Bolting
2007-03-10	2008-03-13	NASA1757A			Bolting
2007-03-17	2008-03-17	TASA	660.00	680.00	Bolting
2007-03-17	2008-03-17	TASA	720.00	740.00	Bolting
2007-03-17	2008-03-17	TASA	1400.00	1420.00	Bolting
2007-03-17	2008-03-17	TASA	1520.00	1540.00	Bolting
2007-03-19	2007-03-19	TASA	40.00	60.00	Bolting
2007-03-19	2007-08-30	TASA	60.00	80.00	Bolting
2007-03-19	2007-08-30	TASA	80.00	100.00	Bolting
2007-03-20	2007-08-30	TASA	100.00	120.00	Bolting
2007-03-20	2007-08-30	TASA	120.00	140.00	Bolting
2007-03-20	2007-08-30	TASA	140.00	160.00	Bolting
2007-03-20	2007-08-30	TASA	160.00	180.00	Bolting
2007-03-20	2007-08-30	TASA	180.00	200.00	Bolting
2007-03-20	2007-08-30	TASA	220.00	240.00	Bolting

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2007-03-21	2007-03-22	TASA	360.00	380.00	Bolting
2007-03-21	2007-08-30	TASA	340.00	360.00	Bolting
2007-03-21	2008-03-19	TASA	360.00	380.00	Bolting
2007-03-22	2007-08-30	TASA	380.00	400.00	Bolting
2007-03-22	2007-08-30	TASA	400.00	420.00	Bolting
2007-03-22	2007-08-30	TASA	440.00	460.00	Bolting
2007-03-22	2007-08-30	TASA	460.00	480.00	Bolting
2007-03-26	2007-04-10	TASA	20.00	40.00	Additional scaling
2007-03-26	2007-08-30	TASA	480.00	500.00	Bolting
2007-03-26	2007-08-30	TASA	500.00	520.00	Bolting
2007-03-26	2007-08-30	TASA	520.00	540.00	Bolting
2007-03-26	2007-08-30	TASA	860.00	880.00	Bolting
2007-03-27	2007-03-27	TASA	0.00	20.00	Additional scaling
2007-03-27	2007-08-30	TASA	1720.00	1740.00	Bolting
2007-03-27	2007-08-30	TASA	1900.00	1920.00	Bolting
2007-03-27	2007-08-30	TASA	2100.00	2120.00	Bolting
2007-03-27	2007-08-30	TASA	2160.00	2180.00	Bolting
2007-03-27	2007-08-30	TASA	2260.00	2280.00	Bolting
2007-03-27	2007-08-30	NASA2198A			Bolting
2007-03-27	2007-08-30	NASA2376A			Bolting
2007-03-28	2007-08-30	TASA	2700.00	2720.00	Bolting
2007-03-28	2007-08-30	TASD			Bolting
2007-03-29	2007-07-02	TASA	160.00	180.00	Bolting
2007-04-17	2007-04-18	TASA	1760.00	1780.00	Additional scaling
2007-06-11	2007-06-14	TASK			Additional scaling
2007-06-18	2007-06-25	TASA	420.00	440.00	Additional scaling
2007-06-25	2007-06-27	TASA	440.00	460.00	Additional scaling
2007-06-28	2007-06-28	TASA	460.00	480.00	Additional scaling
2007-07-02	2007-07-03	TASA	480.00	500.00	Additional scaling
2007-07-03	2007-07-03	TASA	500.00	520.00	Additional scaling
2007-07-03	2007-07-04	TASA	520.00	540.00	Additional scaling
2007-07-04	2007-07-04	TASA	540.00	560.00	Additional scaling
2007-07-04	2007-07-04	TASA	560.00	580.00	Additional scaling
2007-07-04	2007-07-05	TASA	580.00	600.00	Additional scaling
2007-07-05	2007-07-09	TASA	600.00	620.00	Additional scaling
2007-07-09	2007-07-10	TASA	620.00	640.00	Additional scaling
2007-07-10	2007-07-10	TASA	640.00	660.00	Additional scaling
2007-07-10	2007-08-07	TASA	660.00	680.00	Additional scaling
2007-08-07	2007-08-08	TASA	680.00	700.00	Additional scaling
2007-08-08	2007-08-09	TASA	700.00	720.00	Additional scaling
2007-08-20	2007-08-20	TASA	720.00	740.00	Additional scaling
2007-08-21	2007-08-21	TASA	160.00	180.00	Rock reinforcement - net
2007-08-21	2007-08-21	TASA	760.00	780.00	Additional scaling
2007-08-21	2007-08-21	TASA	820.00	840.00	Additional scaling
2007-09-10	2007-09-27	TASD			Additional scaling
2007-09-11	2007-09-11	TASO			Additional scaling
2007-09-13	2007-09-27	TASZ			Additional scaling
2007-09-26	2007-09-26	TASA	3380	3400	Additional scaling
2007-09-26	2007-09-26	TASE			Additional scaling
2007-09-26	2007-10-04	NASA3384A			Additional scaling
2007-10-09	2008-03-26	TASA	0	20	Bolting
2007-10-09	2008-03-26	TASA	20	40	Bolting

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2007-10-09	2008-03-26	TASA	40	60	Bolting
2007-10-10	2008-03-19	TASA	160	180	Bolting
2007-10-10	2008-03-19	TASA	180	200	Bolting
2007-10-10	2008-03-26	TASA	60	80	Bolting
2007-10-10	2008-03-26	TASA	100	120	Bolting
2007-10-10	2008-03-26	TASA	120	140	Bolting
2007-10-11	2008-03-19	TASA	220	240	Bolting
2007-10-11	2008-03-19	TASA	240	260	Bolting
2007-10-16	2008-03-12	TASL	0	5	Bolting
2007-10-22	2007-12-03	TASA	3500	3520	Bolting
2007-10-30	2007-12-03	NASA3384A			Bolting
2007-10-31	2007-11-14	NASA3384A			Bolting
2007-11-05	2007-11-05	NASA2156B			Additional scaling
2007-11-14	2007-11-14	TASF	3384	3384	Bolting
2007-11-15	2007-11-15	NASA3384A			Rock reinforcement - net
2007-12-10	2007-12-10	TASS	2	6.1	Round Drilling
2007-12-10	2007-12-10	TASS	2	2	Round Drilling
2007-12-11	2007-12-11	TASS	2	6.1	Charging
2007-12-11	2007-12-11	TASS	2	6.1	Round
2007-12-11	2007-12-11	TASS	2	6.1	Ventilation
2007-12-12	2007-12-12	TASS			Mucking
2007-12-12	2007-12-12	TASS			Round Drilling
2007-12-17	2007-12-17	TASS			Mucking
2007-12-17	2007-12-17	TASS	6.16	8.47	Charging
2007-12-17	2007-12-17	TASS	6.16	8.47	Round
2007-12-18	2007-12-18	TASS	6.16	8.47	Charging
2007-12-18	2007-12-18	TASS	6.16	8.47	Round
2007-12-18	2007-12-18	TASS			Mucking
2007-12-19	2007-12-19	TASS	6.16	8.47	Charging
2007-12-19	2007-12-19	TASS	6.16	8.47	Round
2007-12-19	2007-12-19	TASS			Mucking

