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Groundwater chemical changes at SFR in Forsmark

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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Summary

The examination of the groundwater sampled at the SFR tunnel system indicated that the groundwater consist mainly of a Na-Cl to Na-Ca-Cl type of water. Most of the samples fall within the Cl range of 2500-5500 mg/l having a neutral pH (6.6-7.7 units). The water is reducing and despite the fact that the tunnel acts like a hydraulic sink constantly withdrawing water out from the rock into the tunnel the groundwater changes are moderate with time. Most of the sampling points in the SFR tunnel system are located under the Sea and M3 calculations indicated that most of the sampling points have a change of water types from an older marine water type affected by glacial meltwater to an more modern marine water type such as Baltic Sea water which has been modified by possibly microbial sulphate reduction and ion exchange. Mass balance calculations indicated that the waters seem to be in equilibrium with the fracture filling mineral such as calcite. The quality of the aluminium data made the modelling with the major rock forming aluminium silicates such as feldspars and clay minerals uncertain and was therefore not reported.

The conclusion is that the groundwater evolution and patterns at SFR are a result of many factors such as:

1. the changes in hydrogeology related to glaciation/deglaciation and land uplift,
2. repeated Sea/lake water regressions/transgressions
3. the closeness to Baltic Sea resulting in relative small hydrogeological driving forces which could preserve old water types from being flushed out,
4. organic or inorganic alteration of the groundwater caused by microbial processes or in situ water/rock interactions
5. tunnel construction which changed the flow system

The modelled present-day groundwater conditions of the SFR site consist of a mixture in varying degrees of different water types. The data indicate that all the groundwater at SFR is strongly affected by Sea water of different origin and ages. The meteoric (0-1000 B.P) portion is located close and under the land. The marine portion consisting of Litorina (>6000 B.P.), Baltic Sea water (0-3000 B.P) and Biogenic (modern modified Sea water) is located in bedrock under the Sea bed. Under this water a mixture of glacial water (>10.000 B.P.) and older Saline water exist from a depth of 100m to 200m.

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1 Introduction

SFR at Forsmark site, located about 150 km north of Stockholm, was the first underground storage for low and medium active radioactive waste in the world. The facility was constructed by SKB during the years of 1983-1988 and has a storage capacity of 63000 m³. The storage is constructed 50 m below the seafloor in crystalline bedrock (see Figure 1-1). The waste stored here is from the nuclear power plants, industrial and research applications of radioactive materials from hospitals. The groundwater has been sampled regularly and the site has been investigated for various chemical and hydrodynamic aspects described by e.g. (Nilsson, 2002; Holmén and Stigsson, 2001a and 2001b; Jerling et al., 2001; Karlsson et al., 2001; Kautsky, 2001; Kumblad, 2001 and 1999; Lindgren et al., 2001; Moreno et al., 2001; Riggare and Johansson, 2001; Stigsson et al., 1999; Andersson et al., 1998a and 1998b; Axelsson, 1998 and Axelsson et al. 1998). The aim of this work is to investigate what kind of groundwater changes and major trends took place at SFR during the open tunnel conditions. The aim is not to make a complete hydrogeochemical groundwater characterisation of the site since such a work requires more resources for data evaluation, testing, modelling and uncertainty evaluation than what was possible within the framework of this project.

a)



b)

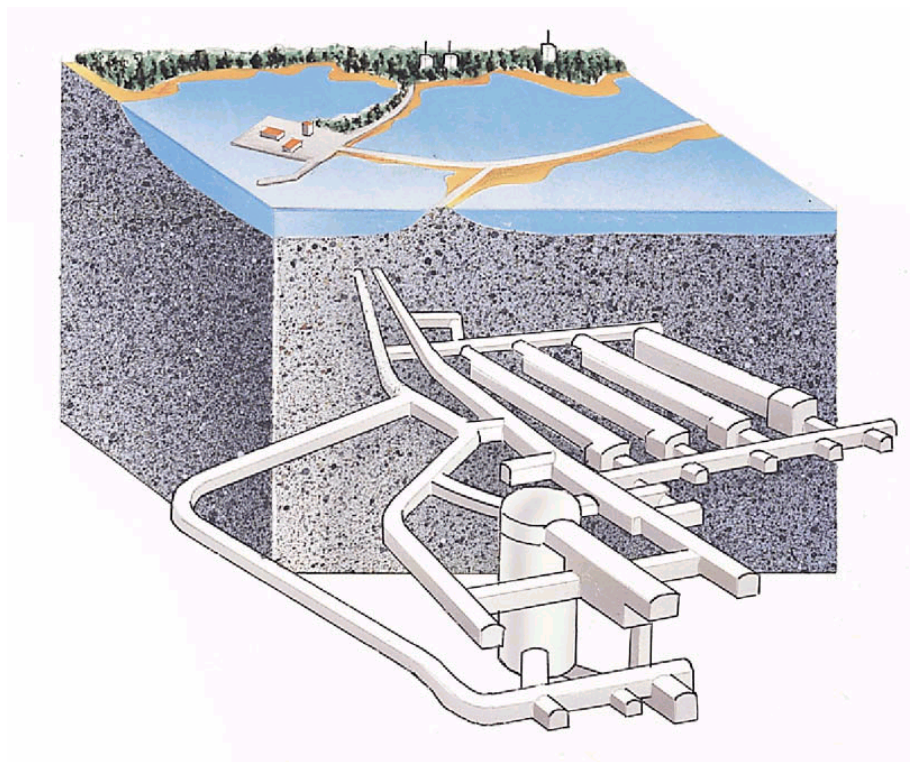


Figure 1-1: SFR site in Forsmark a) overview picture and b) schematic drawing of the SFR tunnel system (pictures from SKB archive).

2 Conceptual model

The first step in the groundwater evaluation is to construct a conceptual postglacial scenario model for the site based on known paleogeological events. This model can be helpful when evaluating data since it gives constraints to the possible groundwater types that may occur. The glacial/post-glacial events that might have affected the SFR site are described below (information compiled from Björck, 1995; Laaksoharju et al., 1999 c,d) and illustrated in Figure Figure 2-1.

- When the continental ice was formed 100,000BP permafrost formation could take place at a depth of several hundred meters which concentrated the existing groundwater by freezing (Bein and Arad, 1992). The water formed had a higher density and could sink to the depth containing a water with the same salinity and density.
- When the continental ice melted and retreated, glacial meltwater was hydraulically injected under considerable head pressure into the bedrock (>13,000BP). The exact penetration depth is still unknown, but a depth exceeding several hundred metres is possible according to hydrogeological modelling (Svensson, 1996).
- Different non-saline and brackish lake/sea stages then covered the SFR site (13,000BP – 4,000BP). Of these only a dense brackish sea water such as Yoldia (Yoldia represents a relative short time period and the effects may be difficult to trace) and Litorina Sea water could penetrate by density overturn and affect the groundwater in the more conductive parts of the bedrock. The density of the intruding sea water in relation to the density of the groundwater determined the final penetration depth of the sea water. The Litorina Sea stage (8,000 to 2,000BP) contained the most saline groundwater (twice the salinity of modern Baltic Sea water) and this water was supposed to have the deepest penetration depth. The result was that the glacial and brine groundwaters in the bedrock were affected by intruding brackish marine water.
- When SFR subsequently rose above sea level a freshwater pillow of meteoric recharge water developed on top of the saline water because of its low density. The continuous land rise increased the hydraulic driving force so that the groundwaters in the upper part of the bedrock were flushed out gradually. This flushing started directly after deglaciation and, since this part of the bedrock had already risen above sea level, the postglacial marine water at these locations did not affect the groundwater composition.

Many of the natural events described above are repeated during a repository lifespan of hundred of thousands of years. As a result of the described sequence of events, brine, glacial, marine and meteoric groundwaters are expected to be mixed in a complex manner at various levels in the bedrock, depending on the hydraulic character of the fracture zones, groundwater density variations and tunnel construction activities prior to groundwater sampling. For the modelling and based on the conceptual model of the site end-members reflecting e.g. glacial meltwater and Litorina Sea water composition were added to the data set (see Table 6-2).

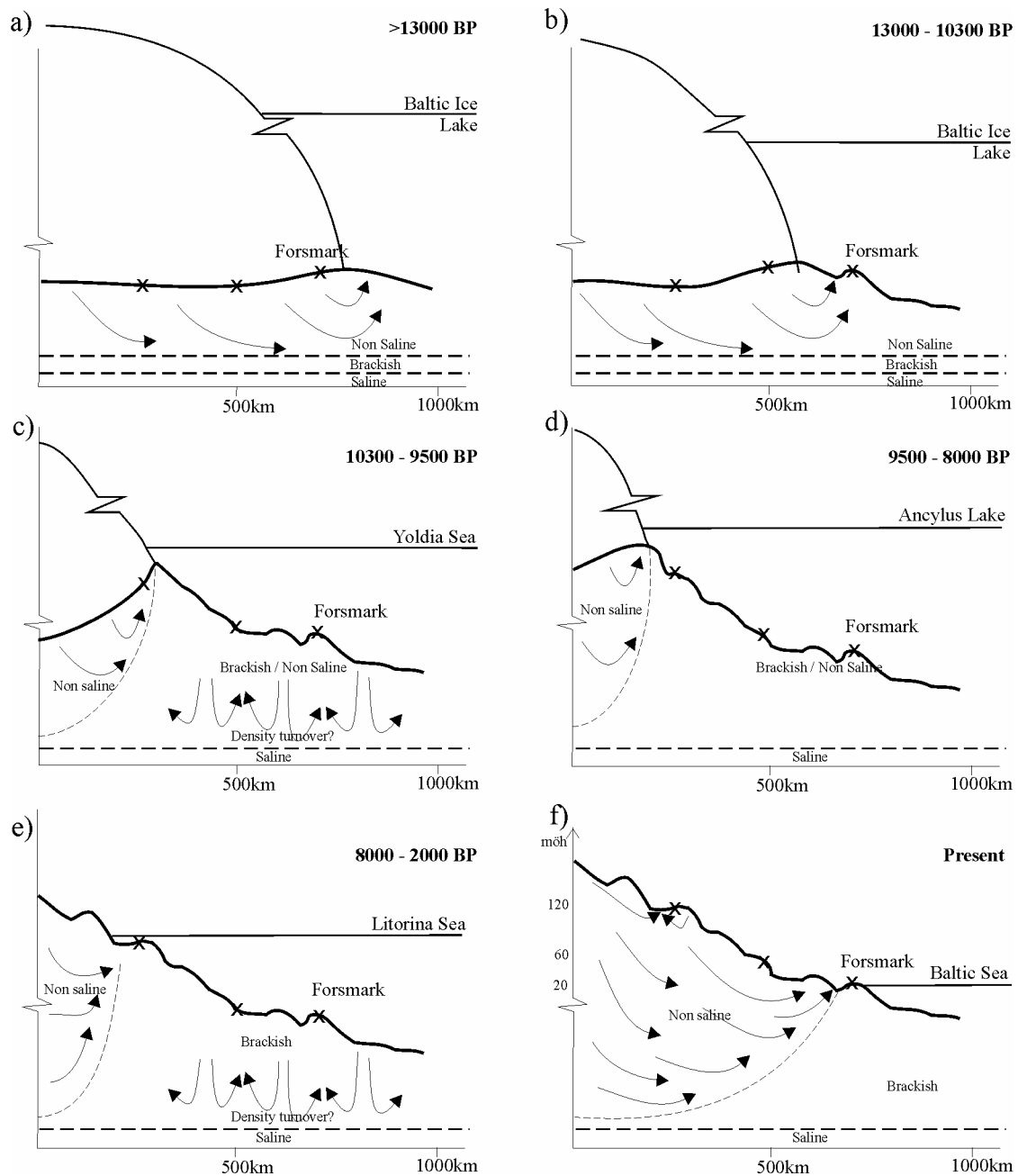


Figure 2-1: A conceptual postglacial scenario model for the Forsmark/SFR site. Possible relation to different known post-glacial stages and land uplift which may have affected the hydrochemical evolution of the site is shown a) Glacial stage. b) Baltic Ice Lake stage, c) Yoldia Sea stage, d) Ancylus Lake stage, e) Litorina Sea stage and f) present day Baltic Sea stage, after Laaksoharju et al., 1999c. From this conceptual model it is expected that water affected by glacial meltwater and various Sea water stages such as Yoldia Sea, Litorina Sea and modern Baltic Sea water could affect the groundwater at the Forsmark/SFR site.

3 Data set used and representativity

The data used within this project were all the groundwater samples collected along the SFR tunnel systems during the years 1989 to 2000. A total of 180 samples were extracted from the SKB database SICADA (Ann-Chatrin Nilsson, pers. comm., 2002) of these 108 samples were used in the modelling. The analytical results have been reported by Nilsson, 2002 and the data have passed the SKB quality control routines. These 108 samples were the most complete having analyses for major elements and isotopes. When values were missing, in order to be able to use as many samples as possible, modelled values were used. The modelled values are explained and indicated in Appendix 5. The groundwater data includes the boreholes KFR01, KFR02, KFR03, KFR04, KFR05, KFR08, KFR09, KFR10, KFR13, KFR19, KFR55, KFR56, KFR7A and KFR7C. The extraction of the data revealed that some of the data lacked coordinates. Groundwater data from other Swedish sites investigated by SKB were included in some of the comparisons this is then indicated in the figures.

By definition a representative sample is considered to be one which best reflects the undisturbed hydrological and geochemical in situ conditions for the sampled section. A sample which reflects in situ, on-line, at-line, on-site or off-site errors such as contamination from drilling, excessive pumping, contamination from tubes of varying compositions, air contamination, losses or uptake of carbon-dioxide, analytical errors etc. has a low representativeness. The representativeness may also be influenced by the rationale in locating the borehole and selecting the sampling points. Some errors are easily avoided; others are difficult or impossible to avoid.

The representativity judgement of the SFR groundwater was in this case a straightforward task. The samples are collected from boreholes and the flow is towards the tunnel. There is therefore no contamination from the drilling or other borehole activities and the samples are regarded as representative. The sample usefulness was determined by the analytical program. In order to be able to use the samples for modelling major components and stable isotopes and tritium had to be analysed.

From the representative data set of 108 samples the samples KFR19:53.7m and KFR04:166.8m were identified for comparison since they were sampled at the most shallow and deepest locations. In addition the samples KFR09:83.7m and KFR10:147.5m are used when comparing small versus large groundwater changes with time. The uncertainty in the groundwater data was addressed in the modelling by using the variability in the samples. The changes in e.g. salinity during sampling can be such an indicator. In addition the known analytical uncertainties generally $\pm 5\%$ was used in the modelling together with known model uncertainties of $\pm 10\%$. The Ion Charge Balance (ICB) which is used to indicate possible analytical problems was satisfying ($< 5\%$) for most of the samples.

The fundamental question in the modelling is generally if the uncertainties lead to a risk of misunderstanding the information in the data. Generally the uncertainties from the measured data are lower than the uncertainties from the modelling.

4 Simulation tools used

For the groundwater chemical evaluation, calculations, simulations and visualisations the following tools were used:

For evaluation and explorative analyses of the groundwater:

AquaChem = Aqueous geochemical data analysis, plotting and modelling tool (Waterloo Hydrogeologic).

ChemStat = advanced chemical statistical program (The scientific software group).

Statgraphics = general statistical program (Manugistics Inc.).

Mathematical simulation tools:

PHREEQC = chemical speciation and saturation index calculations, reaction path and advective-transport and inverse modelling (Pharkhurst et al, 1980).

M3 = Mixing and Massbalance modelling (Laaksoharju et al., 1999b).

Visualisation/animation:

TECPLOT = 2D/3D interpolation, visualisation and animation tool (Amtec Engineering Inc.).

5 Explorative analysis

A commonly used approach in groundwater modelling is to start the evaluation by explorative analysis of different groundwater variables and properties. The next phase often includes a groundwater classification based on the salinity or major constituents of the groundwater. The effects from the major water rock interactions are modelled using some of the standard mass-balance codes.

In Figure 5-1 the Na/Cl, Ca/Cl, HCO₃/Cl and SO₄/Cl plots show that the waters are rather diluted compared with other samples from the Swedish sites but show influences of Sea water. The Mg/Cl plot shows clear indications of Sea water input. The Tritium/Cl plot shows some samples with higher tritium than the modern precipitation (around 10 units ³H). The Oxygen-18/Cl plot shows that the waters from SFR plot between the sea water and glacial water. Multicomponent plots used for classification of the data in Figure 5-2 show that most of the samples are of a Na-Cl type alternatively of a Na-Ca-Cl type of water. Figure 5-3 shows that Cl is increasing with depth, HCO₃ is decreasing with depth, SO₄ is increasing with depth, Mg show no direct trend with depth, tritium is possibly increasing with depth and Oxygen-18 is possibly increasing with depth. The trends are typical for coastal sites affected by Sea water of different ages but also by cold climate water possibly glacial meltwater. Figure 5-4 shows measured Cl with time for the boreholes KFR09 and KFR10 the complete data sets with time series for other boreholes are shown in Appendix 1. Generally the plots show small changes of Cl concentration with time. Figure 5-5 shows the average changes of Cl concentration per year and depth. There are no clear trends which may indicate a complex mixing pattern at the site. Additional tests of Cl trends are presented in Appendix 3. Table 5-1 show water type classification of the SFR samples confirming that most of the waters belong to a Na-Ca-Cl alternatively to a Na-Cl type of water which can indicate Sea water origin or influences. Table 5-2 lists general statistics for some elements and properties of the SFR samples. The results show that e.g. the Cl content is in the range of 2670 to 5380 mg/l (Baltic Sea water has a Cl content of about 3500 mg/l), the pH is from 6.6 to 7.7 units. The data also show that the waters are reducing (indicated by the presence of FeII). Table 5-3 lists a Aquachem modelling result where rain water composition is compared by using the correlation and Euclidean distance (measure of the differences/similarities using several variables) with the composition of the SFR samples. The aim is to trace possible influence of rain water on the sampled groundwater. No clear indications of strong rain water influences on the measured groundwater are found. In Table 5-4 the test is repeated but by using Baltic Sea water in the comparison. The aim this time is to trace possible influence of Baltic Sea water on the sampled groundwater. The influence of Baltic Sea water is confirmed in many of the samples.

The steps above are used for identifying reaction and flow patterns in the data and to summarise and simplify the information. The information is included in the geochemical description of the site, see chapter 7 and for additional examples e.g. Smellie and Laaksoharju 1992, Laaksoharju et al, 1995a and Laaksoharju et al., 1999d.

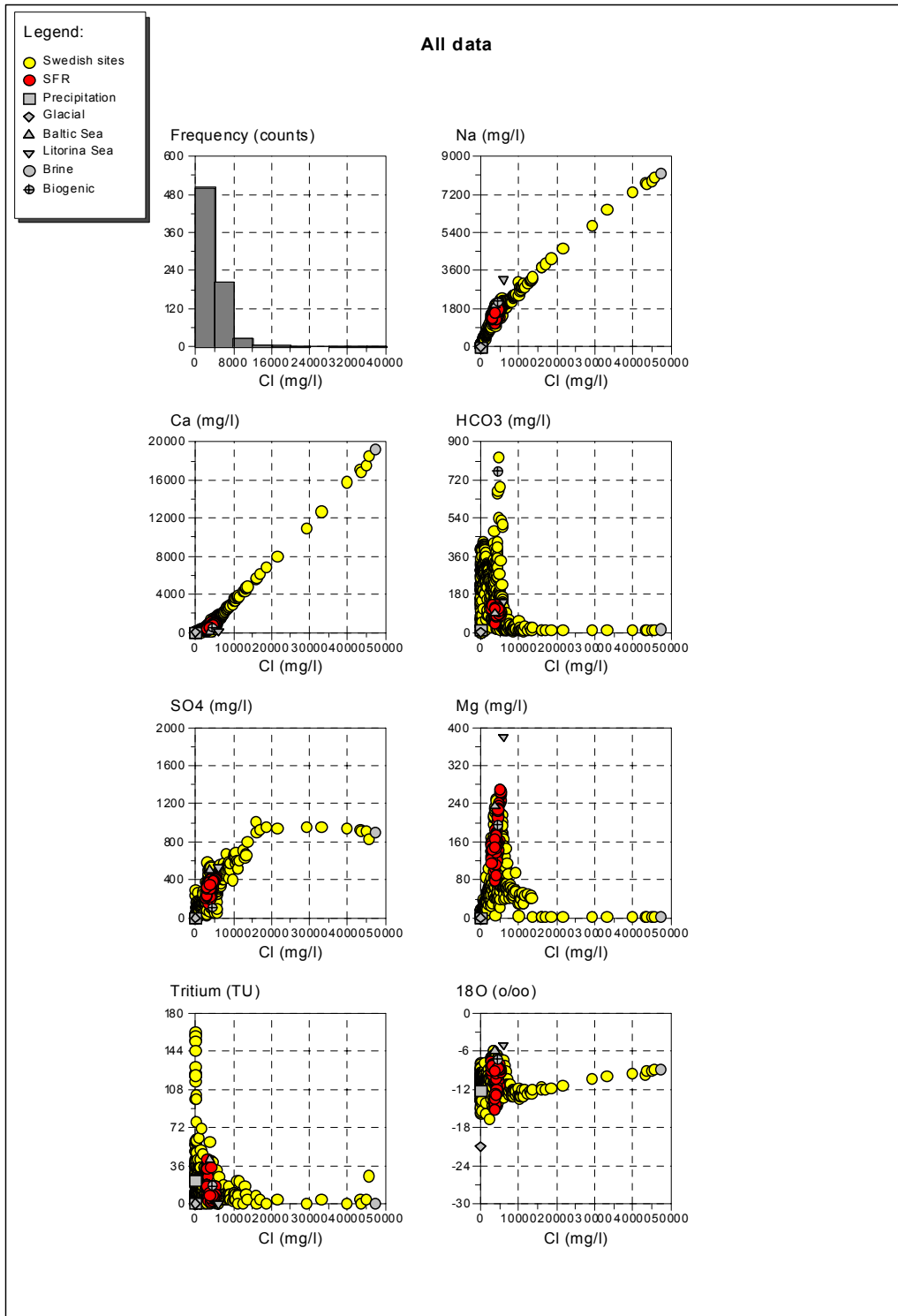


Figure 5-1: The frequency of the Cl samples measured at SFR, Na/Cl, Ca/Cl, HCO₃/Cl, SO₄/Cl, Mg/Cl, Tritium/Cl and Oxygen-18/Cl are plotted for all SFR data and Swedish data.

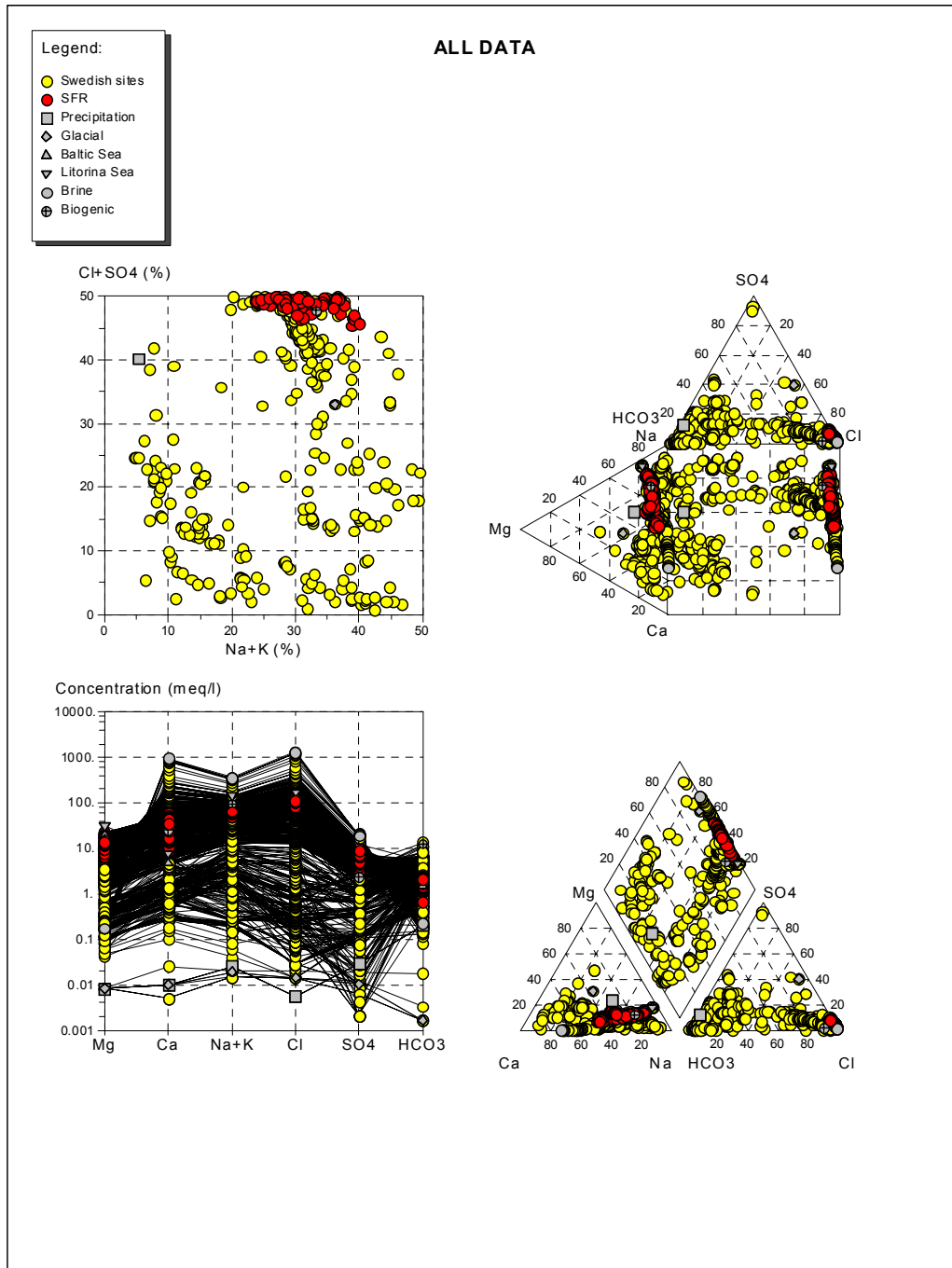


Figure 5-2: Multicomponent plots used for classification of the data. From upper left to lower right: Ludwig-Langelier plot, Durov plot, Shoeller plot and Piper plot applied on all SFR data using AquaChem. The diagrams show that most of the samples are of a Na-Cl alternatively a Na-Ca-Cl type of water.

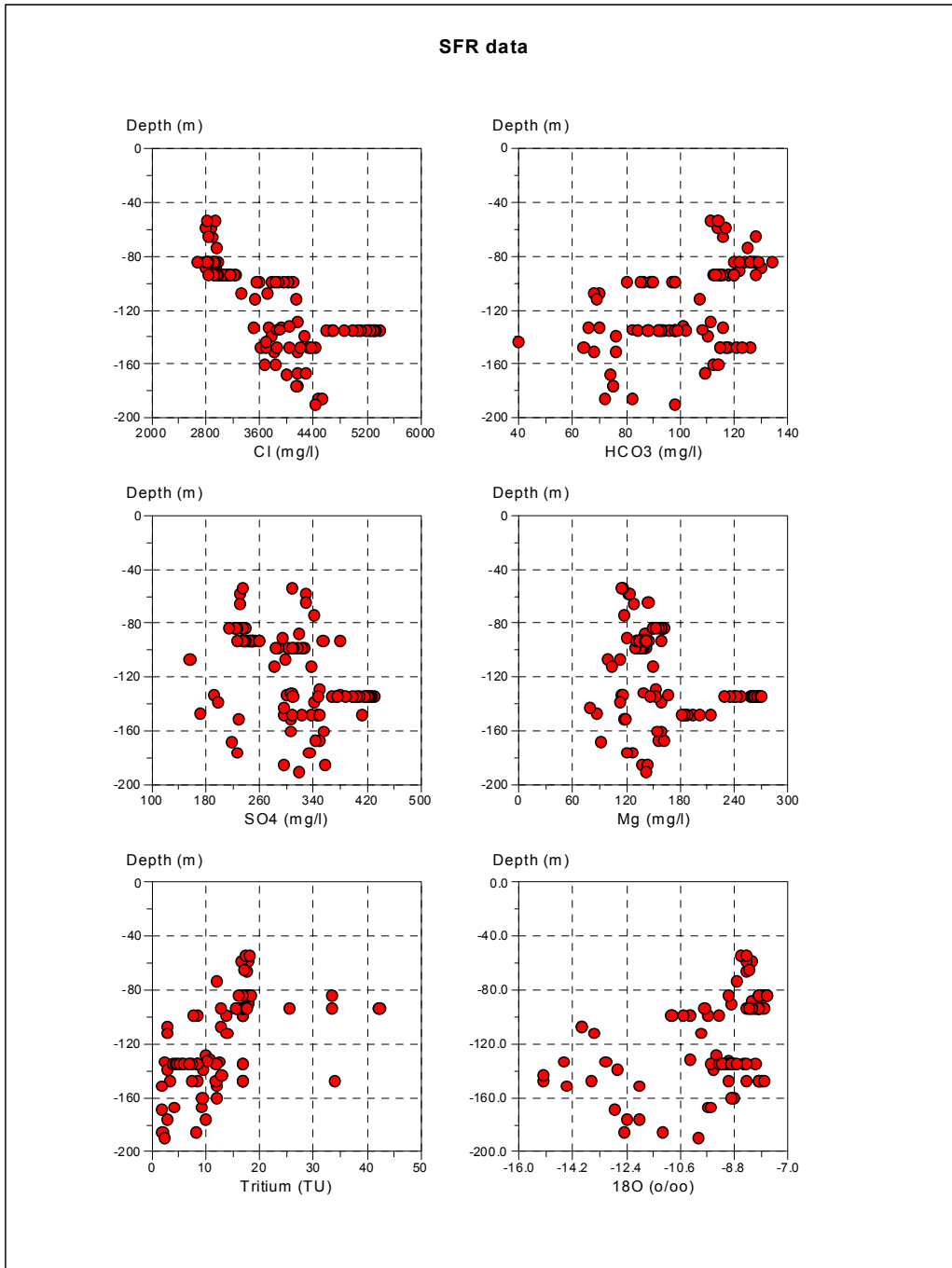


Figure 5-3: The Cl/depth, HCO₃/Depth, SO₄/depth, Mg/depth tritium/depth and Oxygen-18/depth are plotted for SFR data.

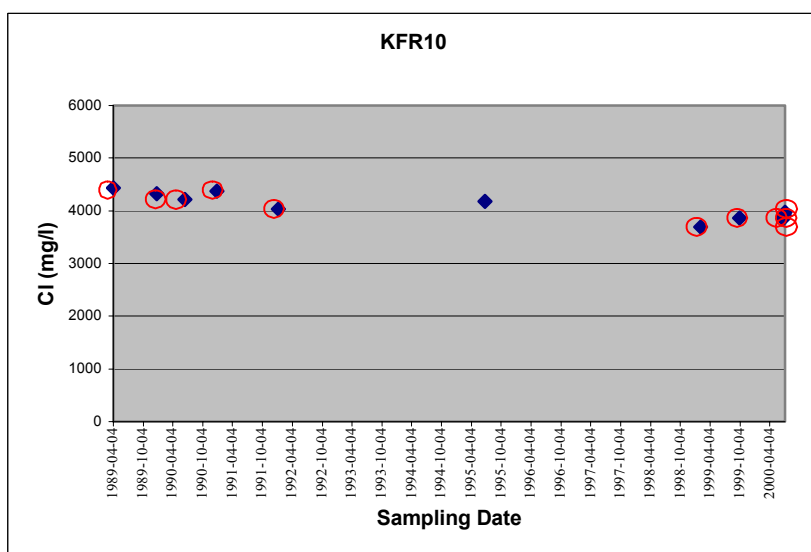
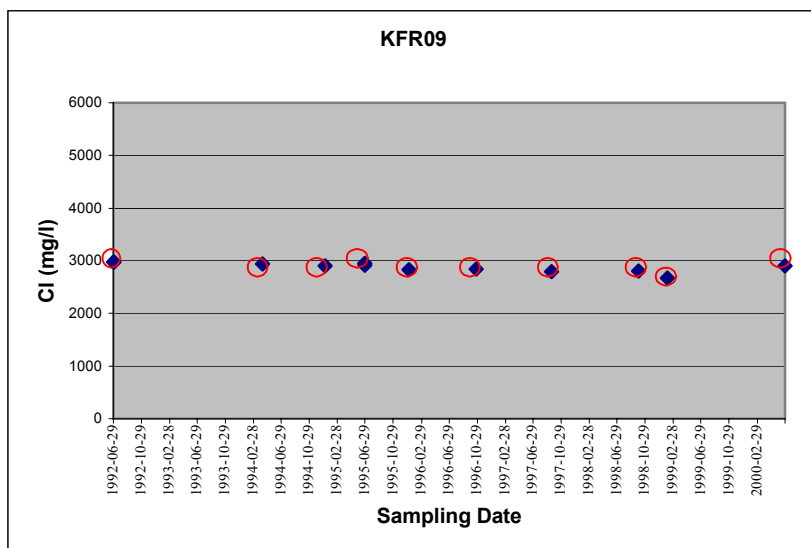


Figure 5-4: Cl sampled at KFR09 (small changes) and KFR10 (large changes) with time. For additional examples of Cl changes with time see Appendix 1. The red circles indicates observations used in the M3 modelling presented in section 6.2.

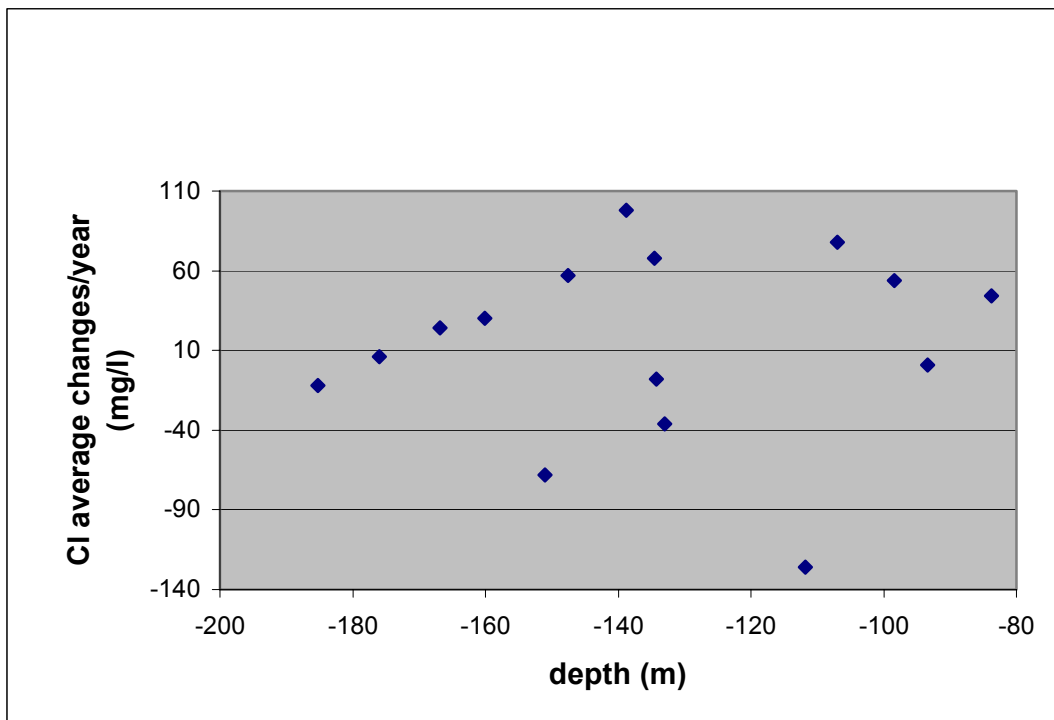


Figure 5-5: The average changes (positive value indicates an increase negative a decrease) of CI concentration per year and depth, the lack of any obvious trend may indicate complex mixing patterns. Additional tests of CI trends are presented in Appendix 3.

Table 5-1: Water type classification of the SFR samples based on the major ions. The results show that most of the waters belong to a Na-Ca-Cl alternatively to Na-Cl type of water which can indicate a Sea water origin/influence for most of the waters.

Observation No.	Borehole	Depth (m)	Water type	Observation No.	Borehole	Depth (m)	Water type
1	KFR01	-73.5	Na-Ca-Cl	55	KFR09	-83.7	Na-Cl
2	KFR01	-98.4	Na-Ca-Cl	56	KFR09	-83.7	Na-Cl
3	KFR01	-98.4	Na-Ca-Cl	57	KFR09	-83.7	Na-Cl
4	KFR01	-98.4	Na-Ca-Cl	58	KFR09	-83.7	Na-Cl
5	KFR01	-98.4	Na-Ca-Cl	59	KFR09	-83.7	Na-Cl
6	KFR01	-98.4	Na-Ca-Cl	60	KFR09	-83.7	Na-Cl
7	KFR01	-98.4	Na-Ca-Cl	61	KFR09	-83.7	Na-Cl
8	KFR01	-98.4	Na-Ca-Cl	62	KFR09	-83.7	Na-Cl
9	KFR01	-98.4	Na-Ca-Cl	63	KFR09	-83.7	Na-Cl
10	KFR01		Na-Ca-Cl	64	KFR09		Na-Cl
11	KFR01		Na-Ca-Cl	65	KFR10	-147.5	Na-Ca-Cl
12	KFR01		Na-Ca-Cl	66	KFR10	-147.5	Na-Ca-Cl
13	KFR01		Na-Ca-Cl	67	KFR10	-147.5	Na-Ca-Cl
14	KFR02		Na-Ca-Cl	68	KFR10	-147.5	Na-Ca-Cl
15	KFR02	-147.3	Na-Ca-Cl	69	KFR10	-147.5	Na-Ca-Cl
16	KFR02	-185.3	Na-Ca-Cl	70	KFR10	-147.5	Na-Ca-Cl
17	KFR02	-185.3	Na-Ca-Cl	71	KFR10	-147.5	Na-Ca-Cl
18	KFR02		Na-Ca-Cl	72	KFR10		Na-Ca-Cl
19	KFR02		Na-Ca-Cl	73	KFR10		Na-Ca-Cl
20	KFR02		Na-Ca-Cl	74	KFR10		Na-Ca-Cl
21	KFR02		Na-Ca-Cl	75	KFR10		Na-Ca-Cl
22	KFR03	-107.0	Na-Ca-Cl	76	KFR13	-143.1	Na-Ca-Cl
23	KFR03	-107.0	Na-Ca-Cl	77	KFR13	-168.1	Na-Ca-Cl
24	KFR03	-133.0	Na-Ca-Cl	78	KFR13	-189.9	Na-Ca-Cl
25	KFR03	-133.0	Na-Ca-Cl	79	KFR19	-58.2	Na-Cl
26	KFR03	-151.0	Na-Ca-Cl	80	KFR19	-65.5	Na-Cl
27	KFR03	-151.0	Na-Ca-Cl	81	KFR19	-58.2	Na-Cl
28	KFR03	-176.0	Na-Ca-Cl	82	KFR19	-53.8	Na-Ca-Cl
29	KFR03	-176.0	Na-Ca-Cl	83	KFR19	-53.8	Na-Ca-Cl
30	KFR04	-111.8	Na-Ca-Cl	84	KFR55	-128.5	Na-Ca-Cl
31	KFR04	-138.8	Na-Ca-Cl	85	KFR55	-131.6	Na-Ca-Cl
32	KFR04	-138.8	Na-Ca-Cl	86	KFR55	-134.3	Na-Ca-Cl
33	KFR04	-166.8	Na-Ca-Cl	87	KFR55	-134.3	Na-Ca-Cl
34	KFR04	-166.8	Na-Ca-Cl	88	KFR56	-64.6	Na-Cl
35	KFR04	-111.8	Na-Ca-Cl	89	KFR7A	-132.8	Na-Ca-Cl
36	KFR05	-160.1	Na-Ca-Cl	90	KFR7A	-134.5	Na-Ca-Cl
37	KFR05	-160.1	Na-Ca-Cl	91	KFR7A	-134.5	Na-Ca-Cl
38	KFR08	-87.9	Na-Cl	92	KFR7A	-134.5	Na-Ca-Cl
39	KFR08	-90.4	Na-Ca-Cl	93	KFR7A	-134.5	Na-Ca-Cl
40	KFR08	-93.4	Na-Cl	94	KFR7A	-134.5	Na-Ca-Cl
41	KFR08	-93.4	Na-Cl	95	KFR7A	-134.5	Na-Ca-Cl
42	KFR08	-93.4	Na-Cl	96	KFR7A	-134.5	Na-Ca-Cl
43	KFR08	-93.4	Na-Cl	97	KFR7A	-134.5	Na-Ca-Cl
44	KFR08	-93.4	Na-Cl	98	KFR7A	-134.5	Na-Ca-Cl
45	KFR08	-93.4	Na-Cl	99	KFR7A	-134.5	Na-Ca-Cl
46	KFR08	-93.4	Na-Cl	100	KFR7A	-134.5	Na-Ca-Cl
47	KFR08	-93.4	Na-Cl	101	KFR7A	-134.5	Na-Ca-Cl
48	KFR08	-93.4	Na-Cl	102	KFR7A	-134.5	Na-Ca-Cl
49	KFR08	-93.4	Na-Cl	103	KFR7A	-134.5	Na-Ca-Cl
50	KFR08	-93.4	Na-Cl	104	KFR7A		Na-Ca-Cl
51	KFR08	-93.4	Na-Cl	105	KFR7A		Na-Ca-Cl
52	KFR08	-93.4	Na-Ca-Cl	106	KFR7A		Na-Ca-Cl
53	KFR08	-93.4	Na-Ca-Cl	107	KFR7A		Na-Ca-Cl
54	KFR08	-93.4	Na-Ca-Cl	108	KFR7C		Na-Ca-Cl

Table 5-2: General statistics for some of the elements and properties measured in the SFR groundwater samples.

108 samples, concentrations in mg/l

	Min	Max	Average	St. Dev.	Dev. Coeff	Var%	Sample No	
Na	1110	1920	1531.9	187.4	12.2	42	108	
Ca	181	1220	678.5	299.8	44.2	85	108	
Mg	79	270	159.0	46.1	29.0	71	108	
Cl	2670	5380	3796.4	733.3	19.3	50	108	
SO4	156	430	313.9	67.5	21.5	64	108	
pH	6.6	7.7	7.3	7.5	102.0	14	94	

Table 5-3: Rain water composition (with the sample name Rain old) is compared by using the correlation and Euclidean distance (measure of the differences/similarities using several variables) with the obtained groundwater composition of the SFR samples. The aim is to trace possible influence of rain water on the sampled groundwater. The samples are listed in descending order of similarities. No clear indications of strong rain water influences on the measured groundwater is found. The variables Na, Ca, Mg, Cl, SO₄, 18O and Tritium were used in the test.