4.3 Opening of valves in tunnel boreholes

The main reason for valve openings in boreholes is water sampling for chemical analyses. Usually, before water samples are taken from a tunnel borehole section, a certain amount of water is discharged to assure that the water is representative for that section. Typically, for chemical sampling, a volume corresponding to five section volumes is discharged. When a valve is opened, the flow rate may vary a lot from section to section due to different transmissivities and pressures. Normally, this type of valve openings has only a minor influence on other boreholes. Therefore, only openings and closures in borehole sections included in the monitoring program are listed in Table 4-2, in which dates when valves have been open are listed. In some cases, due to missing data records, only start or stop date is listed. Since the opening and closing of a valve are un-coupled activities in the database it is also possible, if two successive data records are missing, that the "from" and "to" dates do not match.

Table 4-2 Open valves in tunnel boreholes.

From	To	Borehole:sec
2007-01-09	2007-01-09	KA3539G:
2007-01-09	2007-01-09	KA3548A01:
2007-01-09	2007-01-09	KA3554G01:
2007-01-09	2007-01-09	KA3600F:
2007-01-10	2007-01-10	KA3542G01:
2007-01-10	2007-01-10	KG0021A01:
2007-01-10	2007-01-10	KG0048A01:
2007-01-10	2007-01-11	KA3566G02:
2007-01-10	2007-01-15	KA3590G01:
2007-01-10	2007-01-16	KA3572G01:
2007-01-11	2007-01-15	KA3542G02:
2007-01-11	2007-01-16	KA3554G02:
2007-03-23		KA2563A:1
2007-06-26	2007-06-29	KI0010B01:
2007-06-26	2007-06-29	KI0016B01:
2007-07-03	2007-07-03	KI0010B01:
2007-07-03	2007-07-03	KI0016B01:
2007-07-04	2007-07-04	KI0016B01:
2007-07-05	2007-07-05	KI0010B01:
2007-07-09	2007-07-09	KI0010B01:
2007-07-09	2007-07-13	KI0016B01:
2007-07-13		KI0010B01:
2007-07-16	2007-07-17	KI0010B01:
2007-07-17	2007-07-17	KI0014B01:
2007-07-18	2007-07-19	KI0014B01:
2007-07-19		KI0014B01:
2007-09-24	2007-09-24	HD0025A:
2007-09-24	2007-09-26	KA1061A:
2007-09-27	2007-09-27	KA2162B:
2007-09-27	2007-09-27	KA3600F:
2007-09-27	2007-09-28	KA3573A:

From	To	Borehole:sec
2007-10-02	2007-10-03	KA1755A:3
2007-10-02	2007-10-03	KA3600F:
2007-10-08	2007-10-08	SA3045A:2
2007-10-10	2007-10-10	KA3110A:1
2007-10-10	2007-10-10	KA3385A:1
2007-10-15	2007-10-15	KA3539G:2
2007-10-15	2007-10-15	KA3539G:2
2007-10-15	2007-10-15	KA3542G01:3
2007-10-15	2007-10-15	KA3554G01:2
2007-10-16	2007-10-16	KA3539G:2
2007-10-16	2007-10-16	KA3542G01:3
2007-10-16	2007-10-16	KA3548A01:3
2007-10-16	2007-10-16	KA3548A01:3
2007-10-16	2007-10-16	KA3554G01:2
2007-10-16	2007-10-16	KA3554G02:4
2007-10-17	2007-10-17	KA3542G01:3
2007-10-17	2007-10-17	KA3546G01:2
2007-10-17	2007-10-17	KA3548A01:3
2007-10-17	2007-10-17	KA3554G01:2
2007-10-18	2007-10-18	KA3542G02:2
2007-10-18	2007-10-18	KA3548A01:3
2007-10-18	2007-10-18	KA3552G01:2
2007-10-18	2007-10-18	KA3554G02:4
2007-10-19	2007-10-19	KA2050A:2
2007-10-19	2007-10-19	KA3542G02:2
2007-10-22	2007-10-24	KA2050A:2
2007-11-09	2007-11-09	KA3110A:
2007-11-12	2007-11-16	KA3110A:
2007-12-04	2007-12-04	HD0025A:

4.4 Packer expansion and release

Packers often isolate different fractures or fracture zones from each other in order to prevent flow along the borehole, which otherwise may act as a connection between fractures or zones. Therefore, release and expansion of packers may have an influence on the groundwater system. The dates for packer expansion/release in surface boreholes are listed in Table 4-3 (this refers to the large borehole packers and not the PEM-packers). Surface boreholes not included in the table have no packers.

In Table 4-4, dates for packer expansion and release in tunnel boreholes are presented. In a few cases, data on expansion/release are missing in the database, which means that two entries for packer expansion or release may occur after one another.

Table 4-3 Packer expansion and release in surface boreholes.

Borehole	Expansion	Release
HBH04	2002-02-28	
KAS03	2000-10-09	*2005-07-04*
KAS09	1990-01-01	
KAS16	1992-10-20	
KBH02	1992-05-07	

Italics = This information is not found in the Sicada database

Table 4-4 Packer expansion and release in tunnel boreholes.

Borehole	Expansion	Release
HA1273A	1992-03-12	
HA1278A	1992-09-10	
HA1279A	1992-09-10	
HA1283B	1992-04-15	
HA1327B	1992-09-11	
HA1330B	1992-09-11	
HD0025A	1996-06-02	
KA1061A	1992-01-14	
KA1131B	1992-02-02	
KA1751A	2002-01-30	
KA1754A	2002-01-30	
KA1755A	2003-05-06	
KA2048B	2002-01-11	
KA2050A	2001-12-13	
KA2162B	1999-10-28	
KA2511A	1999-03-17	
KA2563A	1999-03-15	
KA2598A	1998-03-04	
KA2858A	2002-01-11	
KA2862A	2002-03-22	
KA3005A	2001-11-07	
KA3010A	2004-06-29	
KA3065A02	2002-06-29	
KA3065A03	2002-06-28	
KA3067A	2002-06-29	