Used Parameters: Na, Ca, Mg, Cl, SO₄, 18O, Trit

Location	Dbase Index	Corr Coeff	Euclidean distance	Points used for correlation	Location	Dbase Index	Corr Coeff	Euclidean distance	Points used for correlation
Rain old	742	1.000	8.3	6	KFR01	642	-0.105	1487.2	7
Rain	743	1.000	0.0	7	KFR7A	726	-0.105	2156.4	7
Glacial	745	0.997	8.9	6	KFR7A	722	-0.105	1484.8	7
Rain60	744	0.885	750.6	7	KFR02	649	-0.105	1815.8	7
Litorina	749	0.321	2612.1	6	KFR02	653	-0.105	1726.9	7
KFR08	676	-0.090	1298.2	7	KFR08	687	-0.105	1337.0	7
KFR08	674	-0.091	1332.8	7	KFR7A	727	-0.105	2133.0	7
Sea	746	-0.093	1616.5	7	KFR01	635	-0.105	1693.7	7
KFR09	688	-0.093	1266.3	7	KFR03	656	-0.105	1365.2	7
KFR08	684	-0.096	1230.5	7	KFR7A	724	-0.105	2172.6	7
KFR09	692	-0.097	1204.9	7	KFR03	661	-0.106	1708.6	7
KFR09	690	-0.097	1236.9	7	KFR01	645	-0.106	1252.4	7
KFR09	691	-0.097	1240.3	7	KFR01	634	-0.106	1251.3	7
KFR09	689	-0.097	1246.0	7	KFR7C	741	-0.106	1546.0	7
KFR08	683	-0.098	1252.5	7	KFR05	670	-0.106	1550.6	7
KFR08	677	-0.098	1333.2	7	KFR7A	738	-0.106	1831.6	7
KFR09	695	-0.098	1215.5	7	KFR10	704	-0.106	1602.8	7
KFR19	712	-0.098	1217.8	7	KFR01	637	-0.106	1631.6	7
KFR08	675	-0.098	1324.1	7	KFR01	646	-0.106	1420.6	7
KFR19	713	-0.098	1220.9	7	KFR10	705	-0.106	1587.8	7
KFR09	694	-0.098	1209.0	7	KFR02	651	-0.106	1939.3	7
KFR09	693	-0.099	1227.6	7	KFR02	648	-0.106	1489.2	7
KFR09	696	-0.099	1161.7	7	KFR7A	728	-0.106	2139.8	7
KFR08	681	-0.099	1259.3	7	KFR55	720	-0.106	1627.8	7
KFR19	715	-0.099	1222.5	7	KFR7A	725	-0.106	2165.9	7
KFR09	697	-0.099	1241.1	7	KFR03	658	-0.107	1607.4	7
KFR08	680	-0.100	1284.7	7	KFR7A	729	-0.107	2115.0	7
Modified Sea	747	-0.100	1891.3	7	KFR7A	730	-0.107	2081.3	7
KFR08	678	-0.100	1311.7	7	KFR7A	731	-0.107	2063.0	7
KFR08	679	-0.100	1268.6	7	KFR7A	732	-0.107	2032.6	7
KFR10	702	-0.100	1663.2	7	KFR04	664	-0.107	1554.6	7
KFR08	682	-0.100	1265.1	7	KFR7A	736	-0.107	1933.3	7
KFR08	671	-0.101	1195.2	7	KFR13	710	-0.107	1641.7	7
KFR08	673	-0.101	1362.0	7	KFR10	703	-0.107	1544.9	7
KFR19	716	-0.101	1195.8	7	KFR01	644	-0.107	1473.4	7
KFR19	714	-0.102	1199.7	7	KFR55	717	-0.107	1758.1	7
KFR08	686	-0.102	1346.7	7	KFR03	660	-0.107	1710.2	7
KFR56	721	-0.102	1209.1	7	KFR01	641	-0.107	1504.3	7
KFR05	669	-0.102	1592.1	7	KFR10	708	-0.107	1643.4	7
KFR13	709	-0.102	1503.9	7	KFR01	643	-0.107	1488.3	7
KFR08	685	-0.102	1358.0	7	KFR7A	734	-0.107	1922.5	7
KFR02	647	-0.103	1511.6	7	KFR55	718	-0.107	1697.1	7
KFR01	636	-0.103	1652.3	7	KFR7A	733	-0.107	1994.3	7
KFR04	663	-0.103	1439.2	7	KFR03	662	-0.107	1706.9	7
KFR08	672	-0.103	1241.0	7	KFR13	711	-0.108	1834.9	7
KFR03	657	-0.103	1524.2	7	KFR04	668	-0.108	1728.1	7
KFR03	655	-0.103	1518.5	7	KFR04	666	-0.108	1740.4	7
KFR55	719	-0.103	1607.6	7	KFR7A	723	-0.108	2208.9	7
KFR10	701	-0.104	1791.4	7	KFR7A	739	-0.108	1847.7	7
KFR03	659	-0.104	1558.7	7	KFR10	698	-0.108	1828.5	7
KFR01	638	-0.104	1601.5	7	KFR7A	735	-0.108	1898.0	7
KFR10	699	-0.104	1779.8	7	KFR10	706	-0.108	1616.6	7
KFR01	639	-0.104	1560.7	7	KFR02	654	-0.108	1746.0	7
KFR01	640	-0.104	1591.2	7	KFR7A	740	-0.108	1850.9	7
Brine	748	-0.104	19510.1	7	KFR10	707	-0.108	1625.2	7
KFR10	700	-0.104	1735.1	7	KFR02	650	-0.108	1856.6	7
KFR04	665	-0.105	1771.1	7	KFR7A	737	-0.109	1865.6	7
KFR04	667	-0.105	1782.0	7	KFR02	652	-0.109	1892.2	7

Table 5-4: Baltic Sea water composition (with the sample name Sea) is compared by using the correlation and Euclidean distance (measure of the differences/similarities using several variables) with the obtained groundwater composition of the SFR samples. The aim is to trace possible influence of Baltic Sea water on the sampled groundwater. The samples are listed in descending order of similarities. The Baltic Sea influences on the samples are traceable in this test. The variables Na, Ca, Mg, Cl, SO₄, 18O and Tritium were used in the test.

Used Parameters: Na, Ca, Mg, Cl, SO₄, 18O, Trit

Location	Index	Corr Coeff	Euclidean distance	Points used for correlation	Location	Index	Corr Coeff	Euclidean distance	Points used for correlation
Sea	746	1.000	0.0	7	KFR04	668	0.975	324.5	7
Litorina	749	0.999	999.3	6	KFR10	705	0.974	295.6	7
KFR09	697	0.998	380.8	7	KFR10	702	0.974	306.1	7
KFR09	690	0.998	388.7	7	KFR10	708	0.974	303.2	7
KFR09	692	0.997	420.2	7	KFR7A	740	0.974	398.6	7
KFR08	683	0.997	374.2	7	KFR7A	739	0.973	397.1	7
KFR09	691	0.997	386.6	7	KFR55	718	0.973	322.8	7
KFR09	695	0.997	410.6	7	KFR7A	738	0.972	394.4	7
KFR08	676	0.997	331.7	7	KFR10	700	0.972	343.8	7
KFR08	673	0.997	271.9	7	KFR10	699	0.972	365.8	7
KFR09	694	0.997	417.8	7	KFR7A	735	0.971	443.5	7
KFR09	693	0.997	399.9	7	KFR7A	734	0.970	463.1	7
KFR09	688	0.997	363.0	7	KFR01	640	0.970	318.7	7
KFR08	675	0.997	308.9	7	KFR7A	736	0.970	473.7	7
KFR09	689	0.997	383.0	7	KFR10	701	0.969	384.1	7
KFR09	696	0.997	464.1	7	KFR10	698	0.969	407.8	7
KFR08	674	0.996	301.9	7	KFR7A	733	0.969	524.9	7
KFR08	671	0.996	433.5	7	KFR01	638	0.969	327.2	7
KFR19	714	0.995	431.3	7	KFR01	639	0.968	330.3	7
KFR56	721	0.994	425.5	7	KFR13	711	0.968	417.0	7
KFR19	712	0.994	417.0	7	KFR01	636	0.968	339.7	7
KFR19	713	0.994	414.9	7	KFR01	637	0.966	341.5	7
KFR08	682	0.994	373.6	7	KFR7A	732	0.966	566.9	7
KFR08	684	0.994	406.4	7	KFR7A	730	0.966	607.3	7
KFR08	681	0.993	382.2	7	KFR7A	731	0.965	593.7	7
KFR08	680	0.993	360.0	7	KFR7A	724	0.965	688.2	7
KFR08	677	0.993	318.6	7	KFR7A	729	0.964	641.8	7
KFR08	679	0.992	376.2	7	KFR7A	728	0.964	663.0	7
KFR19	716	0.992	443.5	7	KFR7A	725	0.964	685.3	7
KFR08	678	0.992	341.0	7	KFR7A	726	0.963	679.4	7
KFR7A	722	0.991	214.4	7	KFR01	635	0.963	374.9	7
KFR08	687	0.989	333.0	7	KFR7A	727	0.963	661.0	7
KFR19	715	0.988	431.9	7	KFR7A	723	0.962	727.7	7
Modified Sea	747	0.988	356.4	7	KFR03	662	0.949	441.2	7
KFR01	645	0.987	409.8	7	KFR03	660	0.947	448.5	7
KFR05	669	0.987	213.9	7	KFR03	661	0.947	447.1	7
KFR05	670	0.987	219.5	7	KFR03	655	0.947	427.7	7
KFR08	685	0.986	326.8	7	KFR04	663	0.946	442.7	7
KFR7C	741	0.986	227.0	7	KFR02	647	0.945	436.1	7
KFR08	686	0.985	338.7	7	KFR02	653	0.944	466.7	7
KFR01	634	0.985	417.2	7	KFR03	656	0.944	477.3	7
KFR55	719	0.984	237.1	7	KFR04	664	0.944	437.8	7
KFR08	672	0.982	433.9	7	KFR02	652	0.940	562.0	7
KFR55	717	0.981	303.8	7	KFR03	657	0.940	451.1	7
KFR55	720	0.981	259.7	7	KFR02	654	0.940	490.0	7
KFR04	667	0.980	319.5	7	KFR02	651	0.940	594.2	7
KFR04	665	0.980	317.5	7	KFR13	710	0.940	460.9	7
KFR01	642	0.979	288.3	7	KFR13	709	0.940	455.4	7
KFR10	703	0.978	280.8	7	KFR02	649	0.939	526.5	7
KFR01	644	0.977	305.9	7	KFR03	659	0.938	456.4	7
KFR04	666	0.976	320.2	7	KFR03	658	0.938	461.6	7
KFR7A	737	0.976	395.8	7	KFR02	650	0.938	551.2	7
KFR01	641	0.976	298.7	7	KFR02	648	0.934	474.7	7
KFR10	704	0.976	286.6	7	Brine	748	0.834	18092.0	7
KFR01	643	0.976	305.6	7	Glacial	745	0.369	1616.6	6
KFR10	706	0.976	290.4	7	Rain old	742	0.339	1616.6	6
KFR10	707	0.975	293.3	7	Rain	743	-0.093	1616.5	7
KFR01	646	0.975	337.6	7	Rain60	744	-0.277	1779.1	7

6 Hydrogeochemical modelling

6.1 Speciation and mass-balance modelling

The main purpose of speciation modelling within PHREEQC is to calculate, based on thermodynamic models, the mineral saturation indices. The indices are indicators of the saturation state of a mineral with respect to a given water composition. A positive value indicates that thermodynamically a mineral can precipitate while a negative value that it can dissolve. A value close to zero indicates that the mineral is not reacting. The saturation index indicates the potential not the rate at which the process will proceed. From this information conclusion concerning possible major reactions taking place and indirect indications of the dynamics of the system can be drawn. The advantage is that it is relatively easy to modify the model to include new species and elements and there is extensive literature on test cases and on complexation reactions and estimates of the stability constants.

The following types of major reactions can generally be modelled:

- 1) Introduction of CO₂ gas in the unsaturated zone
- 2) Dissolution of calcite and dolomite, and precipitation of calcite
- 3) Cation exchange
- 4) Oxidation of iron containing minerals, pyrite and organic matter
- 5) Reduction of oxygen, nitrate, and sulphate, with production of sulphide
- 6) Reductive production of methane
- 7) Dissolution of gypsum, anhydrite and halite
- 8) Incongruent dissolution of primary silicates with formation of clays

The following difficulties can occur (after Parkhurst and Plummer in Alley, (ed.), 1993): 1) The theory used for activity coefficients (Debye-Hückel) or its modification can be applied only on dilute water or on sodium chloride groundwater of at maximum seawater concentration. 2) Insufficient laboratory work has been performed to reproduce mineral solubilities. 3) The thermodynamic data is based on high temperatures because of slow equilibrium in low temperatures (~25°C). 4) Minerals can have a range of stability due to their composition and structure. 5) Lack of mechanisms to account for repulsive forces in mixed electrolytes. 6) Sensitive to accuracy of chemical analyses especially for pH and Eh. One unit change in the pH changes the SI calculations with one unit. This means that pH measurements recorded at surface rather than down-hole can lead to misunderstanding concerning the precipitation/dissolution of a mineral phase. 7) Many of the reactions such as redox reactions are biologically mediated or kinetically slow and therefore not in equilibrium.

For low-temperature calculations, the number of minerals for which meaningful saturation indices can be calculated is relatively small. Reliable indications can be obtained for fast reactions such as: carbonate, sulphate and chloride minerals. For kaolinite, clays, feldspars and other aluminium silicates qualitative results can be obtained due to uncertainties in the thermodynamic data and the aluminium measurements which may have been affected by the borehole equipment.

The results of saturation index modelling performed on the samples (KFR 19 “shallow sample” and KFR04 “deep sample”) are listed in Table 6-1.

Table 6-1: Saturation index (SI) calculations for the sample KRF19 (shallow) and 04 (deep). A positive saturation index SI indicates that the water is supersaturated in respect to that mineral or gas phase. If the value is negative the water is under saturated and the mineral or gas can dissolve. In this particular case the calculations indicated that the groundwater is in equilibrium with the major (fast forming) mineral phases such as Calcite. The calculations show that the samples have a higher CO₂ partial pressure than in the atmosphere (-3.5) which can indicate biogenic activity.

KFR19:53.7m

Phase	SI
Anhydrite	-1.21
Aragonite	0.07
Calcite	0.22
CO2(g)	-2.72
Dolomite	0.11
Gypsum	-0.95

KFR04:166.8m

Phase	SI
Anhydrite	-1.01
Aragonite	-0.03
Calcite	0.12
CO2(g)	-2.47
Dolomite	-0.22
Gypsum	-0.76

The aim of mass-balance modelling is to determine the type and amount of geochemical reactions that are occurring in a groundwater system. This is done by identifying the minerals that are reacting and determining the amounts of the minerals that dissolve or precipitate. The modelling of an important group of minerals such as aluminium silicates (e.g. feldspars and clay minerals) are made uncertain at SFR due to difficulties associated with Al determinations and are therefore not reported here.

6.2 M3 modelling

The challenge in groundwater modelling is to reveal the origin, mixing and reactions altering the groundwater samples. The groundwater modelling concept M3 (Multivariate Mixing and Mass-balance calculations) Laaksoharju and Skårman, (1995); Laaksoharju et al., (1999b,) can be used for this type of modelling. In M3 modelling the assumption is that the groundwater is always a result of mixing and reactions. M3 modelling uses a statistical method to analyse variations in groundwater compositions so that the mixing components, their proportions, and chemical reactions are revealed. The method quantifies the contribution to hydrochemical variations by mixing of groundwater masses in a flow system by comparing groundwater compositions to identified reference waters. Subsequently, contributions to variations in non-conservative solutes from reactions are calculated.

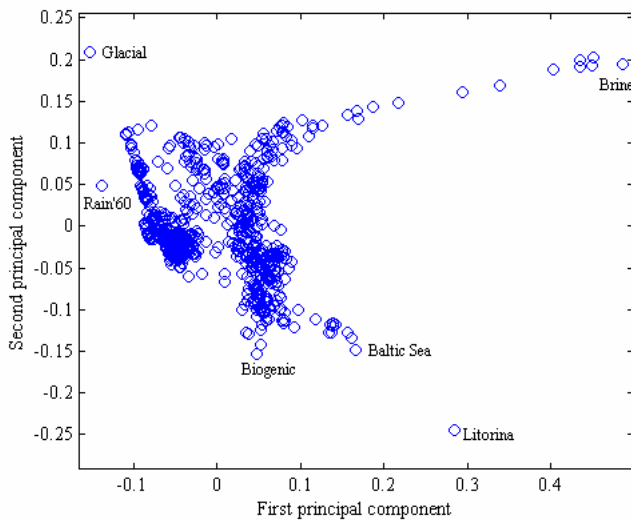
The M3 method has been tested, evaluated, compared with standard methods over several years within domestic and international research programmes supported by the SKB. The main test and application site for the model has been the Äspö HRL (Laaksoharju and Wallin (eds.) 1997; Laaksoharju et al., 1999c). Mixing seems to play an important role at many crystalline and sedimentary rock sites where M3 calculations have been applied such as in different Swedish sites (Laaksoharju et al., 1998), Canada (Smellie and Karlsson, 1996), Oklo in Gabon (Gurban et al., 1998) and Palmottu in Finland (Laaksoharju et al, 1999a).

The features of the model are:

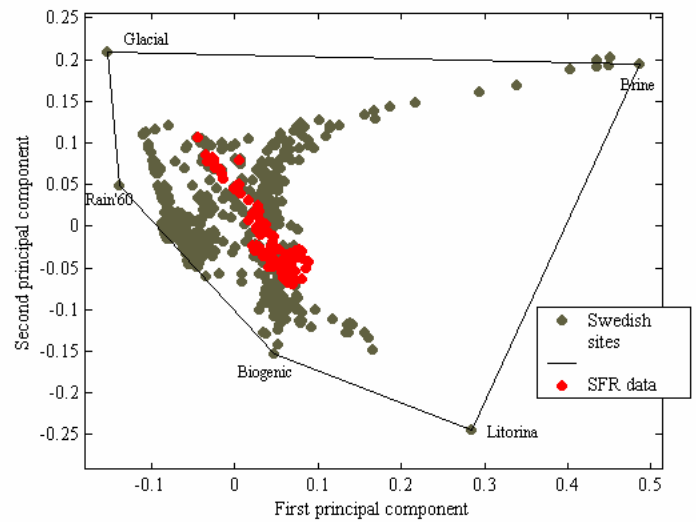
- It is a mathematical tool which can be used to evaluate groundwater field data, to help construct a conceptual model for the site and to support expert judgement for site characterisation.
- It uses the entire hydrochemical data set to construct a model of geochemical evolution, in contrast to a thermodynamic model that simulates reactions or predicts the reaction potential for a single water composition.
- The results of mixing calculations can be integrated with hydrodynamic models, either as a calibration tool or to define boundary conditions.
- Experience has shown that to construct a mixing model based on physical understanding often requires more information than available especially at site scale. M3 results can provide additional information of the major flow paths, flow directions and residence times of the different groundwater types which can be valuable in transport modelling.
- The numerical results of the modelling can be visualised and presented for non-expert use.

The M3 model consists of 4 steps where the first step is a standard principal component analysis (PCA), selection of reference waters, followed by calculations of mixing proportions, and finally mass balance calculations (for more details see Laaksoharju et al., 1999b; Laaksoharju, 1999d). The following four modelling steps are employed on SFR data in Figure 6-1.

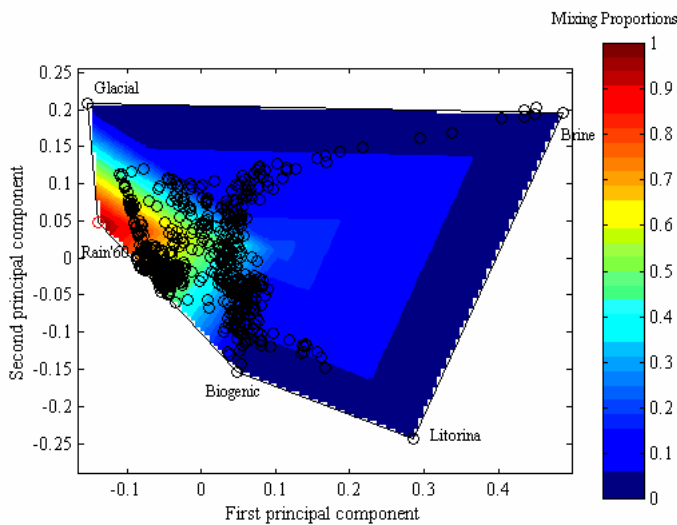
a) Principal component analysis



b) Identification of Reference waters



c) Mixing calculations



d) Mass-balance calculations

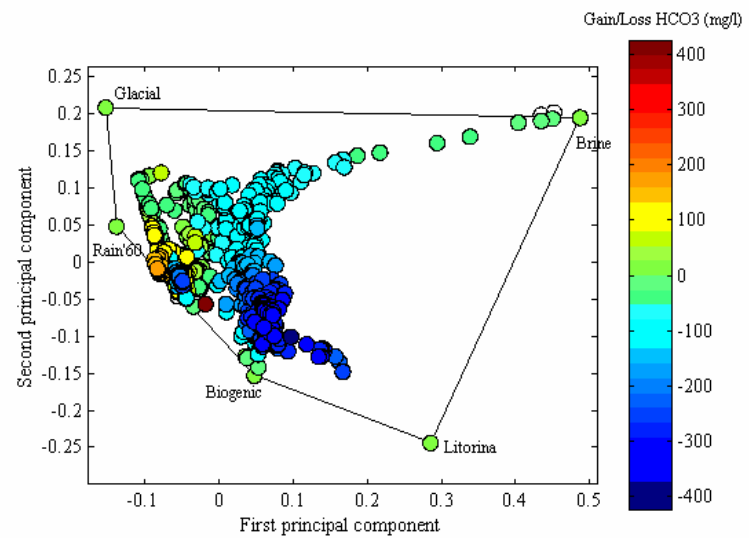


Figure 6-1: Different steps in the M3 modelling: a) Principal Component Analysis is used to obtain the maximum resolution of the data set in order to summarise the information and identify extreme waters. b) Selection of reference waters affecting the SFR site - the other groundwaters are compared to these. The polygon defines the observations that can be described by the selected reference waters. The data from Swedish sites is used as background information in the figures SFR groundwaters are depicted in colour in this figure. c) Mixing calculations – the linear distance of a sample to the reference waters e.g. the portions of meteoric water (%) are shown. d) Mass-balance calculations – the sources and sinks (mg/l) of carbonate (HCO_3) are shown which cannot be accounted for by using the ideal mixing model.

Five reference waters were chosen at the SFR site using the M3 method: Brine type, Glacial, Litorina Sea, Biogenic and Rain '60. The existence of these reference waters is also supported by the conceptual post-glacial scenario model (Figure 2-1) of the site. In this particular case Litorina Sea water was selected in the modelling although also modern Baltic Sea water (3500 mg/l, Cl) could have been used. The reason is that the obtained Cl range of the samples (2670-5380 mg/l, Cl) suggested that Litorina Sea water (6100 mg/l, Cl) could have affected the samples and could therefore be an important end-member. In order to test the differences in the mixing modelling an alternative model run is presented in Appendix 4 where Baltic Sea water is used as a reference water instead of Litorina Sea water. The selected reference waters for the current modelling are (for analytical data see Table 6-2):

- **Brine, type of reference water** which represents the sampled deep brine type (Cl = 47000 mg/L) of water found in KLX02: 1631-1681m (Laaksoharju et al., 1995a).
- **Glacial, reference water** represents a possible melt-water composition from the last glaciation >13000BP. Modern sampled glacial melt water from Norway was used for the major elements and the $\delta^{18}\text{O}$ isotope value (-21 ‰ SMOW) was based on measured values of $\delta^{18}\text{O}$ in calcite surface deposits (Tullborg and Larsson, 1984). The $\delta^2\text{H}$ value (-158 ‰ SMOW) is a modelled value based on the equation ($\delta\text{H} = 8 \times \delta^{18}\text{O} + 10$) for the meteoric water line.
- **Litorina Sea water** which represents modelled, 6000 year old Baltic sea water.
- **Biogenic water** which represents Baltic Sea affected by microbial sulphate reduction.
- **Rain 1960 water** corresponding to infiltration of meteoric water (the origin can be rain or snow) from 1960. Sampled modern meteoric water with simulated high tritium (100 TU) content was used to represent precipitation from that period.