Borehole	Expansion	Release
KA3068A	2002-06-29	
KA3105A	2001-12-19	
KA3110A	2004-06-29	
KA3385A	2003-05-06	
KA3386A01	2005-12-05	
KA3510A	2001-05-09	
KA3539G	2002-12-03	
KA3542G01	2003-04-26	
KA3542G02	2003-04-26	
KA3543A01	2002-01-30	
KA3543I01	2002-01-30	
KA3544G01	2002-11-12	
KA3546G01	2003-04-26	
KA3548A01	2003-04-26	
KA3548D01	2002-01-30	
KA3548G01	2002-01-30	
KA3550G01	2003-04-27	
KA3550G05	2002-01-29	
KA3551G05	2003-04-27	
KA3552A01	2002-01-30	
KA3552G01	2000-06-07	
KA3552H01	2002-12-01	
KA3553B01	2002-01-30	
KA3554G01	2003-04-27	
KA3554G02	2003-04-27	

Borehole	Expansion	Release
KA3557G	2002-01-29	
KA3563A01	2001-04-02	
KA3563D01	2001-04-02	
KA3563G	2001-03-27	
KA3563I01	2001-04-03	
KA3566C01	2001-04-02	
KA3566G01	2001-03-20	
KA3566G02	2001-03-20	
KA3568D01	2001-04-02	
KA3572G01	2001-03-21	
KA3573A	2001-03-29	
KA3573C01	2001-04-02	
KA3574D01	2001-04-02	
KA3574G01	2001-03-07	
KA3576G01	2001-03-07	
KA3578C01	2001-04-03	
KA3578G01	2001-03-08	
KA3578H01	2001-04-03	
KA3579D01	2001-04-03	
KA3579G	2001-03-08	
KA3584G01	1999-02-03	
KA3588C01	2001-04-03	
KA3588D01	2001-04-03	

Borehole	Expansion	Release
KA3588I01	2001-04-03	
KA3590G01	2001-02-28	
KA3590G02	2001-03-06	
KA3592C01	2001-04-03	
KA3593G	2001-02-27	
KA3597D01	2001-04-03	
KA3597H01	2001-04-03	
KA3600F	2001-03-28	
KF0051A01	2006-01-20	
KF0069A01	2002-05-21	
KG0021A01	2001-05-30	
KG0048A01	2001-05-29	
KI0023B	1998-06-17	
KI0025F	1999-07-28	
KI0025F02	2003-09-02	
KI0025F03	2003-06-25	
KXTT1	2001-11-07	
KXTT2	2005-11-18	
KXTT3	2005-10-26	
KXTT4	2005-10-27	
KXTT5	2004-06-30	
SA3045A	2002-06-29	

4.5 Drilling

Only tunnel boreholes have been drilled during 2007 within the Äspö Hard Rock Laboratory.

During drilling, water is injected under high pressure into the borehole, and the effect at different locations in the borehole may be either injection or removal of water. During drilling interruptions, water flows out of the borehole and the net result on pressure registrations mainly seems to be a pumping effect. In Table 4-5, dates when boreholes were drilled, borehole length and type of drilling are presented. Drilling before rounds and drilling for bolting are not included in the table.

Table 4-5 Drilling

Start	Stop	Borehole	Borehole length (m)	Type of drilling
2007-03-12	2007-03-12	KI0010B01	2.91	Core drilling
2007-03-13	2007-03-14	KI0016B01	2.30	Core drilling
2007-03-19	2007-03-20	KI0014B01	2.30	Core drilling
2007-04-11	2007-04-21	KI0010B01	100.64	Core drilling
2007-04-26	2007-05-03	KA3065A03	12.11	Core drilling
2007-05-12	2007-06-07	KXTT3	17.43	Core drilling
2007-06-01	2007-06-08	KI0016B01	100.24	Core drilling
2007-06-14	2007-06-18	KI0014B01	100.27	Core drilling
2007-08-01	2007-08-16	KXTT4	13.60	Core drilling
2007-08-23	2007-08-30	DK0025G01		Various drilling
2007-08-29	2007-08-31	DA1622A01		Various drilling
2007-08-29	2007-08-31	DA1622A01		Various drilling
2007-11-13	2007-11-13	SS0004A05	7.89	Percussion drilling

Start	Stop	Borehole	Borehole length (m)	Type of drilling
2007-11-13	2007-11-13	SS0004A09	8.00	Percussion drilling
2007-11-13	2007-11-13	SS0004A13	8.00	Percussion drilling
2007-11-13	2007-11-13	SS0004C01	8.50	Percussion drilling
2007-11-13	2007-11-13	SS0004A01	8.53	Percussion drilling
2007-11-13	2007-11-13	SS0004G21	11.50	Percussion drilling
2007-11-13	2007-11-13	SS0004H03	9.50	Percussion drilling
2007-11-13	2007-11-13	SS0004H07	10.00	Percussion drilling
2007-11-13	2007-11-13	SS0004H11	10.50	Percussion drilling
2007-11-13	2007-11-13	SS0004G17	11.27	Percussion drilling
2007-11-14	2007-11-14	SS0004I07	10.50	Percussion drilling
2007-11-14	2007-11-14	SS0004I03	10.50	Percussion drilling
2007-11-14	2007-11-14	SS0004D01	11.00	Percussion drilling
2007-11-14	2007-11-14	SS0004B16	11.00	Percussion drilling
2007-11-14	2007-11-14	SS0004B12	10.99	Percussion drilling
2007-11-14	2007-11-14	SS0004B08	10.99	Percussion drilling
2007-11-14	2007-11-14	SS0004B04	11.44	Percussion drilling
2007-11-14	2007-11-14	SS0004G01	11.36	Percussion drilling
2007-11-14	2007-11-14	SS0004G05	11.49	Percussion drilling
2007-11-14	2007-11-14	SS0004G09	10.99	Percussion drilling
2007-11-14	2007-11-14	SS0004G13	11.09	Percussion drilling
2007-12-03	2007-12-03	SS0004A03	7.96	Percussion drilling
2007-12-03	2007-12-03	SS0004A07	8.00	Percussion drilling
2007-12-03	2007-12-03	SS0004A15	8.00	Percussion drilling
2007-12-03	2007-12-03	SS0004G23	11.50	Percussion drilling
2007-12-03	2007-12-03	SS0004G19	11.50	Percussion drilling
2007-12-03	2007-12-03	SS0004G15	11.00	Percussion drilling
2007-12-03	2007-12-03	SS0004H09	10.00	Percussion drilling
2007-12-03	2007-12-03	SS0004I01	10.50	Percussion drilling
2007-12-03	2007-12-03	SS0004B14	11.00	Percussion drilling
2007-12-03	2007-12-03	SS0004B02	11.49	Percussion drilling
2007-12-03	2007-12-03	SS0004G03	11.40	Percussion drilling
2007-12-03	2007-12-03	SS0004G07	11.50	Percussion drilling
2007-12-03	2007-12-03	SS0004G11	11.00	Percussion drilling
2007-12-06	2007-12-06	SS0004A02	8.66	Percussion drilling
2007-12-06	2007-12-06	SS0004G24	8.00	Percussion drilling
2007-12-06	2007-12-06	SS0004G22	11.00	Percussion drilling
2007-12-06	2007-12-06	SS0004I02	10.50	Percussion drilling

4.6 Tests

A number of different tests are described below. However, during 2007 only a few of the tests have been performed.