Table 6-2: Analytical or simulated data* used as reference waters in the M3 modelling for SFR.

	Cl (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	HCO ₃ (mg/L)	SO ₄ (mg/L)	³ H (TU)	$\delta^2\text{H}$ ‰	$\delta^{18}\text{O}$ ‰
Brine	47200	8500	45.5	19300	2.12	14.1	906	4.2	-44.9	-8.9
Glacial	0.5	0.17	0.4	0.18	0.1	0.12	0.5	0	-158*	-21*
Litorina	6100*	3180*	154*	152*	380*	146*	527*	0*	-35*	-5*
Biogenic	4920	2300	29	730	233	1200	36	14	-50.4	-7.3
Rain 1960	0.23	0.4	0.29	0.24	0.1	12.2	1.4	100*	-80	-10.5

The following six reactions have been considered, with comments on the qualitative outcomes of mixing and mass balance modelling with M3:

1. *Organic decomposition*: This reaction is detected in the unsaturated zone associated with Meteoric water. This process consumes oxygen according to the reaction: $O_2 + CH_2O \rightarrow CO_2 + H_2O$. M3 reports a gain of HCO_3^- as a result of this reaction.
2. *Organic redox reactions*: An important redox reaction is reduction of iron III minerals through oxidation of organic matter: $4Fe(III) + CH_2O + H_2O \rightarrow 4Fe^{2+} + 4H^+ + CO_2$. M3 reports a gain of Fe and HCO_3^- as a result of this reaction. This reaction takes place in the shallow part of the bedrock associated with influx of Meteoric water.
3. *Inorganic redox reaction*: An example of an important inorganic redox reaction is sulphide oxidation in the soil and the fracture minerals containing pyrite according to the reaction: $HS^- + 2O_2 \rightarrow SO_4^{2-} + H^+$. M3 reports a gain of SO_4^{2-} as a result of this reaction. This reaction takes place in the shallow part of the bedrock associated with influx of Meteoric water.
4. *Dissolution and precipitation of calcite*: There is generally a dissolution of calcite in the upper part and precipitation in the lower part of the bedrock according to the reaction: $CO_2 + CaCO_3 \rightarrow Ca^{2+} + 2HCO_3^-$. M3 reports a gain or a loss of Ca and HCO_3^- as a result of this reaction. This reaction can take place in any groundwater type.
5. *Ion exchange*: Cation exchange with Na/Ca is a common reaction in groundwater according to the reaction: $Na_2X_{(s)} + Ca^{2+} \rightarrow CaX_{(s)} + 2Na^+$, where X is a solid substrate such as a clay mineral. M3 reports a change in the Na/Ca ratios as a result of this reaction. This reaction can take place in any groundwater type.
6. *Sulphate reduction*: Microbes can reduce sulphate to sulphide using organic substances in natural groundwater as reducing agents according to the reaction: $SO_4^{2-} + 2(CH_2O) + OH^- \rightarrow HS^- + 2HCO_3^- + H_2O$. This reaction is of importance since it may cause corrosion of the copper canisters. Vigorous sulphate reduction is generally detected in association with marine sediments that provide the organic material and the favourable salinity interval for the microbes. M3 reports a loss of SO_4^{2-} and a gain of HCO_3^- as a result of this reaction. This reaction modifies the seawater composition by increasing the HCO_3^- content and decreasing the SO_4^{2-} content.

The above information is included in the geochemical description of the site, see section 7. The SFR data is compared with groundwater data from other Swedish sites in Figure 6-2. The Figure indicates that most of the samples plot between the reference waters Glacial and Baltic Sea water alternatively Biogenic which may indicate that these waters may have affected most of the obtained groundwater composition. Changes in groundwater composition during open tunnel conditions are demonstrated in Figure 6-3 for the SFR boreholes. The major changes are that the water becomes more marine with time. Figure 6-4 shows M3 mixing proportions for the boreholes KFR09 (small changes) and KFR10 (relatively large changes). In KFR10 an increasing amount of glacial water is drawn toward the tunnel until it is consumed and when there is no

source for this water it is replaced by marine water (Biogenic). The changes in Cl content are relatively small for these boreholes (c.f. Figure 5-4). Similar illustrations of changes of mixing proportions with time for other SFR boreholes are shown in Appendix 1.

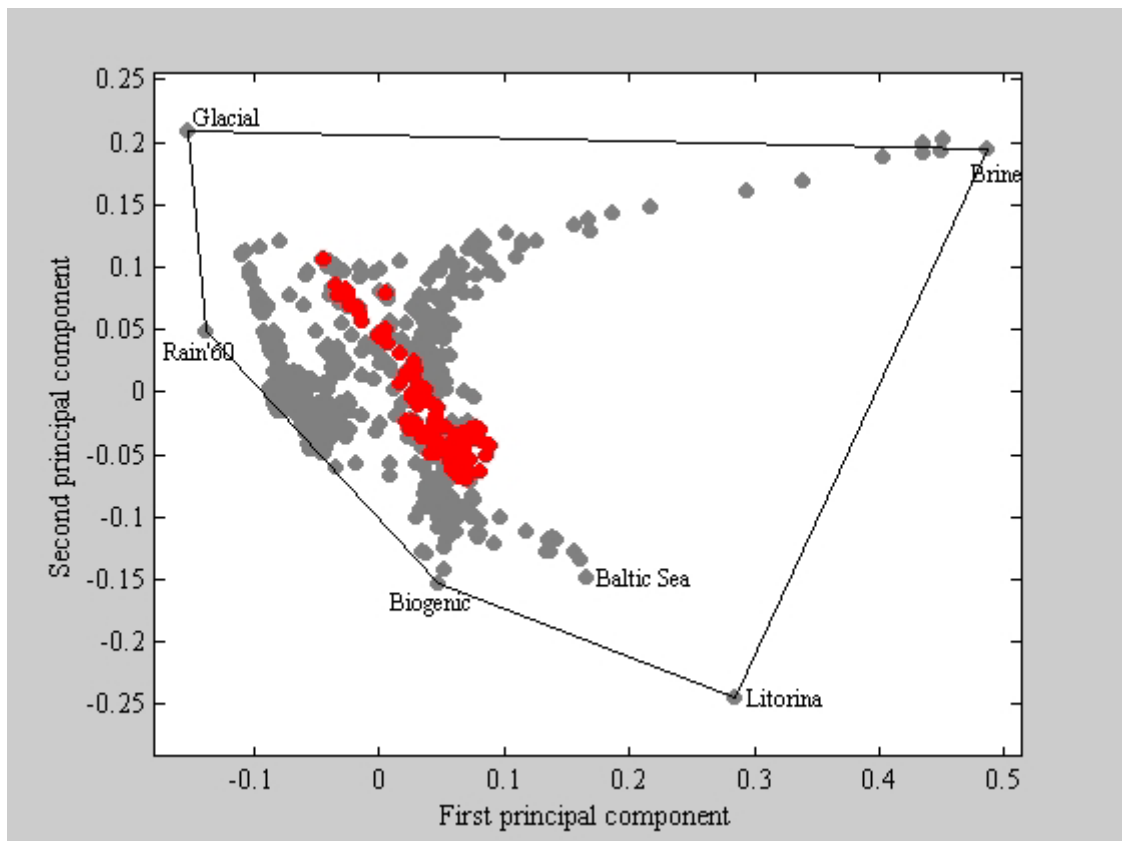


Figure 6-2: Principal Component Analysis is used to compare SFR data (red dots) with data from other Swedish sites (grey dots). The analysis is based on the major groundwater components, stable isotopes and tritium (listed in Appendix 5). The analysis show that most of the samples plot between the reference waters Glacial, Biogenic and Baltic Sea which may indicate that these waters have affected the obtained groundwater composition. The polygon represents the model used in M3 mixing calculations used to quantify the mixing proportions listed in Appendix 5. The first and second principal component summarise 70% of the groundwater information which is regarded as a high value.

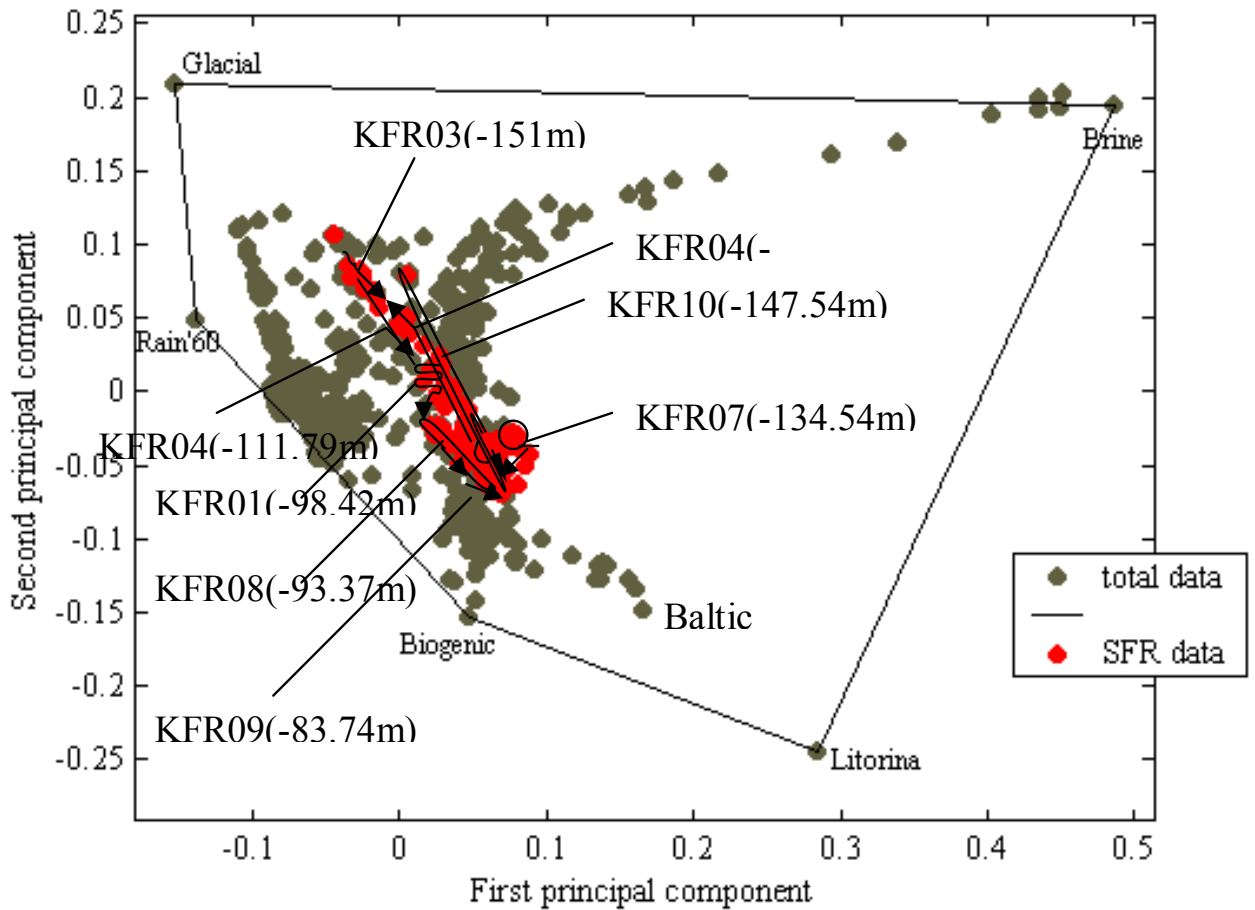


Figure 6-3: Principal Component Analyses is used to show groundwater changes for SFR boreholes (red dots) with time (the arrows start at the first observation and ends at the last observation). The general trend is that most of the boreholes get a more marine (Biogenic and Baltic) signature with time. Data from other Swedish sites are indicated with grey dots. The analysis is based on the major groundwater components, stable isotopes and tritium (listed in Appendix 5). The polygon represent the model used in M3 mixing calculations used to quantify the mixing proportions listed in Appendix 5. The first and second principal component summarise 70% of the groundwater information which is regarded as a high value.

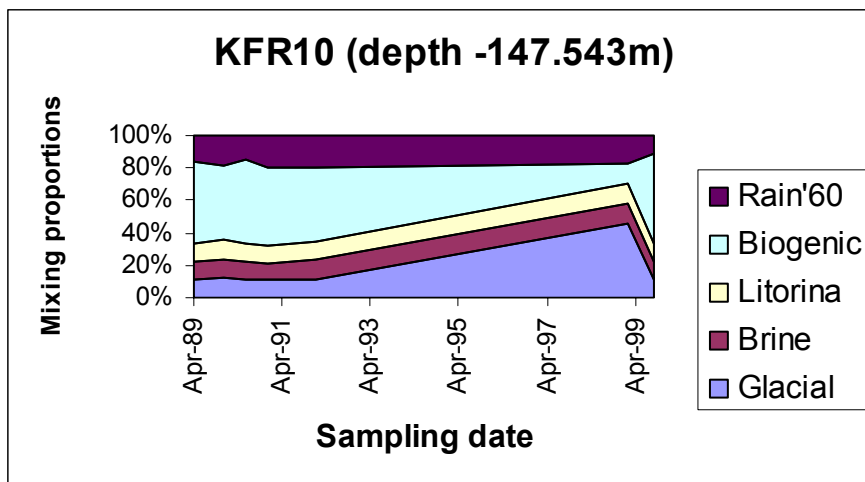
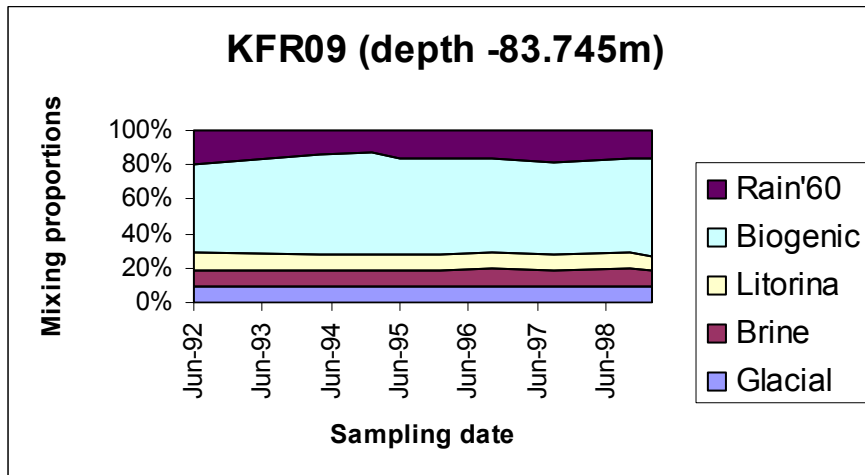


Figure 6-4: M3 mixing proportions (listed in Appendix 5) are used to illustrate changes for two boreholes with time. The borehole KFR09 represents a borehole with small changes and borehole KFR10 a borehole with relatively large changes in mixing proportions. In KFR10 an increasing amount of glacial water is drawn toward the tunnel until it is consumed and since then it is replaced by marine water (Biogenic).

6.3 Model uncertainties

The following uncertainties can affect the M3 calculations:

- 1) Input hydrochemical data errors originating as sampling errors caused by the effects from drilling, borehole activities, extensive pumping, hydraulic short-circuiting of the borehole and uplifting of water which changes the in-situ pH and Eh conditions of the sample, or as analytical errors.

- 2) Conceptual errors such as wrong general assumptions, selecting wrong type/number of end-members and mixing calculations for samples that are not mixtures.
- 3) Methodological errors such as oversimplification, bias or non-linearity in the model, and the systematic uncertainty which is attributable to use of the centre point to create a solution for the mixing model.

An example of a conceptual error is assuming that the groundwater composition is a good tracer for the flow system. The water composition is not necessarily a tracer of mixing directly related to flow since there is not a point source as there is when labelled water is used in a tracer test.

Another source of uncertainty in the mixing model is the loss of information in using only the first two principal components. The third principal component gathers generally around 10% of the groundwater information compared with the first and second principal components which contain around 70% of the information. A sample could appear to be closer to a reference water in the 2D surface than in a 3D surface involving the third principal component. In the latest version of M3 the calculations can also be performed in 3D.

Uncertainty in mixing calculations is smaller near the boundary of the PCA polygon and larger near the centre. The uncertainties have been handled in M3 by calculating an uncertainty of 0.1 mixing units (with a confidence interval of 90%) and stating that a mixing portion <10% is under the detection limit of the method. The effects from data uncertainties ($\pm 5\%$) and model uncertainties ($\pm 10\%$) are shown in Figure 6-5.

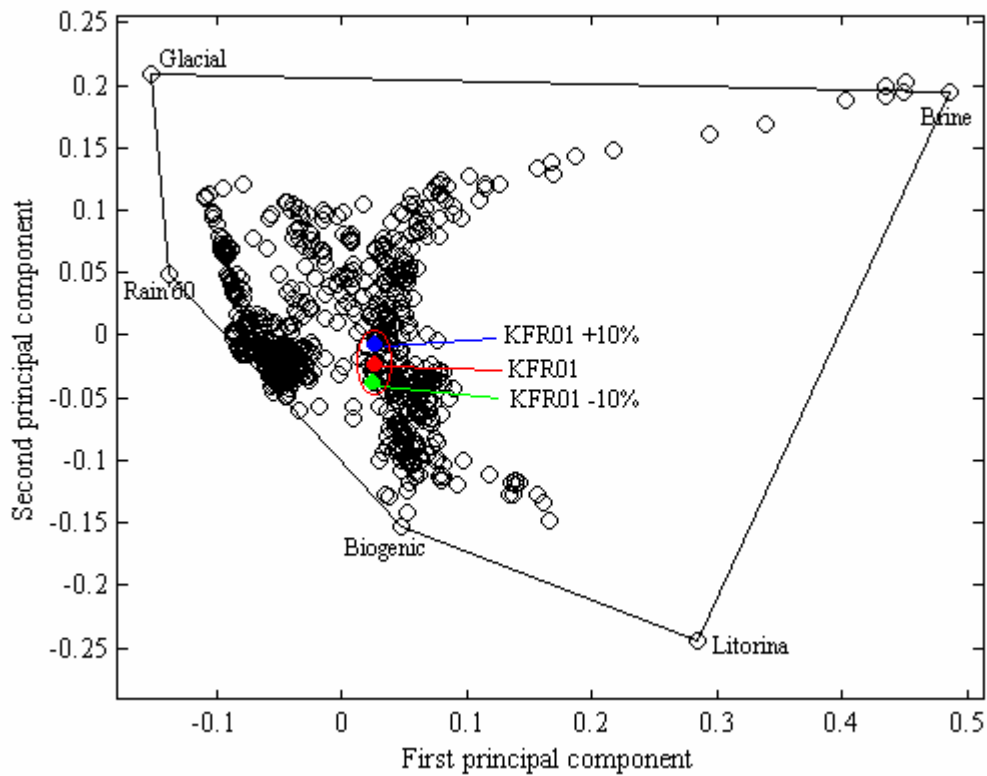


Figure 6-5: The effect from the data uncertainties and model uncertainties are plotted on the PCA for the sample (KFR01, depth -73.5m). The model uncertainty $\pm 10\%$ shows the deviation of the point in the PCA: in red is the actual value, in blue the deviation of $+10\%$ and in green the deviation of -10% . The shift of the point in the PCA does not change or affect the overall interpretation. The effect from analytical uncertainties is $\pm 5\%$ and is therefore half of the $\pm 10\%$ uncertainties shown in the figure.

6.4 Visualisation of the salinity distribution

To visualise the measured salinity (for simplification only Cl is used) distribution along the SFR tunnel system a 2D modelling by using TecPlot was performed. The result of the measured Cl content in various boreholes along the tunnel is shown in Figure 6-6. The information from the modelling is integrated in the geochemical description of the site, see chapter 7.

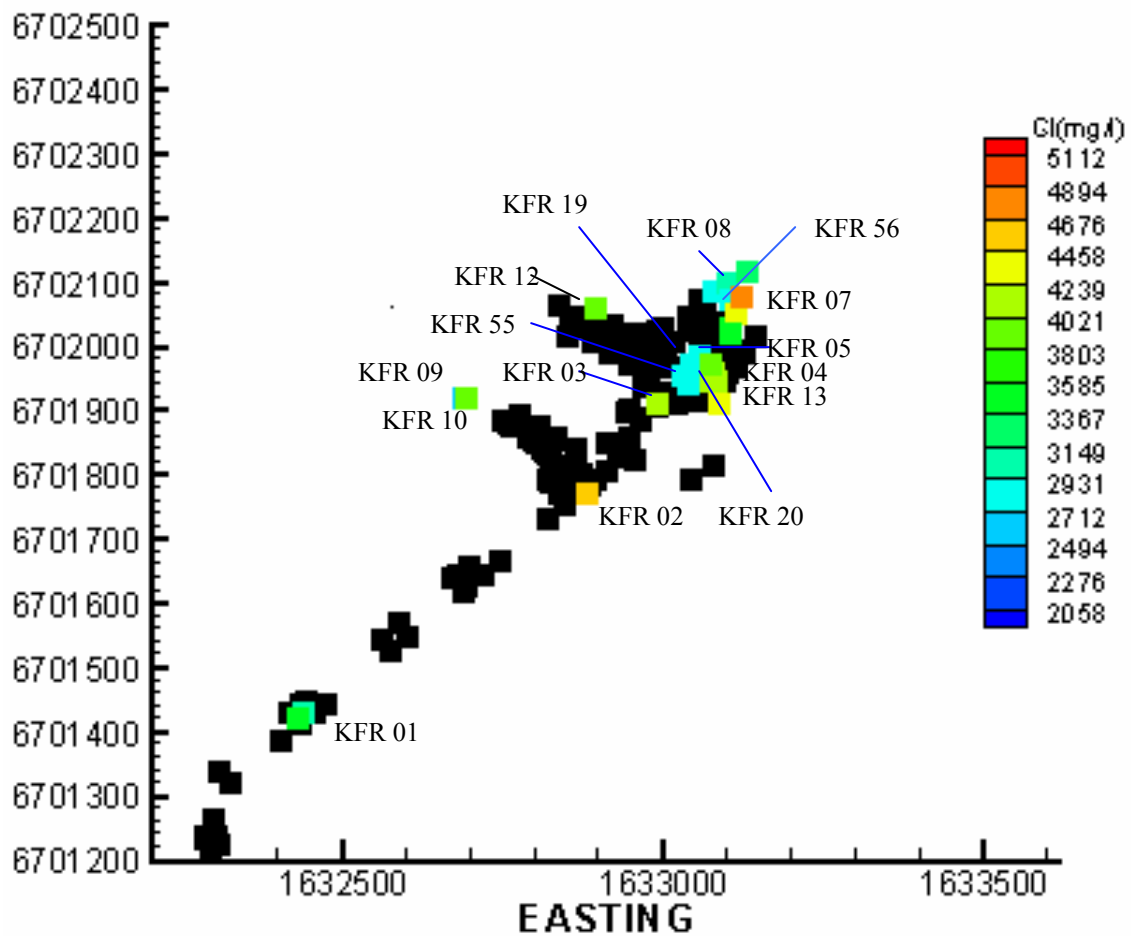


Figure 6-6: Visualisation of the SFR tunnel (black dots) and the Cl content (in colour) in the SFR boreholes represented from above the tunnel (the east and north coordinates are printed on the axes).