Tracer tests are performed in a number of different ways:

Dilution test is a single-hole test where the tracer is circulated in one section. No water is withdrawn or added to the circulation section (except for a small amount of tracer solution). The test is performed during either natural or stressed hydraulic gradient.

During ***radially converging or dipole tests*** water is pumped out of one section and tracer injected in another section. In radially converging tests, there is usually no excess pressure in the injection section while during dipole tests a certain injection flow is maintained during the test.

Flow logging means that a single or a pair of packers is expanded at certain intervals in the borehole and the flow rate from inside/between the packers is measured.

Interference tests mean that pumping or flowing is done in one borehole section to induce and study responses in other sections. The length of such a test and the magnitude of flow may vary over a wide range.

Pressure build-up test (PBT). The borehole is discharged between 30 minutes and a few hours before the valve is closed and the pressure recovery is studied.

Recovery test. A hydraulic test where the recovery after withdrawal of water is studied.

Constant pressure test is a hydraulic test where water is either injected or withdrawn from a test section of a borehole under constant pressure. This type of tests may be performed in several ways:

Transient injection test. A hydraulic test where water is injected under constant pressure. Transient evaluation.

Steady state injection test. A hydraulic test performed in a similar way as a transient injection test but generally of shorter duration. Steady state evaluation.

Pulse injection test is a type of water injection test where the test section is short (50 mm) and the injection under constant pressure is performed during only a few minutes (a pulse).

Constant flow test. A hydraulic test performed in the same way as a constant pressure test, but instead of pressure, the flow rate is held constant.

Outflow tests with constant flow or constant pressure are equivalent to pumping tests in a surface borehole.

Slug test is a type of disturbance test**.** This type of slug test is performed by expanding a double packer at certain intervals in the borehole. The pressure in the section between the packers is increased momentary and the recovery is then studied during 5-20 minutes.

Table 4-6 Tests

From	To	Borehole:sec	Borehole length (m) from	to	Activity
2007-04-13	2007-04-14	KI0010B01:	15.00	29.19	Pressure Build Up Test (PBT)
2007-05-21	2007-05-22	KI0010B01:	2.80	100.00	Pumping test-submersible pump
2007-05-21	2007-05-22	KI0010B01:	0.96	99.76	Flowlogging-PFL-DIFF_overlapping
2007-06-02	2007-06-03	KI0016B01:	7.40	17.13	Pressure Build Up Test (PBT)
2007-06-03	2007-06-04	KI0016B01:	19.40	31.85	Pressure Build Up Test (PBT)
2007-06-04	2007-06-05	KI0016B01:	31.40	43.30	Pressure Build Up Test (PBT)
2007-06-05	2007-06-06	KI0016B01:	54.00	62.73	Pressure Build Up Test (PBT)
2007-06-06	2007-06-07	KI0016B01:	73.00	80.63	Pressure Build Up Test (PBT)
2007-06-07	2007-06-08	KI0016B01:	86.00	94.65	Pressure Build Up Test (PBT)
2007-06-08	2007-06-09	KI0016B01:	90.00	100.24	Pressure Build Up Test (PBT)
2007-07-10	2007-07-12	KI0016B01:	3.50	93.50	Double packer flow logging
2007-07-16	2007-07-17	KI0010B01:	4.00	97.00	Double packer flow logging
2007-07-18	2007-07-19	KI0014B01:	4.50	97.50	Double packer flow logging
2007-10-09	2007-10-09	DA1619A02:1	5.74	4.15	Pressure Build Up Test (PBT)
2007-10-10	2007-10-10	DA1619A02:2	7.42	5.83	Pressure Build Up Test (PBT)
2007-10-15	2007-10-15	KA3554G01:2	22.60	24.15	Pressure Build Up Test (PBT)
2007-10-15	2007-10-15	KA3539G:2	15.85	17.60	Pressure Build Up Test (PBT)
2007-10-15	2007-10-15	KA3542G01:3	18.60	20.30	Pressure Build Up Test (PBT)
2007-10-16	2007-10-16	KA3554G02:4	10.50	12.20	Pressure Build Up Test (PBT)
2007-10-16	2007-10-16	KA3554G01:2	22.60	24.15	Pressure Build Up Test (PBT)
2007-10-16	2007-10-16	KA3539G:2	15.85	17.60	Pressure Build Up Test (PBT)
2007-10-16	2007-10-16	KA3548A01:3	8.80	10.75	Pressure Build Up Test (PBT)
2007-10-16	2007-10-16	KA3542G01:3	18.60	20.30	Pressure Build Up Test (PBT)
2007-10-17	2007-10-17	KA3548A01:3	8.80	10.75	Pressure Build Up Test (PBT)
2007-10-17	2007-10-17	KA3554G01:2	22.60	24.15	Pressure Build Up Test (PBT)
2007-10-17	2007-10-17	KA3554G02:4	10.50	12.20	Pressure Build Up Test (PBT)
2007-10-17	2007-10-17	KA3546G01:2	6.75	8.30	Pressure Build Up Test (PBT)
2007-10-17	2007-10-17	KA3542G01:3	18.60	20.30	Pressure Build Up Test (PBT)
2007-10-18	2007-10-18	KA3548A01:3	8.80	10.75	Pressure Build Up Test (PBT)
2007-10-18	2007-10-18	KA3552G01:2	4.35	6.05	Pressure Build Up Test (PBT)
2007-10-18	2007-10-18	KA3542G02:2	25.60	27.20	Pressure Build Up Test (PBT)
2007-10-19	2007-10-19	KA3542G02:2	25.60	27.20	Pressure Build Up Test (PBT)
2007-11-13	2007-11-13	DA1619A02:3	37.05	35.46	Pressure Build Up Test (PBT)
2007-11-13	2007-11-13	DA1619A02:4	54.09	52.50	Pressure Build Up Test (PBT)
2007-11-13	2007-11-14	DA1619A02:5	62.59	61.00	Pressure Build Up Test (PBT)
2007-11-14	2007-11-14	DA1619A02:5	62.59	61.00	Pressure Build Up Test (PBT)

5 Results

5.1 Groundwater levels in surface boreholes

In most surface boreholes, there have only been small changes in groundwater levels during 2007. In most of the borehole sections, the change over the year is within some metre with both increasing and decreasing levels.