7 The SFR Site Descriptive model

To summarise the results from the modelling of the SFR site a *Schematic site descriptive model* has been constructed (see Figure 7-1). The illustration shows the distribution of the major water types, indicates the mixing proportions of the water types and lists the major reactions occurring at the site.

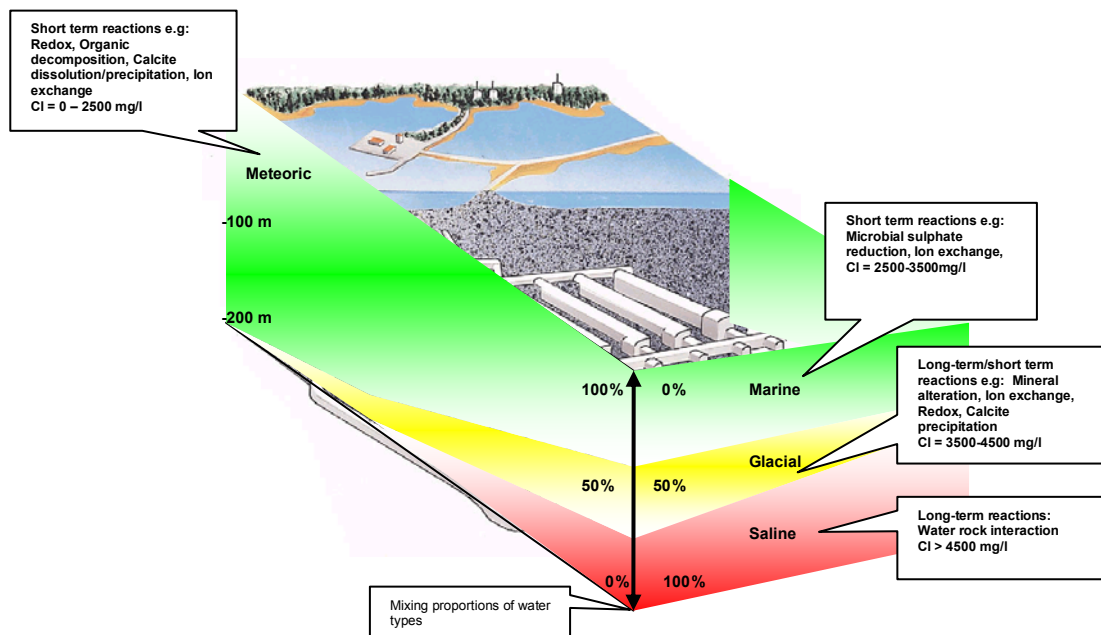


Figure 7-1: A schematic site descriptive model for SFR. The dominating water types, mixing proportions of water types and major reactions are indicated. The water types are: Meteoric Type (HCO_3 rich water type named Rain 1960 in M3 calculations), Marine Type (Na-Cl rich water type named Litorina Sea and Biogenic in M3 calculations), Glacial Type (Na-Ca-Cl rich water type with low Oxygen-18 content) and Saline type (Na-Ca-Cl rich water type with high Oxygen-18 content) indicated by Brine portions in M3 calculations.

The major characteristics of the dominating waters types (Meteoric, Marine, Glacial and Saline at SFR are:

Meteoric Type (HCO_3 - SO_4 to Na- HCO_3 rich water type): As seen in the upper-left corner of Figure 7-1 the part under the land is expected to be dominated by modern meteoric water (0-1000 B.P) to a depth of approximately 50 m. This water type is altered by fast short-term reactions such as redox reactions that prevent deep oxygen penetration into the bedrock. Oxygen consumption and carbonate production linked to organic decomposition, iron reduction and methane production is generally the dominating redox reaction (Pedersen and Karlsson, 1995, Banwart et al., 1996). Saturation index calculations and M3 modelling indicated dissolution of calcite in the upper recharge part of the bedrock and the resulting precipitation of calcite in the lower part of the bedrock which can alter the direction of the groundwater flow paths in

fractured bedrock. Sinks and sources of anions and cations due to sorption/desorption (i.e. surface complexation and ion exchange) can alter the water composition of the meteoric groundwater (Laaksoharju and Wallin (eds), 1997).

Marine Type (Na-Cl rich water type): The bedrock located under Baltic Sea is dominated by marine water. The penetration depth can vary from 100m to 200m. The source of Mg is shown to be associated with marine water consisting of present Baltic Sea (0-3000 B.P.), Biogenic (modified modern Baltic Sea water) or possibly Litorina Sea water (>6000 B.P.). Marine water is characterised by fast, short-term reactions that modify the waters when they enter the bedrock and have been identified as a sink of K and Na, and a gain of Ca, due to ion-exchange with clays (Laaksoharju and Wallin (eds.) 1997). The Marine water can undergo decomposition of organic material due to microbiological sulphate reduction (Biogenic) which has been detected by M3 modelling as a sink for SO₄ and a source for HCO₃ (Laaksoharju (ed.), 1995). This conclusion is supported by the measurements of sulphate reducing bacteria at some locations of the Äspö-HRL.

Glacial Type (Na-Ca-Cl rich water type with low $\delta^{18}\text{O}$ value): An important water type found at SFR has been affected by a component of cold climate recharge (Tullborg, 1997). The low $\delta^{18}\text{O}$ value indicates a climate which corresponds to a mean annual temperature of -3°C using Dansgaard's formula (Dansgaard, 1964). Such a low temperature has not prevailed during post-glacial times in the area. Cold climate signatures (>10000 B.P.) are found in many samples from SFR. The interpretation from the conceptual model (see Figure 2-1) and the M3 calculations are that this water type has been formed by the continental ice sheet melting and the water has pushed the saline water downwards. The amount, oxidation state, penetration depth of the glacial meltwater are not completely known. Despite the many indications of glacial meltwater at depth, there is no clear evidence from the fracture mineral distribution that this water was oxygenated to more than 50-100m in the upper part of the bedrock (Tullborg, 1997). The calculated sink for Ca may be due to calcite precipitation during injection of glacial groundwater and consequent mixing with calcite-saturated saline groundwater which caused super saturation of calcite (Laaksoharju and Wallin (eds.), 1997).

Saline Type (Na-Ca-Cl rich watertype with high low $\delta^{18}\text{O}$ value): At depths below 150 m the saline groundwater mixing portion in the M3 calculations starts to increase. The origin of the saline component > 4500 mg/l at the SFR could be old Sea water. This water type is believed to be the oldest water type at the site.

The conclusion is that the modelled present-day groundwater conditions of the SFR site consist of a mixture in varying degrees of different water types. The data indicate that all the groundwater at SFR is strongly affected by Sea water of different origin and ages. The meteoric (0-1000 B.P) portion is located close and under the land. The marine portion consisting of Litorina (>6000 B.P.), Baltic Sea water (0-3000 B.P) and Biogenic (modern modified Sea water) is located in bedrock under the Sea bed. Under this water a mixture of glacial water (>10.000 B.P.) and older Saline water exist from a depth of 100m to 200m.

8 Acknowledgements

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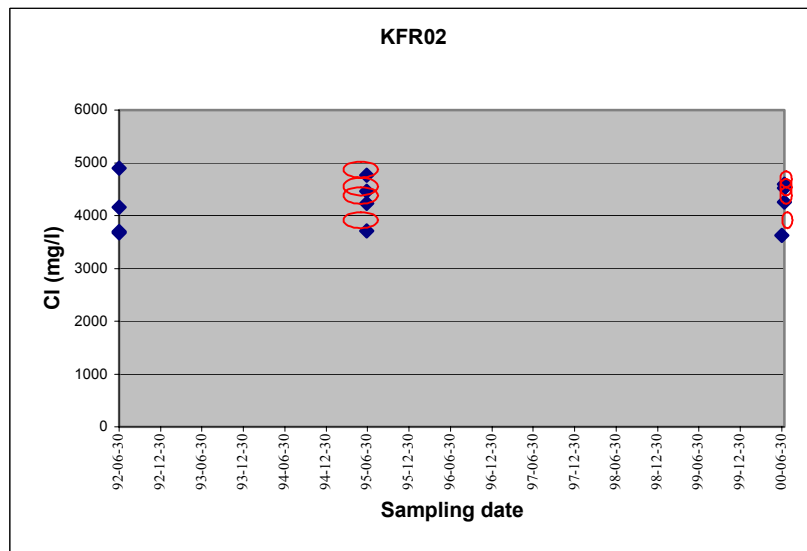
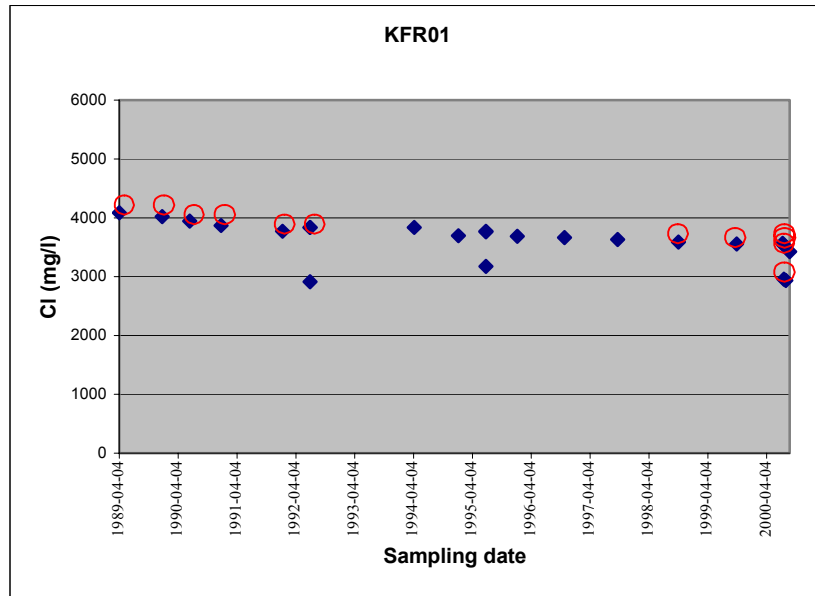
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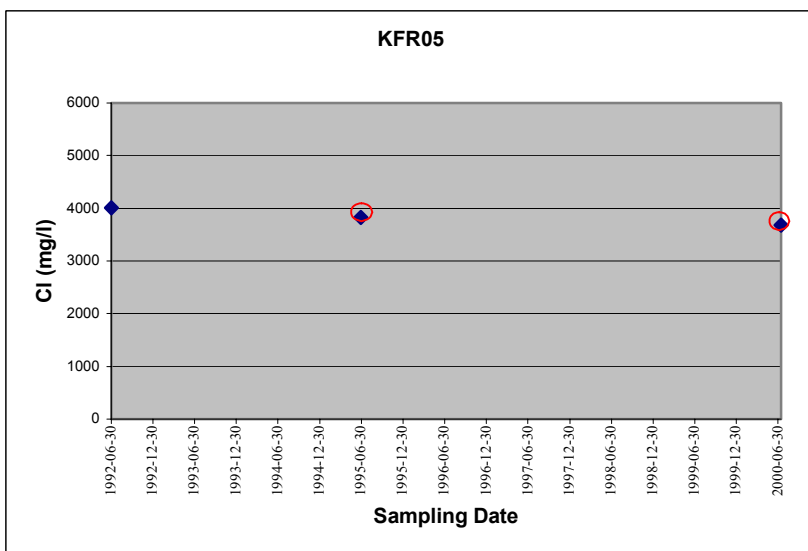
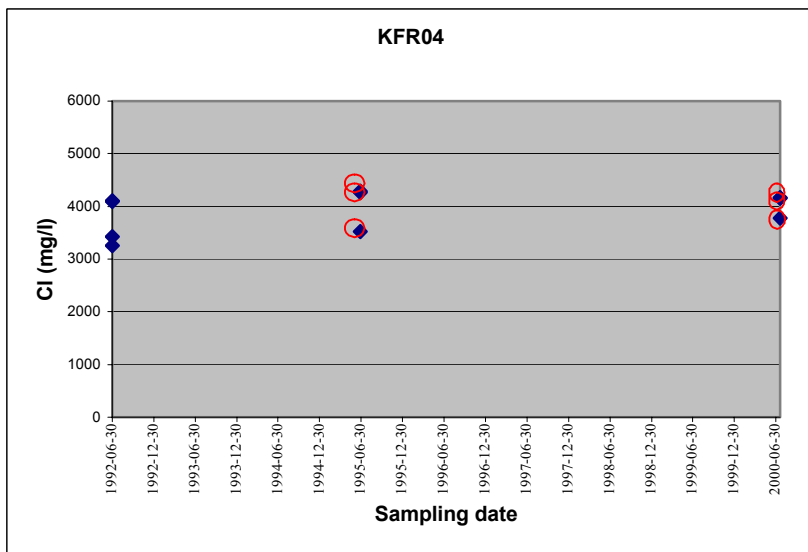
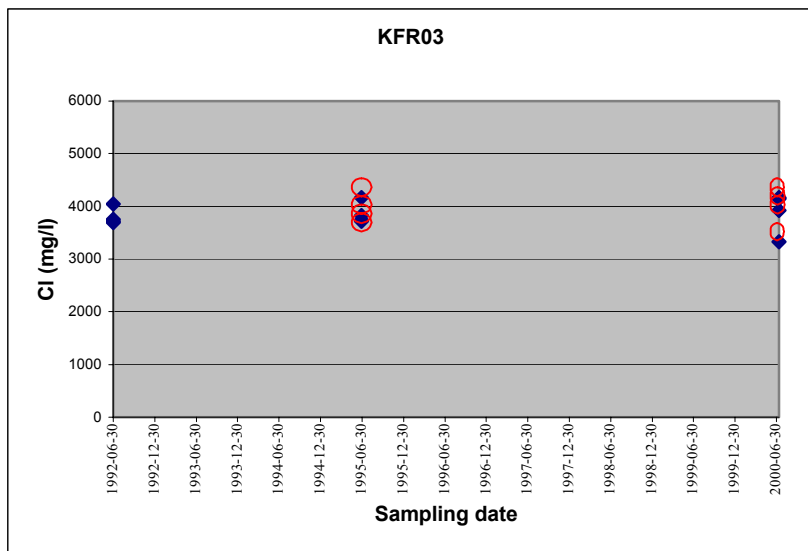
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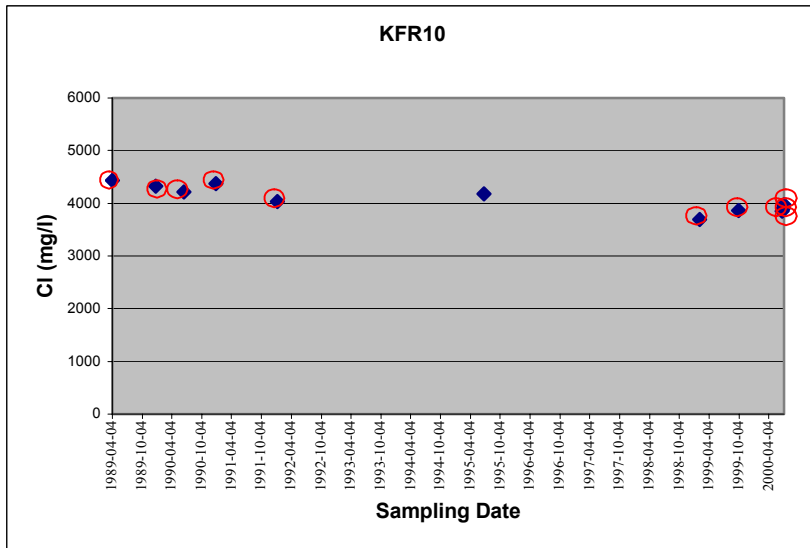
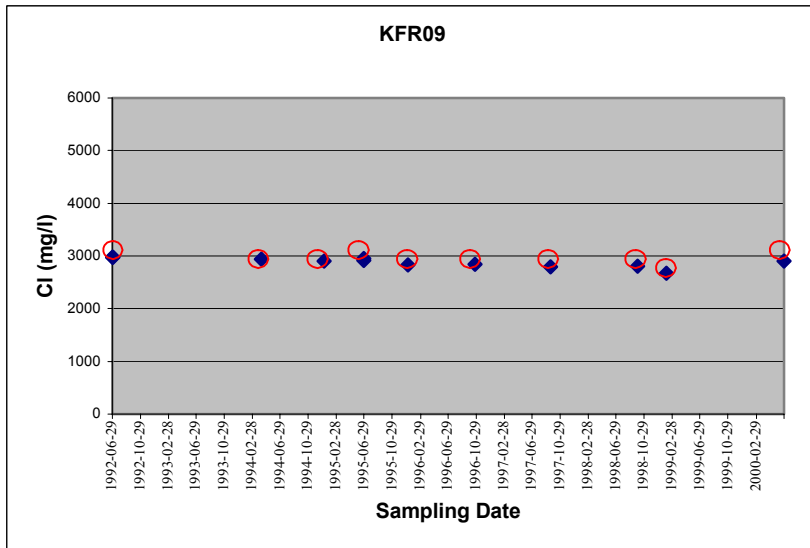
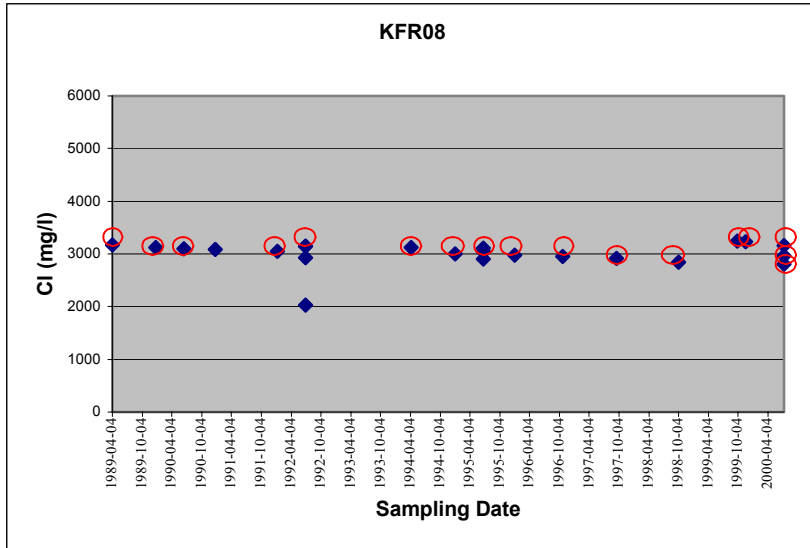
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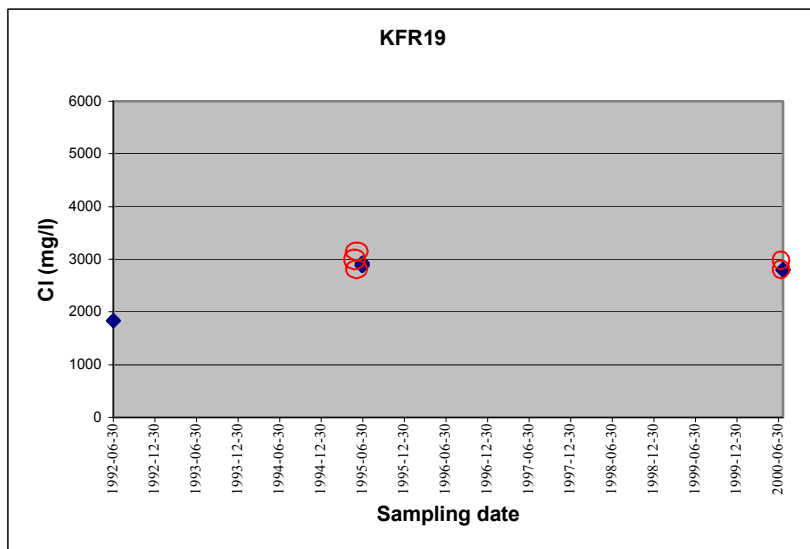
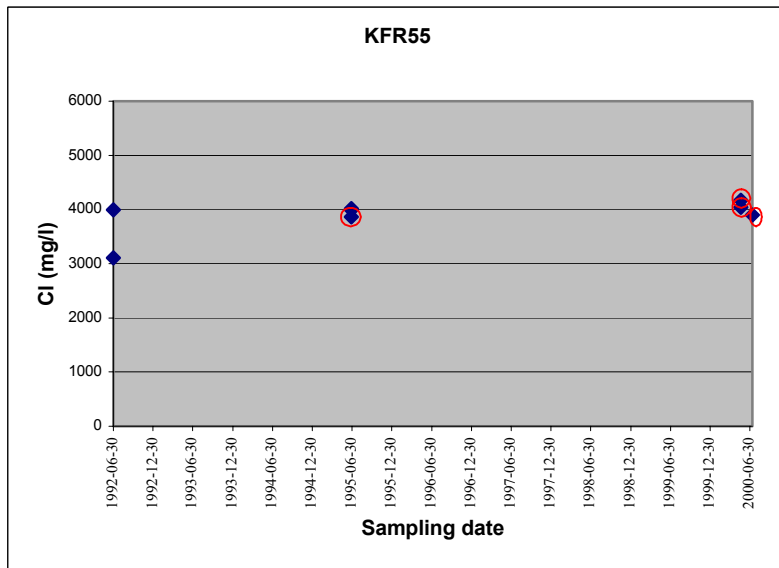
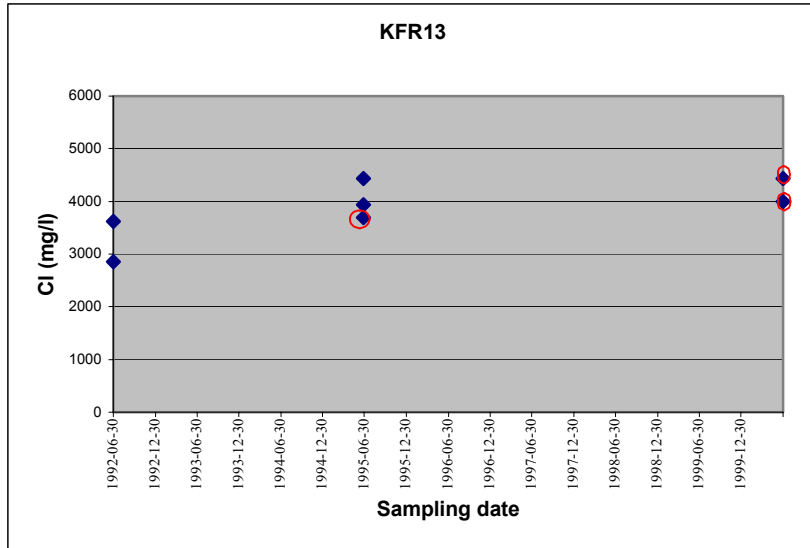
Appendix 1

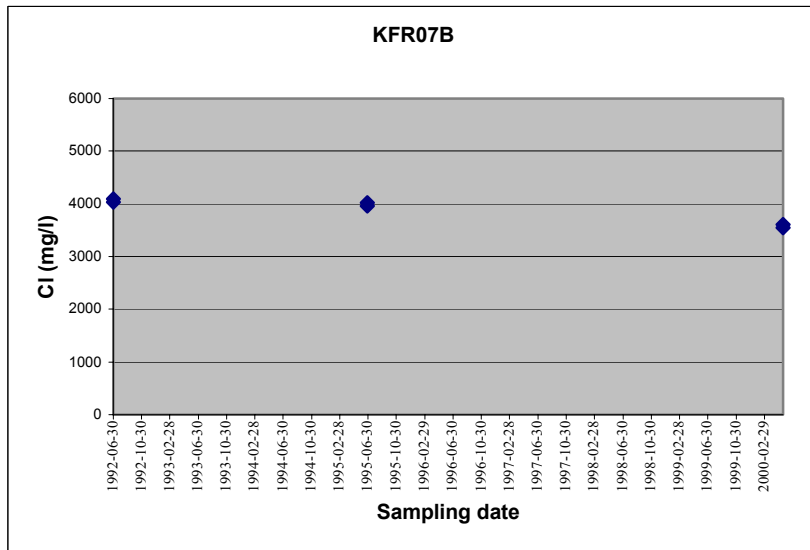
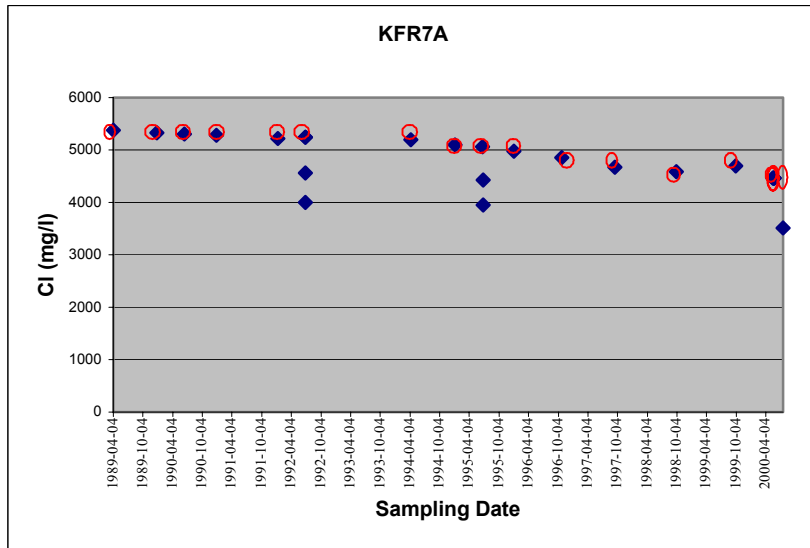
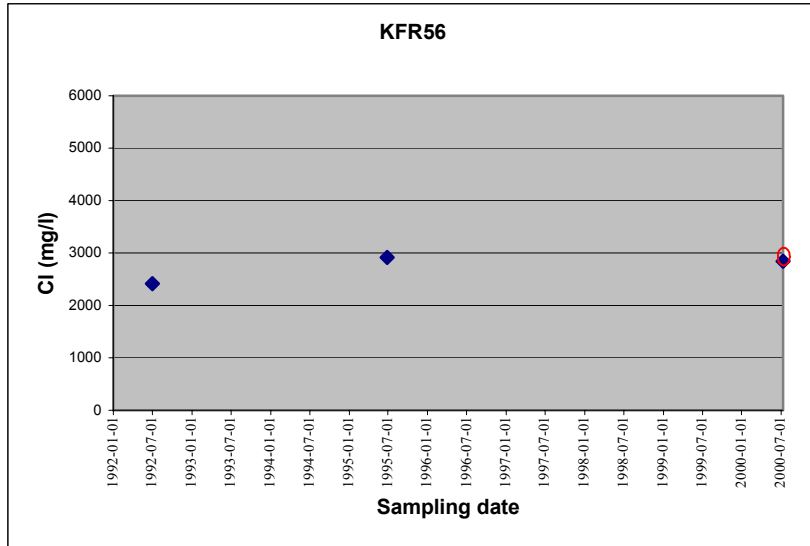
This appendix represent the Cl (mg/l) concentration sampled for each borehole with time. The circled values are the values used in the M3 modelling. Observations with different Cl content from the same time period represent water sampled from the same borehole but at different depths.

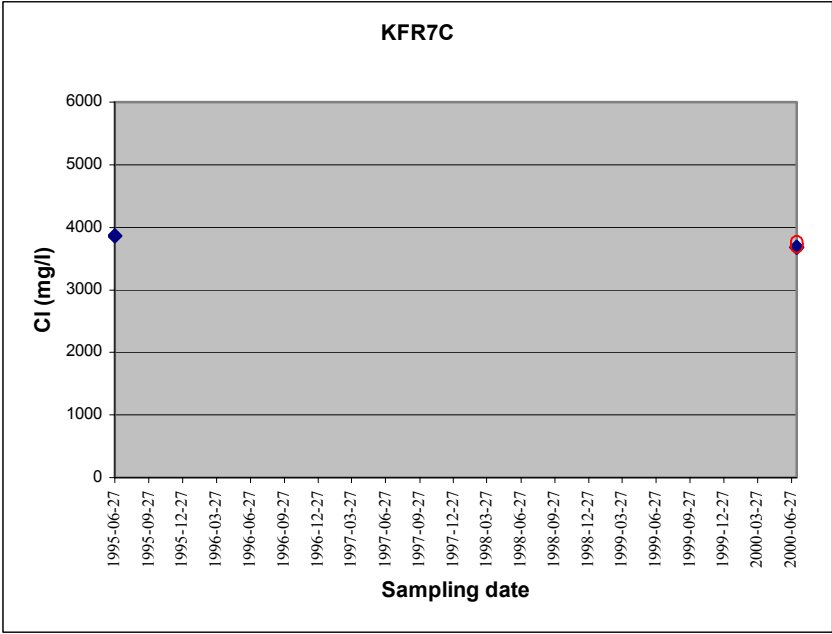








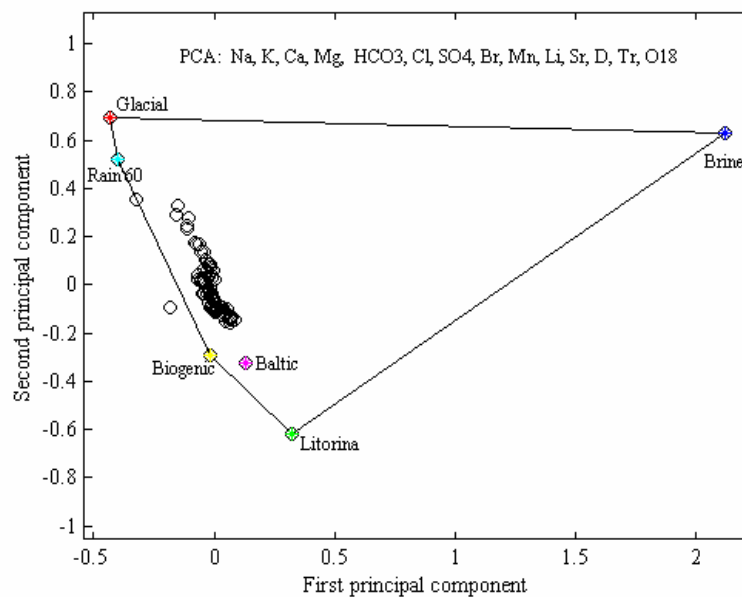
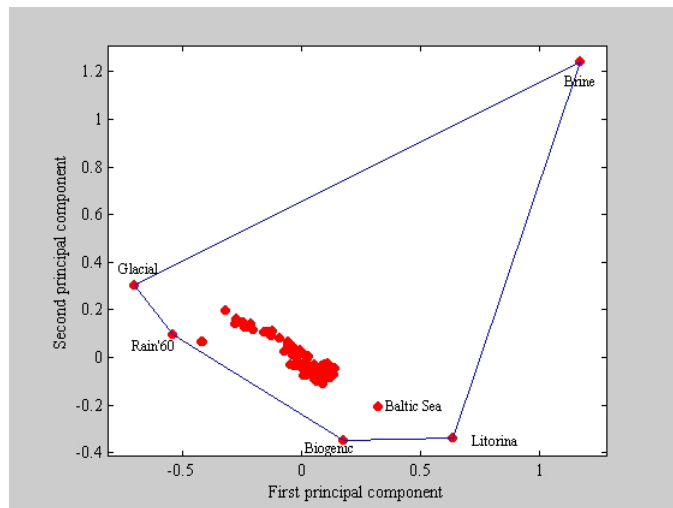


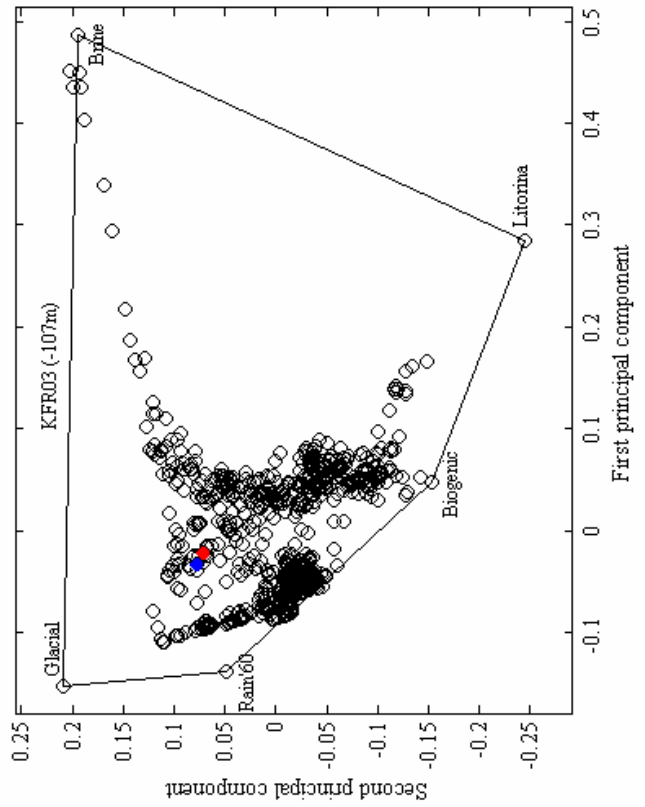
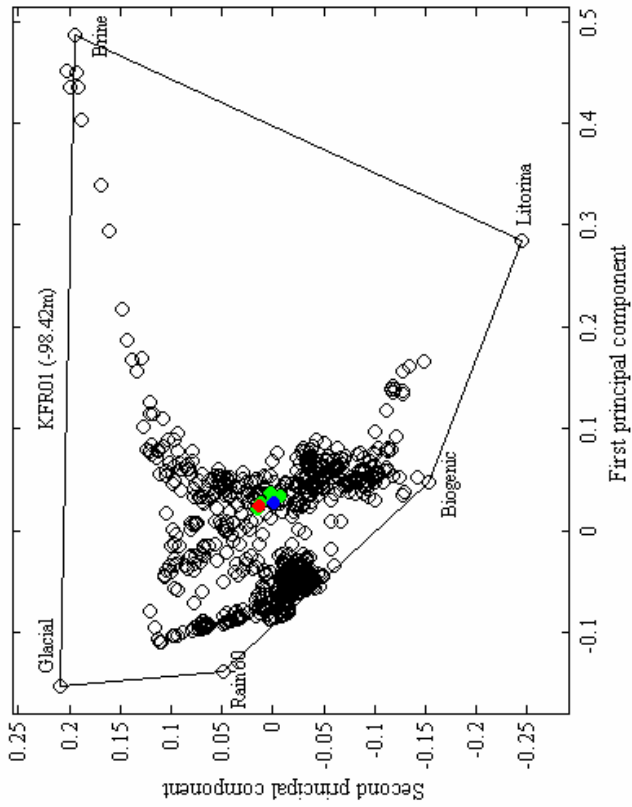
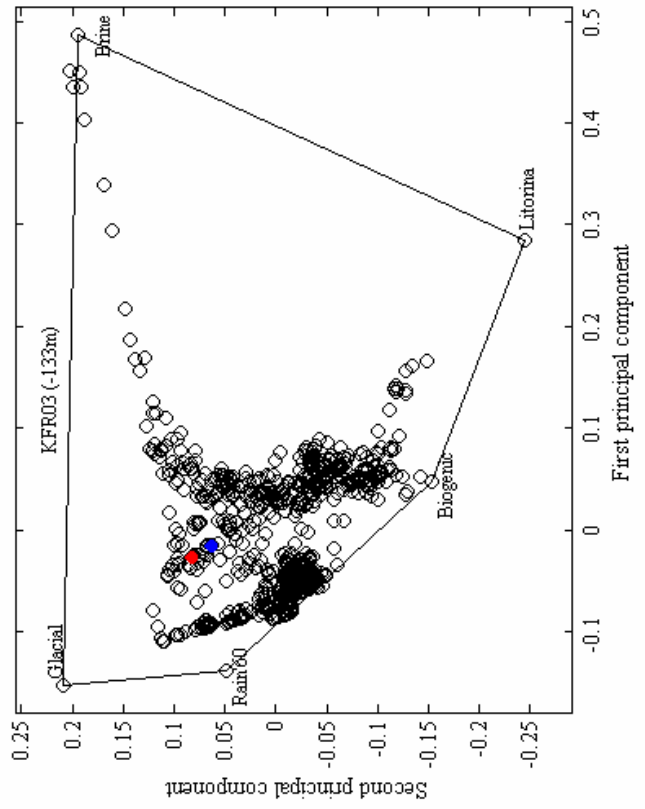
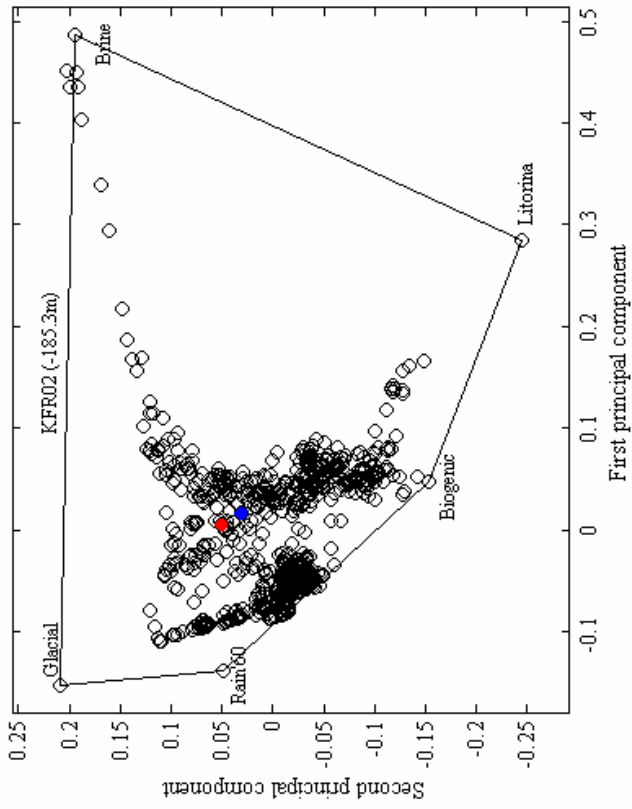


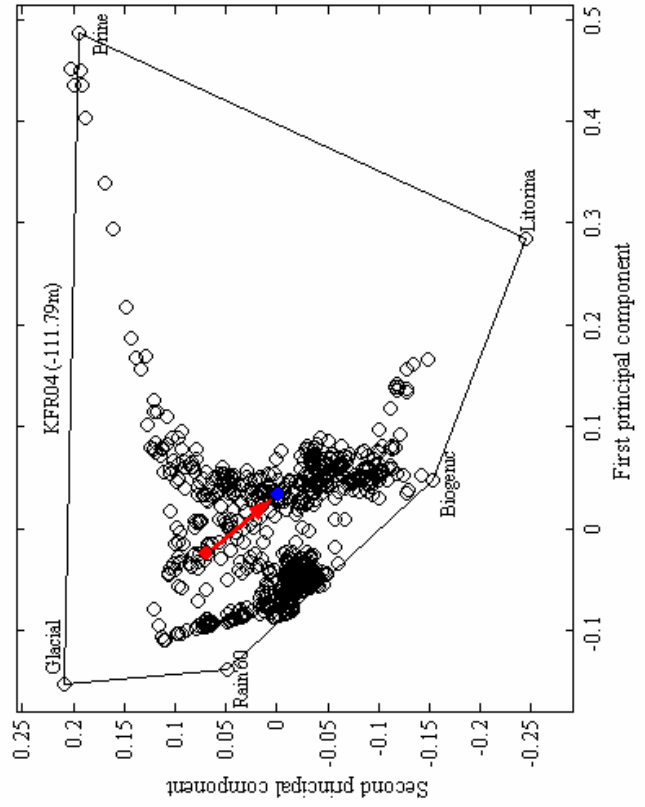
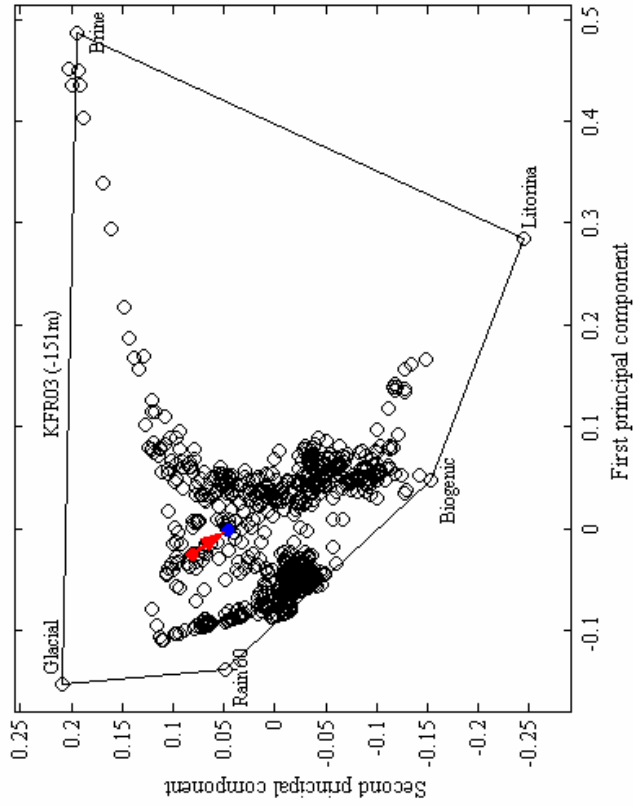
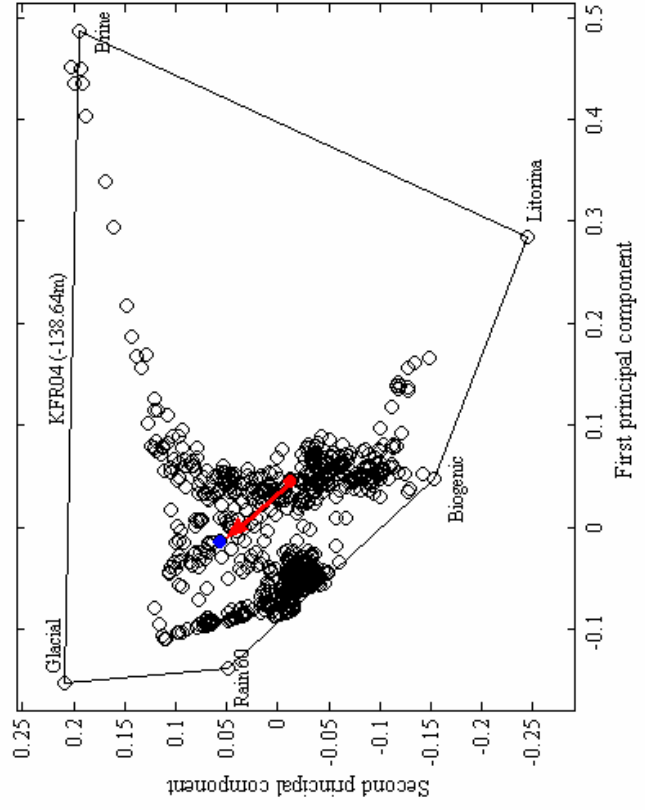
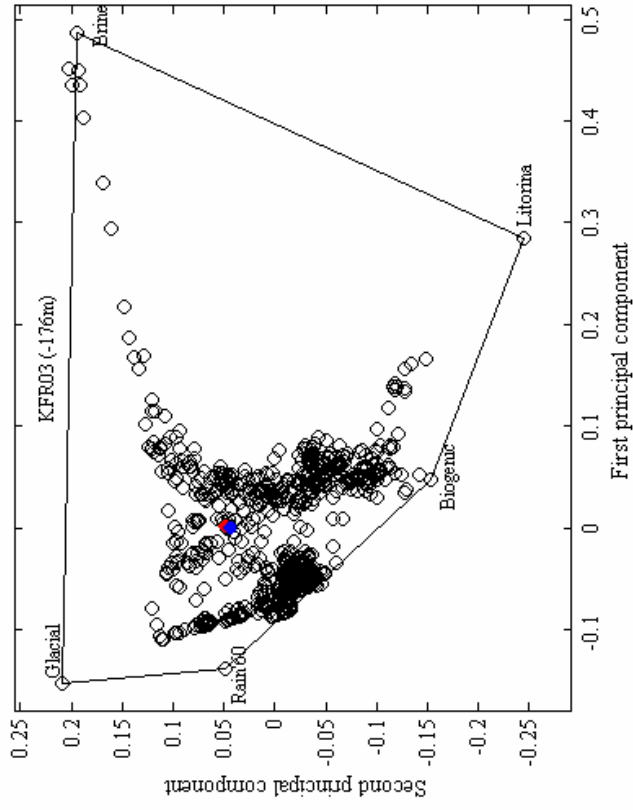
Appendix 2