The response to precipitation varies from borehole to borehole. In some boreholes, there is a fairly quick response with pronounced peeks after each rain (for example HAS01 and HAS13). In other boreholes, the response is more or less dampened (for example HAS21), while in some sections it is difficult to see any responses to rain at all. The dominating features of the seasonal variation during 2007 are high precipitation during June and July and low precipitation in April (see Figure 5-2).

In the short term, the groundwater levels in surface boreholes seem to be influenced mainly by variations in climate factors. However, in borehole HAS06 a pronounced effect from tunnel activities can be seen. As seen earlier, the groundwater level in HAS06 responds to activities in the tunnel borehole KA3065A03 and its surrounding boreholes. In addition, there are probably minor responses also in other boreholes due to tunnel activities.

5.2 Groundwater pressure in tunnel boreholes

In the tunnel, the pressure in many of the borehole sections decreased by about 10 - 100 kPa during 2007. However, there were also a large number of sections, mainly in the Prototype area in the deeper part of the tunnel, with increasing pressure during the year. Due to a lot of activities in the tunnel (for example blasting of a new tunnel, drilling, packer expansion and releases, opening, closing and pumping different boreholes), it is difficult to say whether the pressure changes are “natural” or due to the activities. Seen over the last years, the pressure has been steadily decreasing in most of the boreholes except during 2003 when many borehole sections showed increasing pressure.

Some activities during the year causing major disturbances, as seen in many boreholes, in the tunnel were:

- Over-core drilling and re-installation/un-installation of boreholes KA3065A03, KXTT3 and KXTT4 in **April** through **May**.
- Drilling of boreholes KI0010B01, KI0014B01 and KI0016B01 with subsequent activities (pressure build up tests, flow logging etc.) in **April** through **July**.
- Due to a computer error at a measurement station (HMSC), data are missing for **some days in May, June and August** for the boreholes connected to this station.
- Blasting of a new tunnel, TASS, at the -450 m level, starting in **November**.

5.3 Water flow in the tunnel

The flow in all gauging boxes is shown in Figure 5-1 as daily mean values during October - December 2007. For comparison purposes, data for the corresponding period during the years 1995-2006 are also illustrated. Although data is missing for some boxes for certain periods (especially during 1995 and 1996), the diagram gives realistic values since the flow has been fairly constant during the period presented.

Figure 5-1 shows that, seen over all years, the mean flow for the comparison period October – December has decreased at most locations. However, during 2007 there is an increase in some of the gauging boxes, especially the ones located in the deepest part of the tunnel. This may be a result of the new excavation of a side tunnel and drilling of new boreholes, plus the addition of external water in connection to these and other activities.

In January 2002, a new gauging box, MG0004G, was installed. The water from the G-tunnel, earlier collected in the gauging box MF0061G, is now lead to MG0004G. As a result, a decrease in flow in MF0061G was noted and this also explains the low values for year 2002 and forward in Figure 5-1.

In February 2004, measurements were started in three new weirs, MA3515G, MA3525G and MA3535G. These weirs are collecting water from various sections in the Prototype repository tunnel. The accuracy of the flow calculations for these weirs is very low, the error may be on the order of a factor 10 and almost always resulting in flow values that are too high. However, the water passing the three new weirs flows into gauging box MA3426G, as it was before the new weirs were installed.

From August 2007 all values from MA3515G are missing due to erroneous values from the water level gauge.

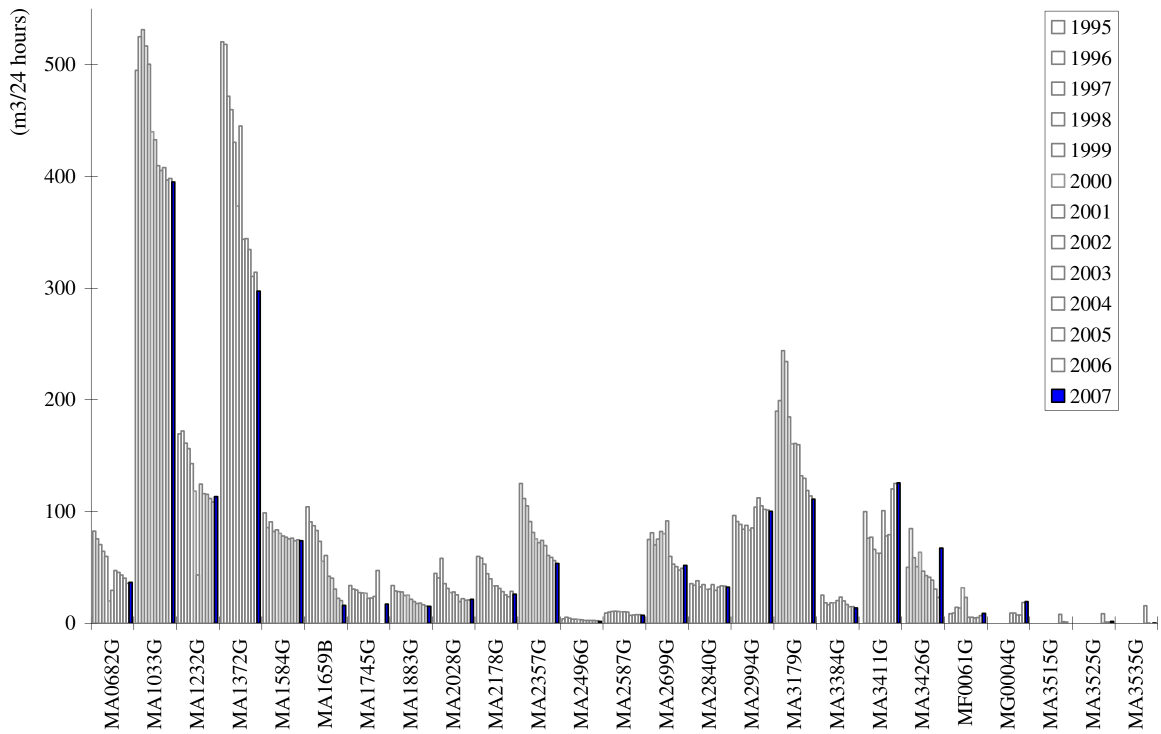

Figure 5-1 Water flow in gauging boxes as a mean during October - December.

5.4 Water flow in tunnel pipes

The pumped flow rate out from the tunnel has been decreasing steadily since 1995, but it has increased during 2007.

The mean daily flow of water in the pipes during October - December for the last thirteen years are given in Table 5-1.

Table 5-1 Water flow in tunnel pipes, October - December.