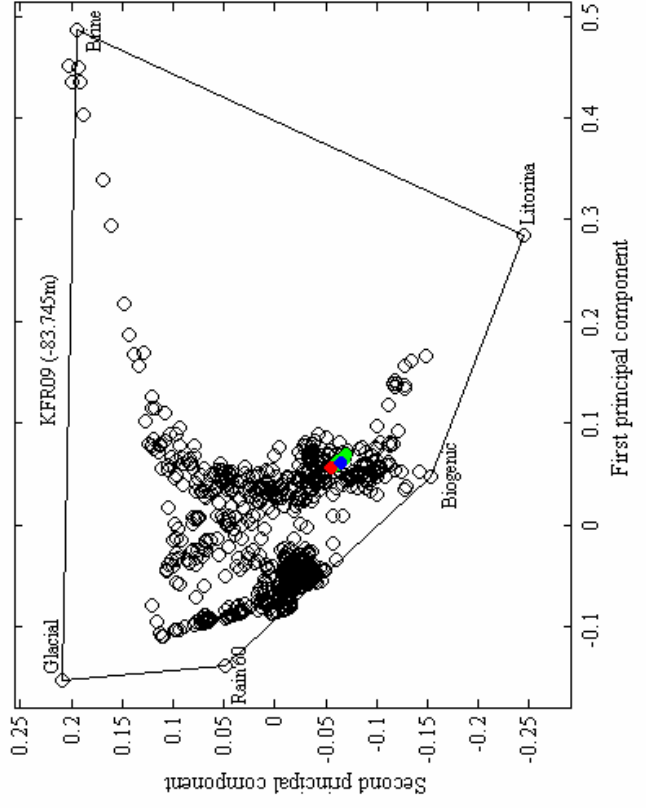
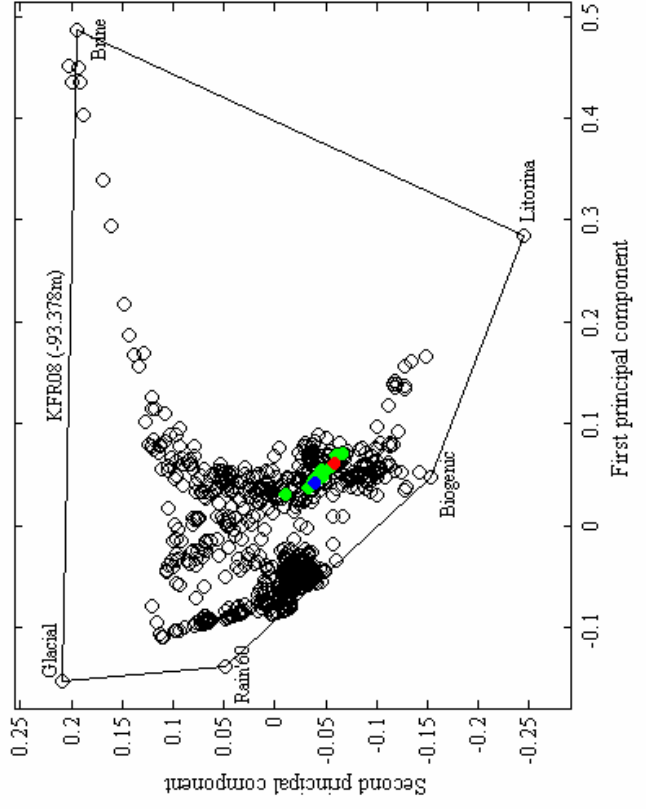
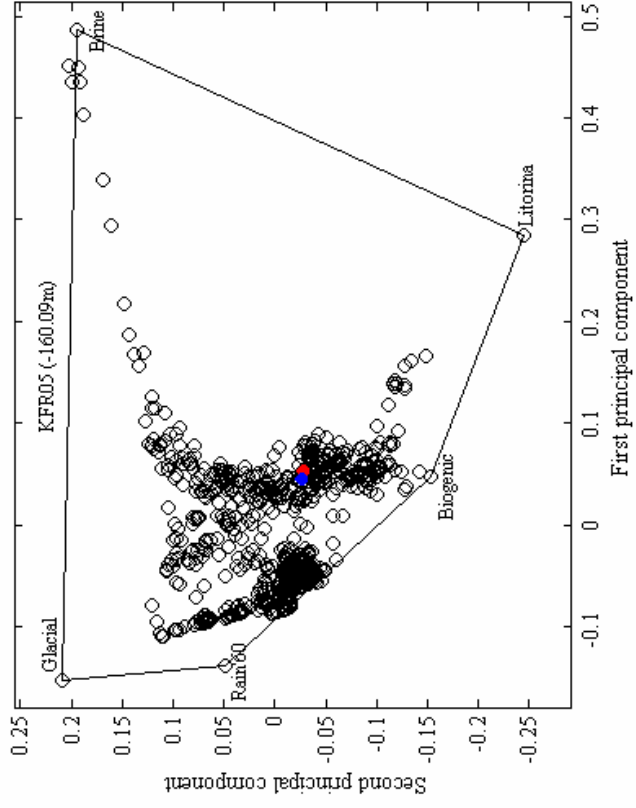
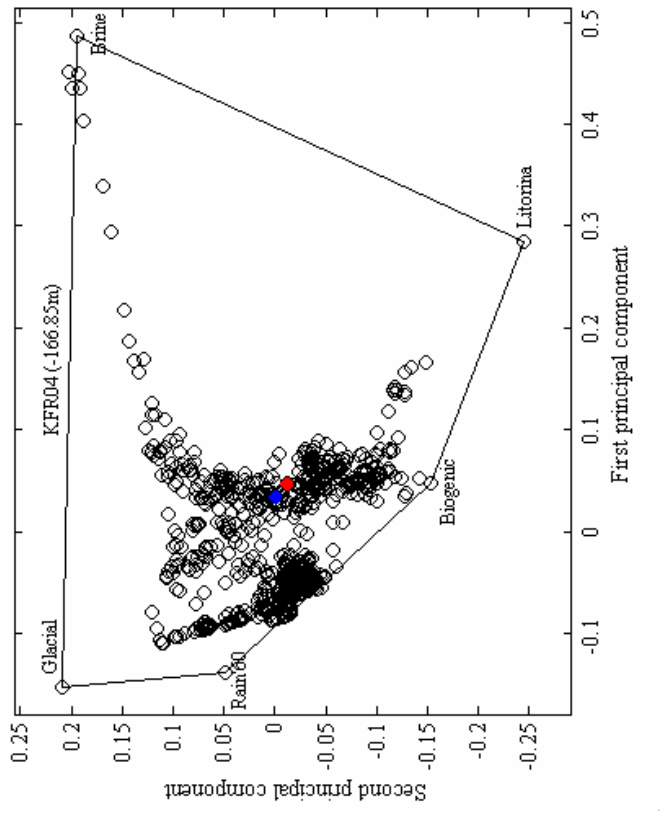
The two PCA plots on this page show a test where only data from SFR was used (upper PCA) and the lower PCA plot show the results from a test where elements such as Br, Mn, Li and Sr were added to the PCA (80 samples could be used for this purpose). The overall shape remain fairly unchanged indicating minor effects from these elements or by using a reduced data set compared with the selected PCA shown in Figure 6-2 where also the samples from other sites in Sweden were included.

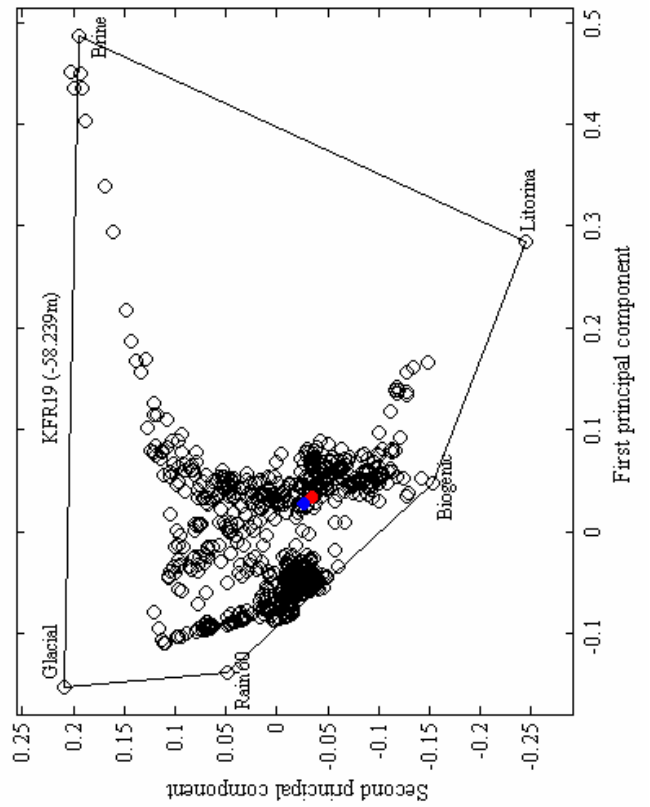
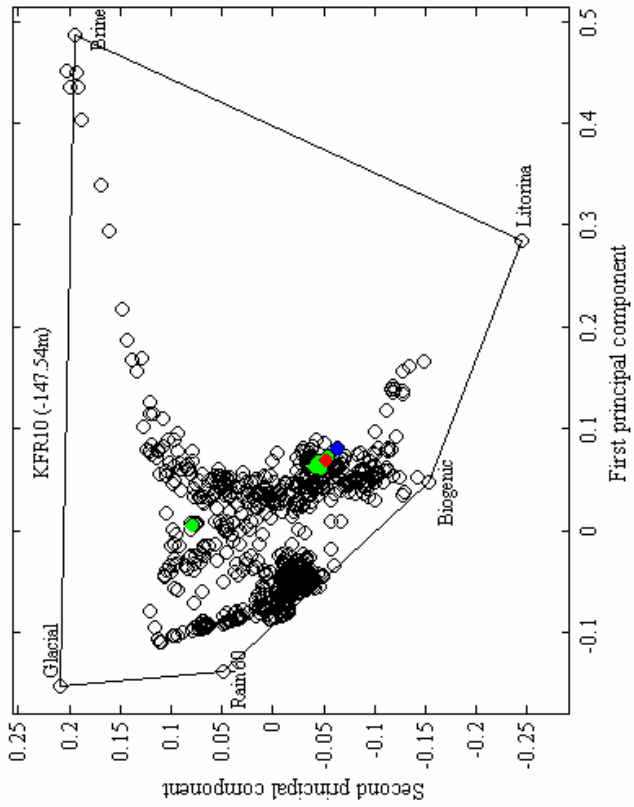
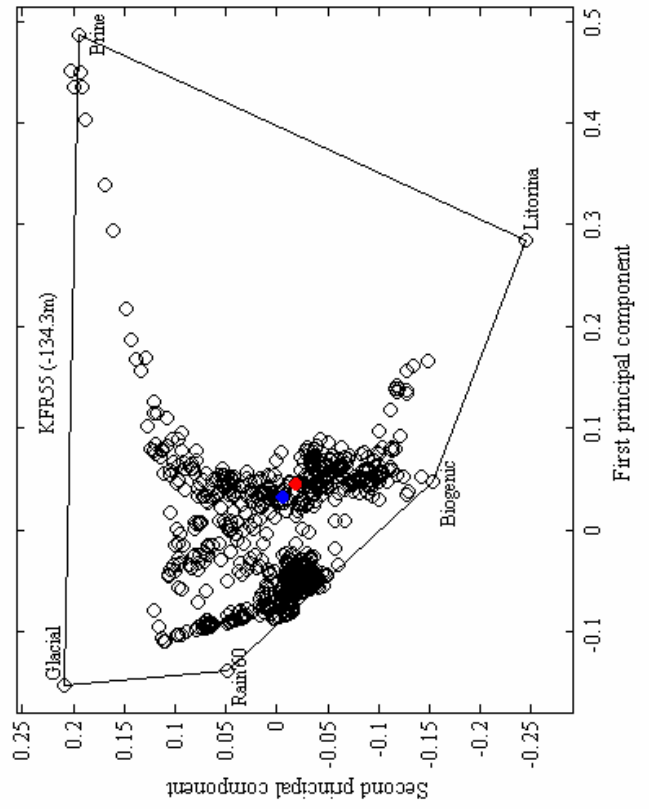
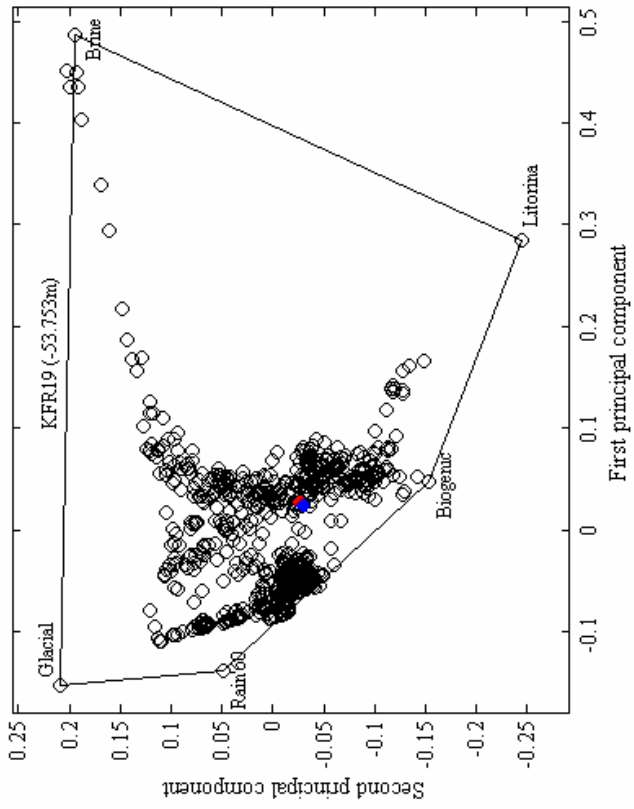
The PCA plots presented on the pages 47-51 are used to show the geochemical evolution of the groundwater composition with time for all the sampled sections. Indicated in red is the first sample and in blue the last sample. When there are time series from the sampled section, the samples between the first and last samples are represented in green.

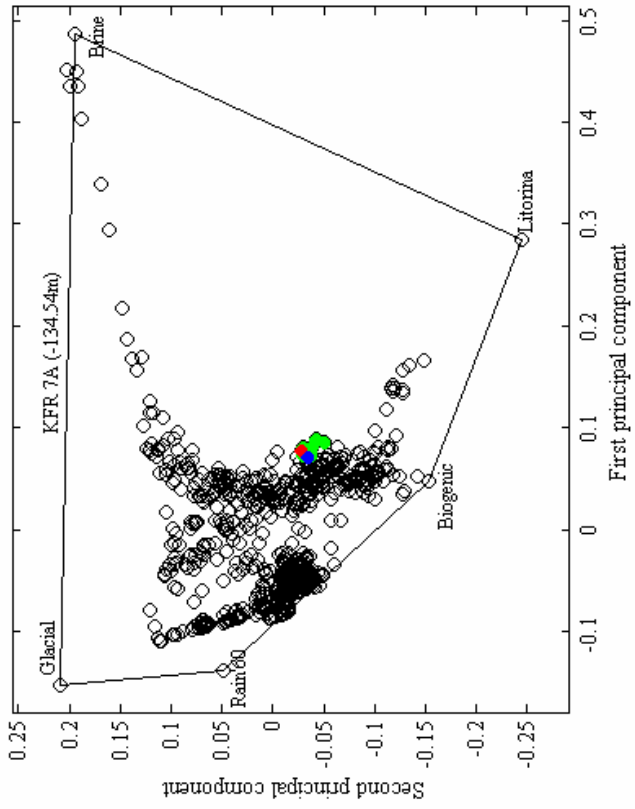






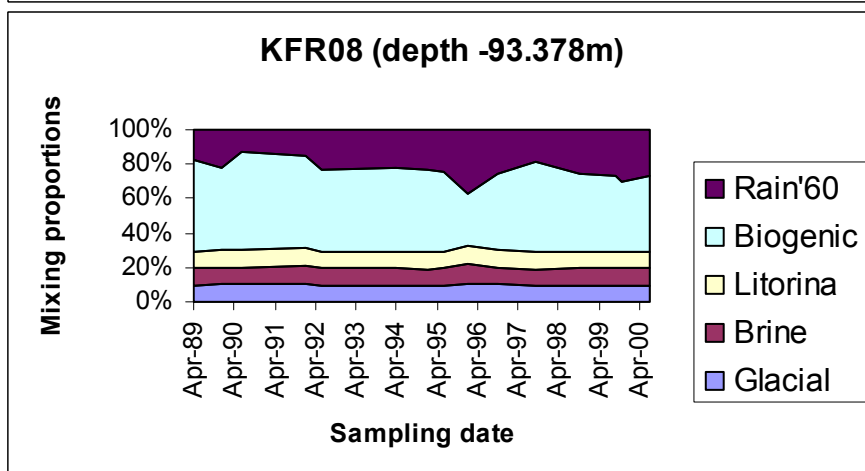
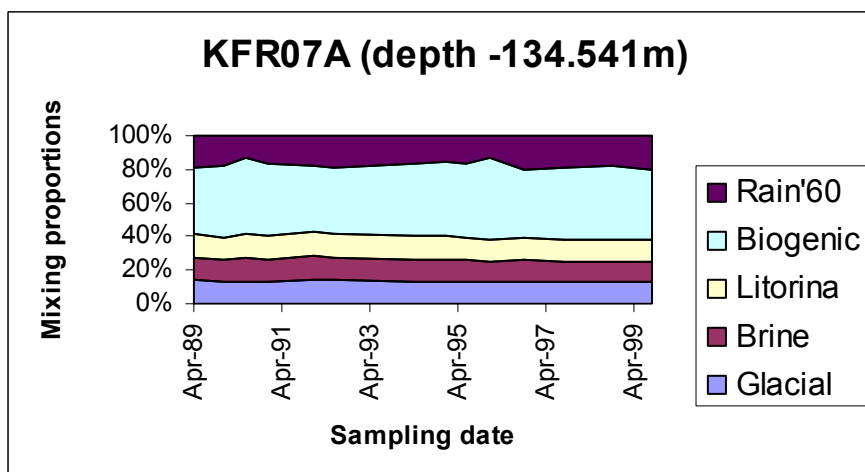
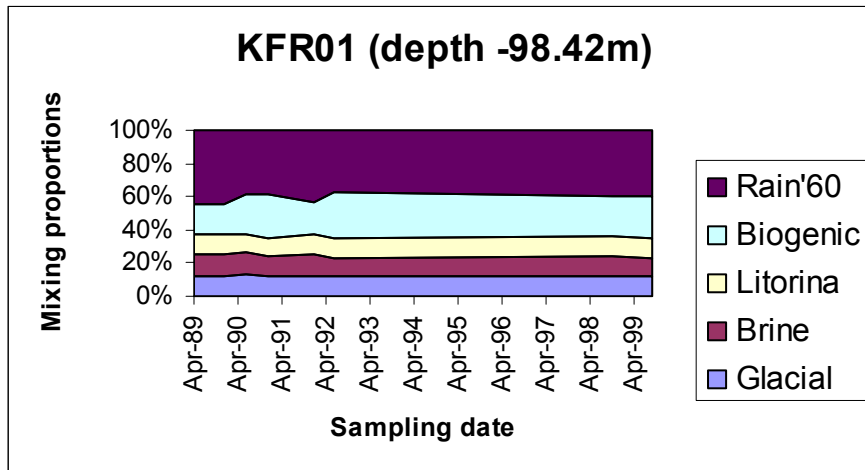




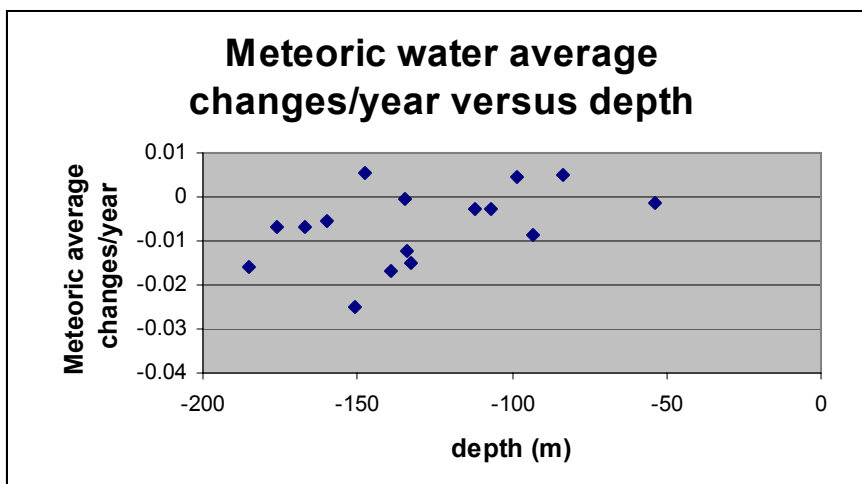
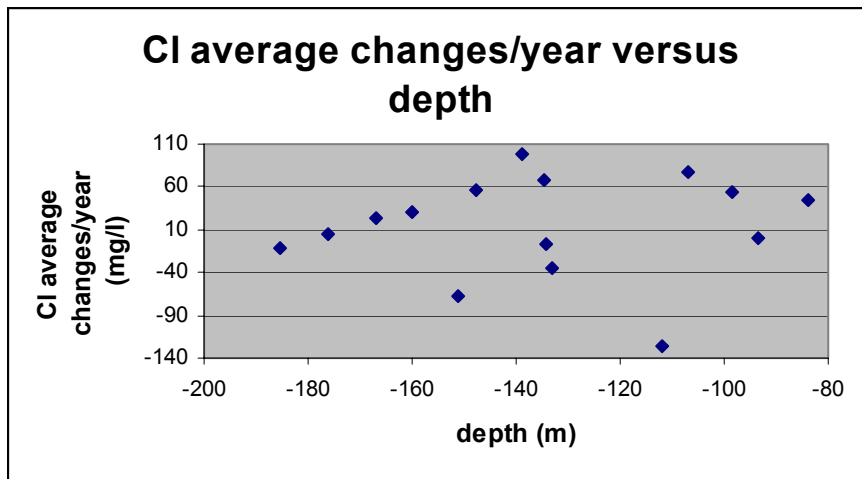


Appendix 3

The variation of the M3 mixing proportions with time are presented below for some sampled borehole sections. In general, only the Rain 1960 (meteoric), biogenic and Litorina mixing portions show some variations.