Year	Water in (m^3/d)	Water out (m^3/d)
1995	4.4	2479
1996	9.6	2438
1997	11.0	2393
1998	9.2	2268
1999	—	2105
2000	—	1930
2001	—	1848
2002	—	1821
2003	—	1748
2004	—	1730
2005	—	1697
2006	—	1686
2007	—	1702

5.5 Electrical conductivity of tunnel water

Electrical conductivity of tunnel water has been measured in eight gauging boxes for flow measurements, at one location along the discharge pipe leading water from the gauging boxes to one of the sumps and in two of the sumps (see section 3.6).

The same electrical conductivity meter is used for periods in the four gauging boxes MA3384G, MA3411G, MA3426G, MF0061G and in the sump PG5, all in the deepest part of the tunnel system.

5.6 Temperature, humidity and pressure of tunnel air

Temperature and relative humidity of tunnel air are measured at thirteen places in the Äspö tunnel, starting in November 2006 (see section 3.7). Also, measurements are made of incoming and outgoing air in the ventilation shafts. At three of these positions air pressure is also measured.

5.7 Precipitation

Precipitation at the SMHI stations at Norra Äspö for 2006-2007 and in Oskarshamn for 1987-2005, as well as means for Oskarshamn for the period 1961-1990, are presented in Figures 5-2 and 5-3. All precipitation values are measured values without any corrections. See also section 3.8.1.

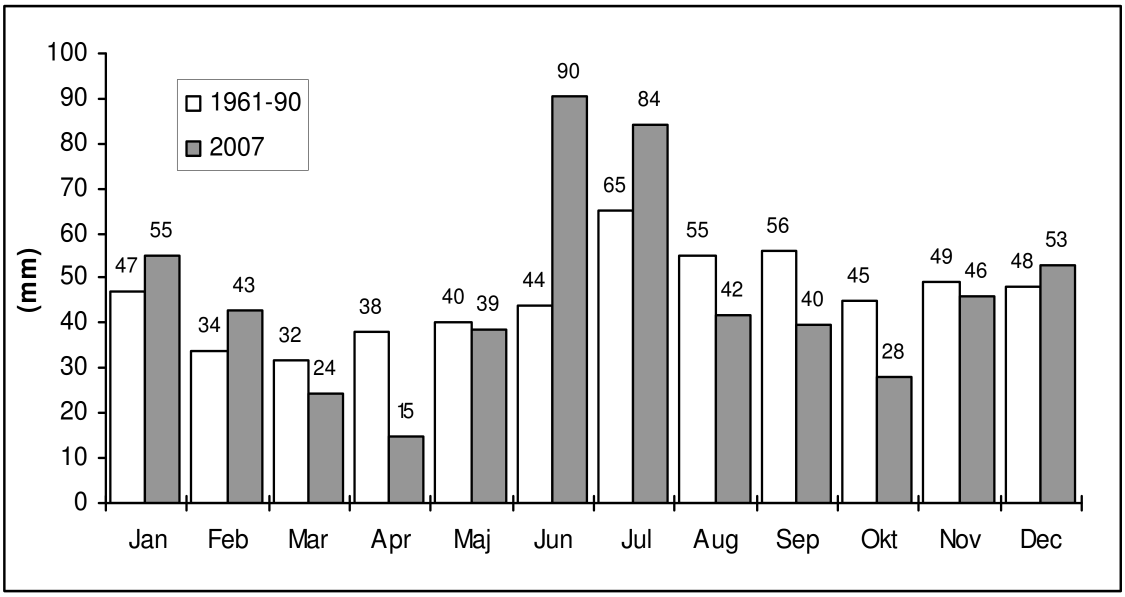

Figure 5-2 Precipitation at Oskarshamn/Äspö: Monthly values for Norra Äspö 2007 and monthly means for Oskarshamn 1961 – 1990.

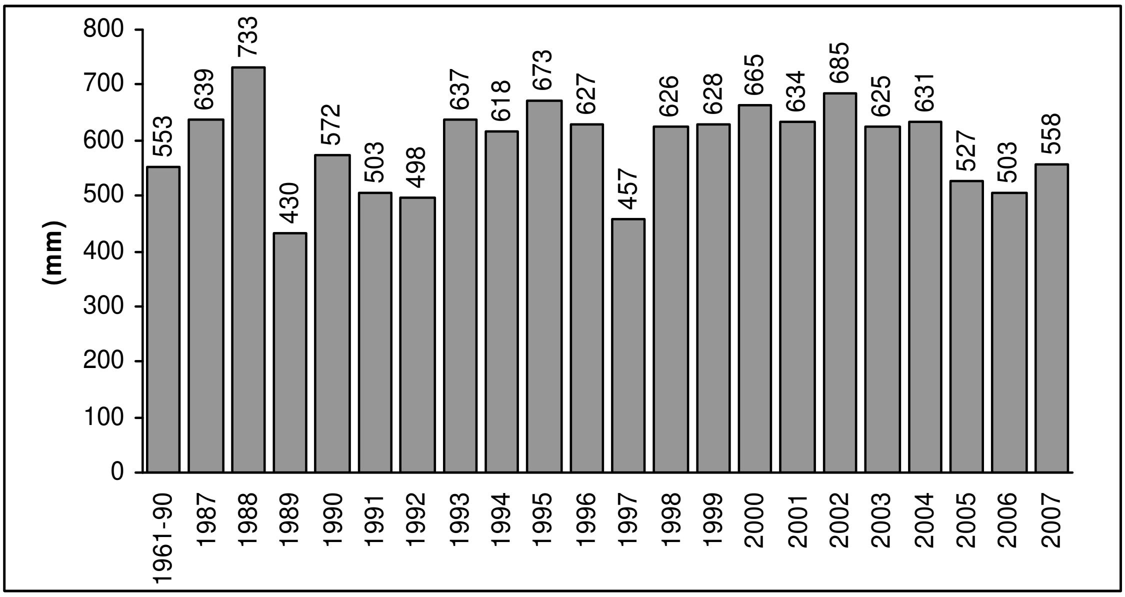

Figure 5-3 Precipitation at Oskarshamn/Äspö. Yearly values for Norra Äspö 2006 - 2007 and for Oskarshamn 1987 - 2005 and yearly mean for Oskarshamn for the period 1961 - 1990.

5.8 Air temperature

Temperature at the SMHI stations at Norra Äspö for 2006-2007 and in Oskarshamn for 1987-2005, as well as means for Oskarshamn for the period 1961-1990, are presented in Figures 5-4 and 5-5. See also section 3.8.2.

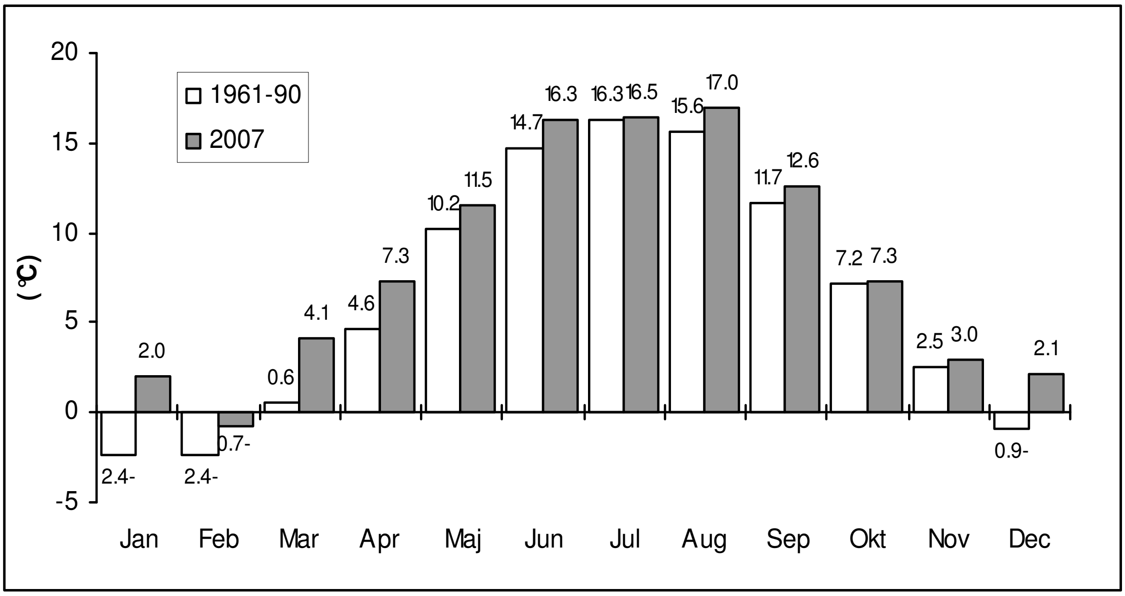

Figure 5-4 Temperature at Oskarshamn/Äspö: Monthly values for Norra Äspö 2007 and monthly means for Oskarshamn 1961 – 1990.

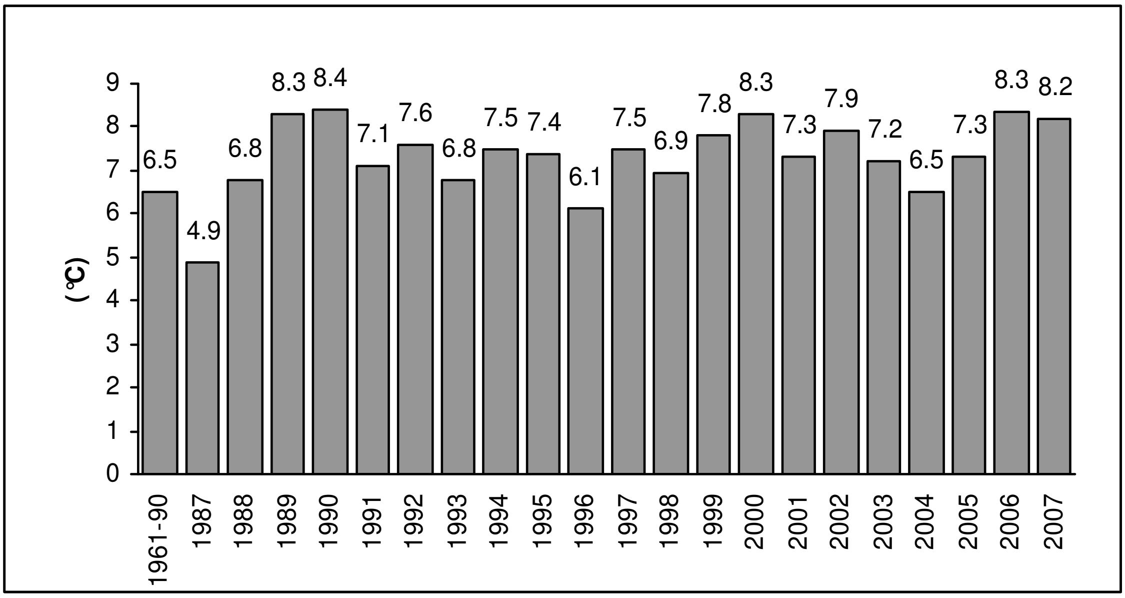

Figure 5-5 Temperature at Oskarshamn/Äspö. Yearly values for Norra Äspö 2006 - 2007 and for Oskarshamn 1987 - 2005 and yearly mean for Oskarshamn for the period 1961 - 1990.

5.9 Potential evapotranspiration

Potential evapotranspiration at the SMHI stations at Norra Äspö for 2006-2007 and in Gladhammar and Ölands Norra Udde for 1987-2005, as well as means for Norra Äspö, Gladhammar and Ölands Norra Udde for the period 1987-2007, are presented in Figures 5-4 and 5-5. See also section 3.8.3.

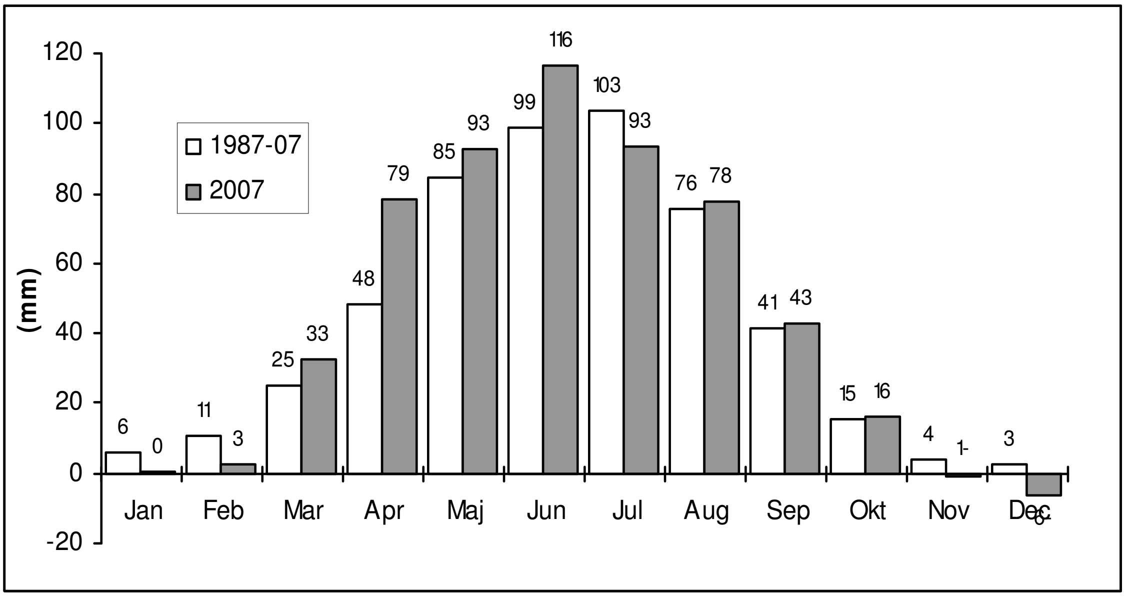

Figure 5-6 Potential evapotranspiration. Monthly values for Norra Äspö 2007 and monthly means from Norra Äspö, Gladhammar and Ölands Norra Udde 1987 – 2007.

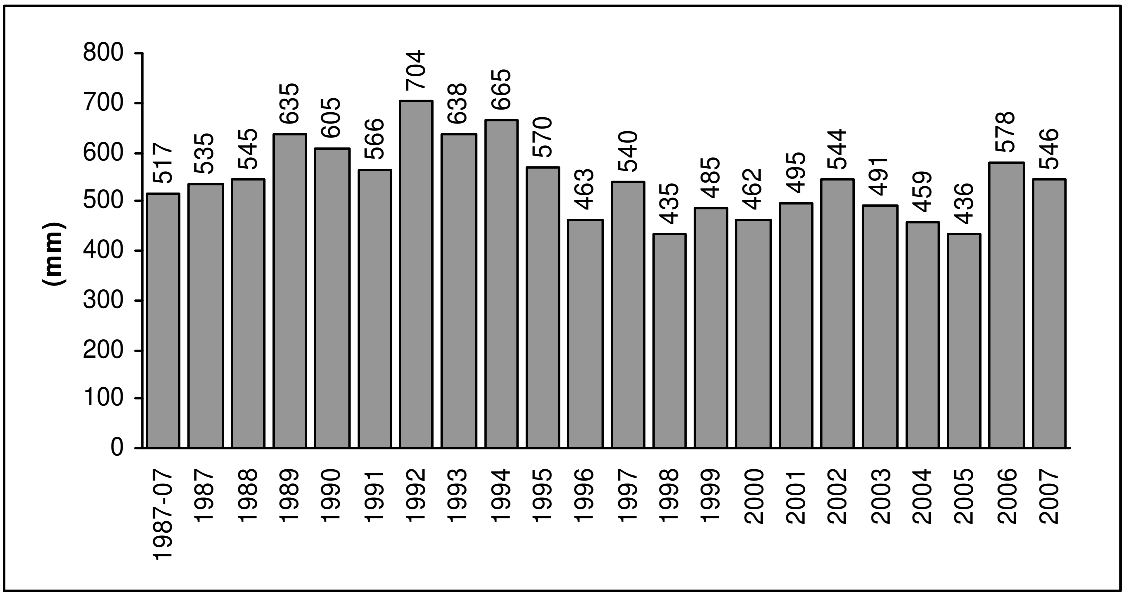

Figure 5-7 Potential evapotranspiration. Yearly values for Norra Äspö 2006 - 2007, for Gladhammar and Ölands Norra Udde 1987 - 2005 and yearly mean for the period 1987 - 2007.

References

Eriksson, B., 1980. The water balance of Sweden. Annual mean values (1931-60) of precipitation, evaporation and run-off (in Swedish). SMHI Nr RMK 18 and Nr RHO 21 (1980), SMHI, Norrköping.

Gottschalk, L., 1982. Hydrologi (in Swedish). Compendium in hydrology, Lund.

Manual för Hydro Monitoring System (HMS), 1994. SKB Tekniskt PM Nr. 25-94-014, SKB, Stockholm.

Nyberg, G., Jönsson, S., Ekman, L., 1991. Äspö Hard Rock Laboratory. Groundwater level program. Report for the Period 1987-1989. SKB Progress Report PR 25-90-18.

Nyberg, G., Jönsson, S., Ekman, L., 1992a. Äspö Hard Rock Laboratory. Groundwater level program. Report for 1990. SKB Progress Report PR 25-91-19.

Nyberg, G., Jönsson, S., Ekman, L., 1992b. Äspö Hard Rock Laboratory. Groundwater level program. Report for 1991. SKB Progress Report PR 25-92-16.

Nyberg, G., Jönsson, S., Ekman, L., 1993. Äspö Hard Rock Laboratory. Groundwater level program. Report for 1992. SKB Progress Report PR 25-93-09.

Nyberg, G., Jönsson, S., Ekman, L., 1994. Äspö Hard Rock Laboratory. Groundwater level program. Report for 1993. SKB Progress Report PR 25-94-23.

Nyberg, G., Jönsson, S., Ekman, L., 1995. Äspö Hard Rock Laboratory. Groundwater level program. Report for 1994. SKB Progress Report PR 25-95-08.

Nyberg, G., Jönsson, S., Ekman, L., 1996. Äspö Hard Rock Laboratory. Hydro monitoring system. Report for 1995. SKB Progress Report PR HRL-96-17.

Nyberg, G., Jönsson, S., Ekman, L., 1997. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 1996. SKB Progress Report PR HRL-97-17.

Nyberg, G., Jönsson, S., Ekman, L., 1998. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 1997. SKB Progress Report PR HRL-98-19.

Nyberg, G., Jönsson, S., Onkenhout, J., 1999. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 1998. SKB International Progress Report IPR-99-20.

Nyberg, G. and Jönsson, S., 2000. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 1999. SKB International Progress Report IPR-00-17.

Nyberg, G., Jönsson, S., Wass, E., 2001. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2000. SKB International Progress Report IPR-01-29.

Nyberg, G., Jönsson, S., Wass, E., 2002. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2001. SKB International Progress Report IPR-02-56.

Nyberg, G., Jönsson, S., Wass, E., 2003. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2002. SKB International Progress Report IPR-03-33.

Nyberg, G., Jönsson, S., Wass, E., 2004. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2003. SKB International Progress Report IPR-04-46.

Nyberg, G., Jönsson, S., Wass, E., 2005. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2004. SKB International Progress Report IPR-05-26.

Nyberg, G., Jönsson, S., Wass, E., 2006. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2005. SKB International Progress Report IPR-06-14.

Nyberg, G., Jönsson, S., Wass, E., 2007. Äspö Hard Rock Laboratory. Hydro monitoring program. Report for 2006. SKB International Progress Report IPR-07-10.

Wass, E., Nyberg, G., Askling, P., 2005. Äspölaboratoriet. Kalibrering av hydrosensorer 2005-03-14 – 2005-03-17. GRAP 05029, GEOSIGMA Uppsala.