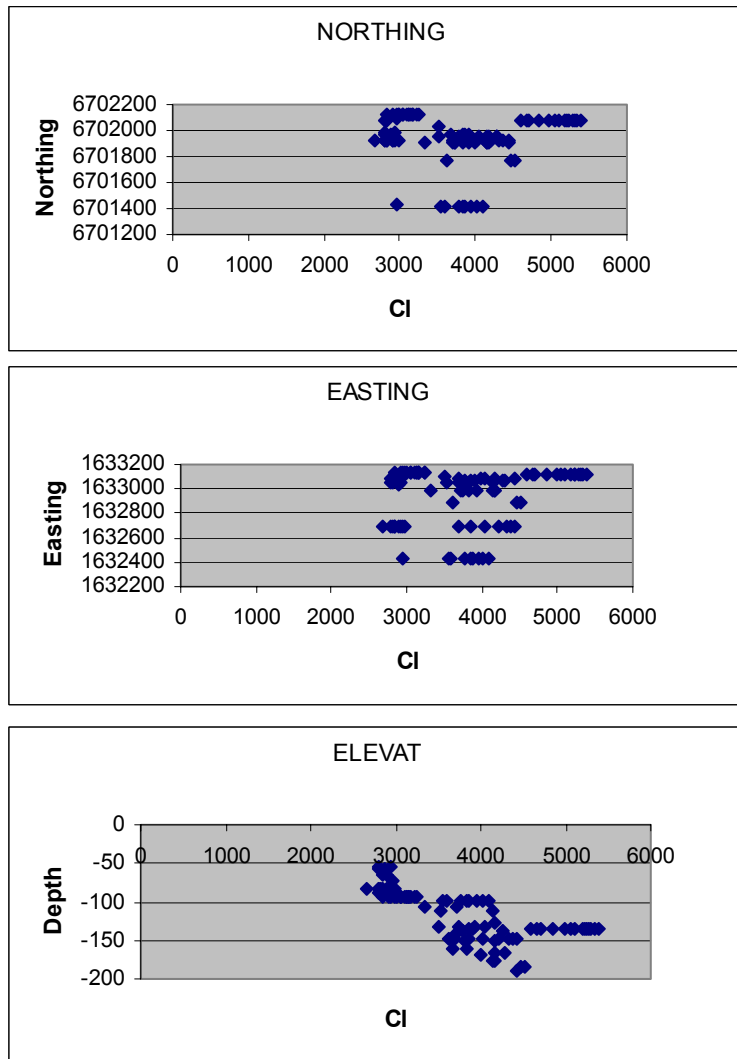


The measured average changes of Cl (mg/l) and mixing proportions with time are examined below. No depth correlation is obtained which may indicate a complex mixing pattern due to the SFR tunnel construction.

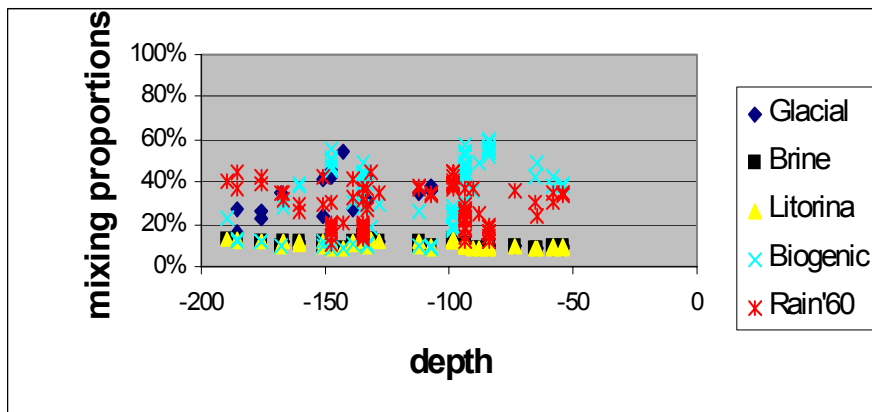
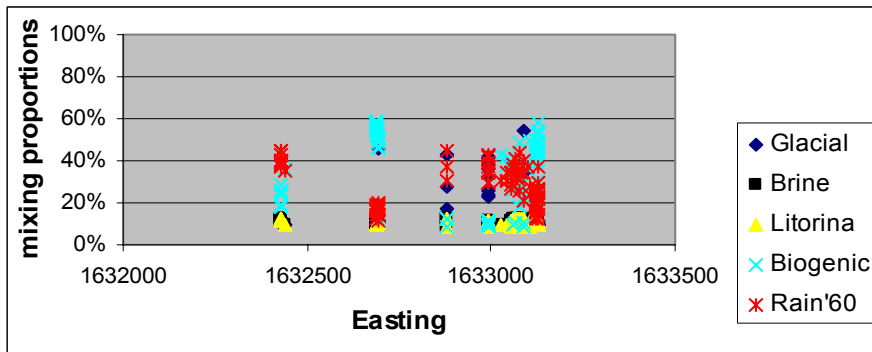
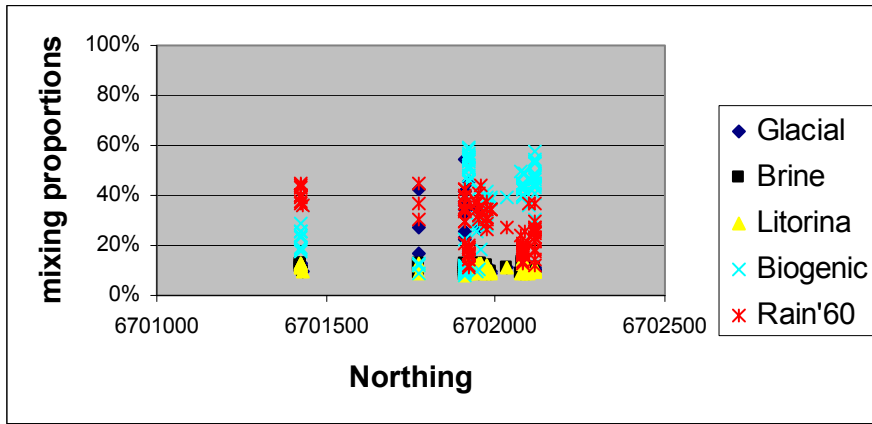


Appendix 4

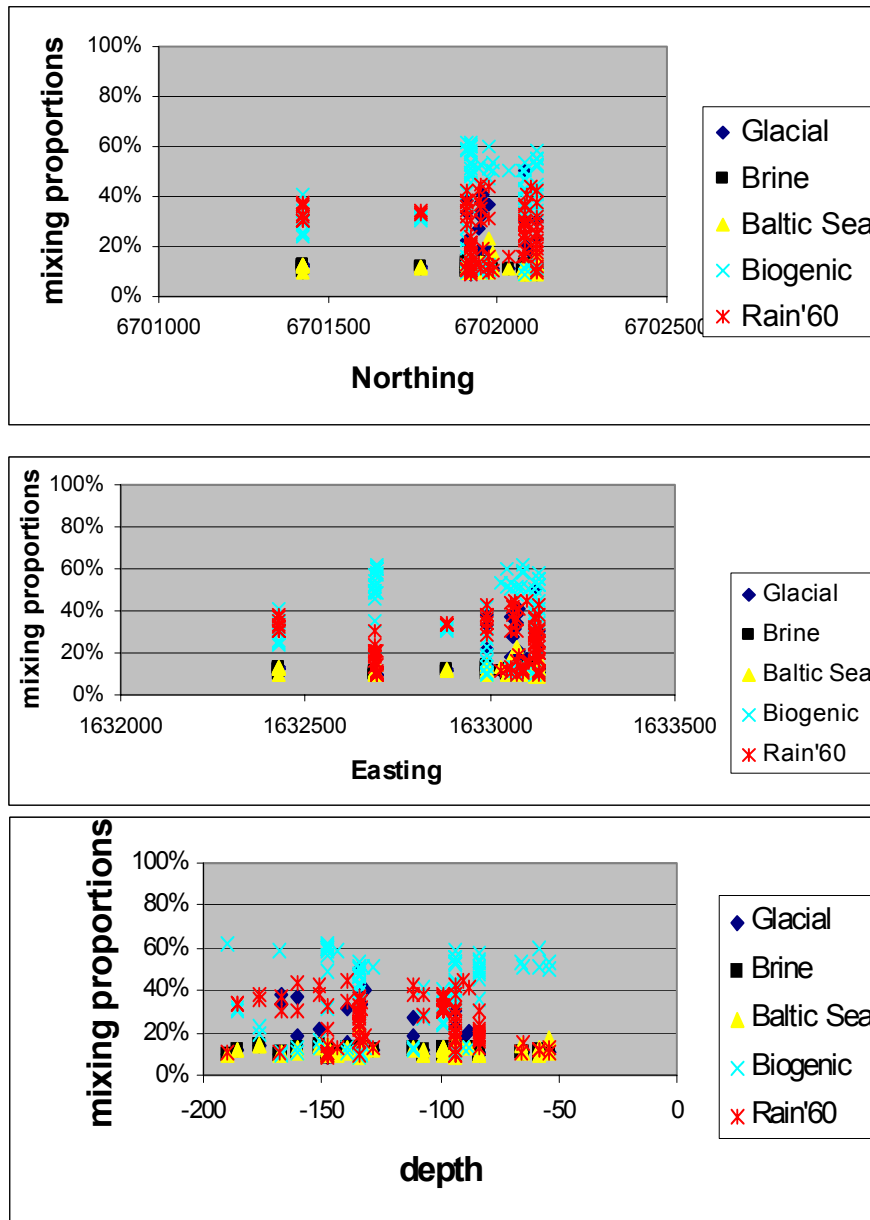
The measured Cl concentration is plotted below against the North, East coordinates and depth (elevation) in order to detect trends in the data set.



Below the M3 mixing proportions are plotted against the North, East coordinates and depth (elevation) in order to detect trends in the data set.



The M3 mixing proportions are plotted below against the North, East coordinates and depth (elevation) in order to detect trends in the data set. In this modelling the Baltic Sea is used as reference water instead of Litorina Sea water in order to test the effect on the modelling. The conclusion was that there is no large difference in the modelling when changing the sea reference water from Baltic Sea water to Litorina Sea water. This change affects mostly the concept of residence time of the water.



Appendix 5

The SFR data used for some of the modelling are listed. In addition the M3 mixing proportions and the deviations are listed. The modelled values were obtained by using the following formulas (these values are indicated with italics):

<i>SO4 calculated from SO4-S: $SO4 = SO4-S * 2.9947$</i>
<i>SO4 modelled when SO4 is missing: $SO4 = 0.08 CI$</i>
<i>Tritium modelled: $T = -0.006 CI + 35$</i>

M3row	Idcode	Sampling date	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	D dev SMOW	Tr TU	O18 dev SMOW	NORTHING	EASTING	ELEVAT
1	KFR01	2000-07-19	1350	10	500	117	125	2960	341	-72.4	11.9	-8.7	6701430.0	1632437.5	-73.5
2	KFR01	1989-04-04	1550	6.8	910	141	89	4090	327.2	-79	16.9	-10.9	6701422.6	1632428.5	-98.4
3	KFR01	1989-12-27	1490	6.7	783	132	86	4020	347.4	-79	16.9	-10.9	6701422.6	1632428.5	-98.4
4	KFR01	1990-06-15	1500	9.4	817	138	85	3950	428.2	-74.5	8.4	-10.3	6701422.6	1632428.5	-98.4
5	KFR01	1990-12-27	1500	15.3	785	137	80	3870	309.6	-77.1	16.9	-10.3	6701422.6	1632428.5	-98.4
6	KFR01	1992-01-10	1460	8.4	774	137	90	3770	395.3	-81.3	16.9	-10.5	6701422.6	1632428.5	-98.4
7	KFR01	1992-06-29	1510	6.7	767	135	98	3840	383.3	-74.2	16.9	-9.3	6701422.6	1632428.5	-98.4
8	KFR01	1998-10-01	1540	7.4	695	135	97	3590	380.3	-79.2	7.7	-9.7	6701422.6	1632428.5	-98.4
9	KFR01	1999-09-30	1540	7.4	643	130	98	3550	374.3	-77	13.7	-9.7	6701422.6	1632428.5	-98.4
10	KFR01	2000-07-11	1490	8.4	691	130	99	3560	348	-79.2	7.7	-9.7			
11	KFR01	2000-07-19	1470	7.8	664	130	101	3530	346	-77.5	6.6	-9.6			
12	KFR01	2000-07-31	1400	10.1	486	115	125	2940	360	-70.3	13.6	-8.7			
13	KFR01	2000-08-22	1380	8	641	125	99	3420	321	-82.5	6.8	-10.1			
14	KFR02	1995-06-27	1161	4.5	887	102	69	3710	224.6	-103.9	12.74	-13.9			
15	KFR02	2000-06-30	1180	4.9	997	87	64	3620	171	-113	3.3	-13.6	6701771.5	1632880.8	-147.3
16	KFR02	1995-06-27	1344	5	1113	137	72	4460	302.5	-94.7	8.24	-12.5	6701771.5	1632880.8	-185.3
17	KFR02	2000-07-10	1460	7	1210	143	82	4520	295	-90.1	1.9	-11.2	6701771.5	1632880.8	-185.3
18	KFR02	1995-06-27	1449	5.9	1184	162	79	4760	356.4	-83.7	6.44	-11.4			
19	KFR02	2000-07-10	1510	7.5	1220	158	89	4600	339	-86.1	2.9	-10.6			
20	KFR02	1995-06-27	1338	5.2	1031	134	78	4230	296.5	-93.6	9.62	-12.2			
21	KFR02	2000-07-10	1390	6.4	1120	134	81	4250	278	-93.6	2.3	-11.7			
22	KFR03	1995-06-27	1191	6	887	112	70	3720	224.6	-103.2	12.68	-13.9	6701910.4	1632991.0	-107.0
23	KFR03	2000-07-10	1110	7.3	833	99	68	3330	156	-110	2.9	-13.9	6701910.4	1632991.0	-107.0
24	KFR03	1995-06-27	1144	5.9	931	114	66	3740	209.6	-107.6	12.56	-14.5	6701910.4	1632991.0	-133.0
25	KFR03	2000-07-10	1270	8	1030	115	70	3920	191	-103.6	2.3	-13.1	6701910.4	1632991.0	-133.0
26	KFR03	1995-06-27	1168	5.4	973	117	68	3820	215.6	-106.8	12.08	-14.4	6701910.4	1632991.0	-151.0
27	KFR03	2000-07-10	1430	7.9	1030	119	76	4160	228	-96.8	1.8	-12	6701910.4	1632991.0	-151.0
28	KFR03	1995-06-27	1376	5.8	1015	127	75	4170	284.5	-94.6	9.98	-12.4	6701910.4	1632991.0	-176.0
29	KFR03	2000-07-10	1460	7.7	1030	120	75	4140	226	-95	2.8	-12	6701910.4	1632991.0	-176.0
30	KFR04	1995-06-27	1139	5.4	851	104	69	3520	215.6	-103.8	13.88	-13.5	6701947.6	1633059.1	-111.8
31	KFR04	2000-07-18	1280	6.4	971	113	76	3780	198	-100.1	2.7	-12.7	6701947.9	1633066.3	-138.8
32	KFR04	1995-06-27	1760	9.5	705	159	110	4269	395.3	-73.4	9.39	-9.5	6701947.9	1633066.3	-138.8
33	KFR04	2000-07-18	1750	10.6	782	155	109	4170	348	-77.1	4.1	-9.7	6701948.2	1633073.8	-166.8
34	KFR04	1995-06-27	1786	10.3	703	162	109	4290	401.3	-73.5	9.26	-9.6	6701948.2	1633073.8	-166.8

M3row	Idcode	Sampling date	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	D dev SMOW	Tr TU	O18 dev SMOW	NORTHING	EASTING	ELEVAT
35	KFR04	2000-07-18	1710	10.5	791	149	107	4150	337	-79.4	2.9	-9.9	6701947.6	1633059.1	-111.8
36	KFR05	1995-06-27	1644	15.3	506	158	112	3830	434.2	-70.1	12.02	-8.8	6701976.3	1633055.0	-160.1
37	KFR05	2000-07-12	1680	16.9	566	154	114	3680	355	-73.7	9.3	-8.9	6701976.3	1633055.0	-160.1
38	KFR08	2000-07-10	1400	21.6	286	141	130	2800	319	-68.1	17.9	-8.2	6702083.9	1633077.5	-87.9
39	KFR08	2000-07-10	1290	10	507	120	122	2960	293	-71.9	17.7	-8.9	6702099.6	1633101.2	-90.4
40	KFR08	1989-04-04	1640	26.5	297	135	114	3170	380	-59.2	16.9	-8	6702118.5	1633129.8	-93.4
41	KFR08	1989-12-27	1600	22.8	250	134	118	3120	416.3	-63.3	42.2	-8.4	6702118.5	1633129.8	-93.4
42	KFR08	1990-06-15	1590	36.8	238	140	120	3100	413.3	-60.1	16.9	-8	6702118.5	1633129.8	-93.4
43	KFR08	1992-01-10	1540	35.7	213	144	120	3050	446.2	-64.7	42.2	-8.1	6702118.5	1633129.8	-93.4
44	KFR08	1992-06-29	1520	19	361	135	128	3150	416.3	-63.5	25.4	-8.3	6702118.5	1633129.8	-93.4
45	KFR08	1994-04-08	1450	17.5	358	138	115	3120	419.3	-60.9	16.28	-8	6702118.5	1633129.8	-93.4
46	KFR08	1995-01-05	1440	17	344	135	120	3000	410.3	-63.7	17	-7.9	6702118.5	1633129.8	-93.4
47	KFR08	1995-06-26	1438	14.6	326	140	118	3050	413.3	-64.4	16.7	-8	6702118.5	1633129.8	-93.4
48	KFR08	1996-01-05	1430	15	322	134	116	2980	407.3	-78.1	17.12	-9.8	6702118.5	1633129.8	-93.4
49	KFR08	1996-10-24	1526.4	15.8	318	131	115	2950	416.3	-66.1	17.3	-8.1	6702118.5	1633129.8	-93.4
50	KFR08	1997-09-18	1530	24.6	195	158	120	2920	398.3	-66	17.48	-7.8	6702118.5	1633129.8	-93.4
51	KFR08	1998-10-01	1540	15.2	309	131	112	2840	398.3	-66.3	33.4	-8	6702118.5	1633129.8	-93.4
52	KFR08	1999-09-30	1450	15.3	477	134	115	3240	380.3	-67.1	15.56	-8.2	6702118.5	1633129.8	-93.4
53	KFR08	1999-11-19	1400	6.8	467	141	113	3230	389.3	-66	15.62	-8.2	6702118.5	1633129.8	-93.4
54	KFR08	2000-07-10	1470	16.2	474	142	120	3160	354	-68.1	12.7	-8.3	6702118.5	1633129.8	-93.4
55	KFR09	1992-06-29	1490	26.3	220	150	134	2980	404.3	-66.3	33.4	-8	6701919.2	1632686.5	-83.7
56	KFR09	1994-04-08	1450	31.5	216	150	127	2940	395.3	-61	17.36	-7.7	6701919.2	1632686.5	-83.7
57	KFR09	1995-01-05	1480	36	181	160	128	2900	401.3	-63.3	17.6	-7.8	6701919.2	1632686.5	-83.7
58	KFR09	1995-06-26	1458	28.3	194	162	126	2920	401.3	-62.9	17.48	-7.9	6701919.2	1632686.5	-83.7
59	KFR09	1996-01-05	1430	29.4	183	162	120	2830	392.3	-65	18.02	-7.9	6701919.2	1632686.5	-83.7
60	KFR09	1996-10-24	1538.3	32.1	207	158	124	2840	389.3	-65.2	17.96	-8	6701919.2	1632686.5	-83.7
61	KFR09	1997-09-18	1529	24.1	195	158	126	2790	398.3	-64.9	18.26	-7.7	6701919.2	1632686.5	-83.7
62	KFR09	1998-10-01	1530	32.2	184	156	122	2810	380.3	-59.2	16.9	-9	6701919.2	1632686.5	-83.7
63	KFR09	1999-02-02	1490	31.6	181	152	129	2670	377.3	-64.9	16.1	-7.7	6701919.2	1632686.5	-83.7
64	KFR09	2000-06-28	1480	34	206	146	130	2900	348	-66.4	15.5	-8			
65	KFR10	1989-04-04	1670	10.5	882	214	118	4430	412	-60.5	8.42	-7.9	6701920.9	1632691.3	-147.5
66	KFR10	1989-12-27	1650	16.2	800	184	115	4320	449.2	-62.7	16.9	-8.4	6701920.9	1632691.3	-147.5
67	KFR10	1990-06-15	1610	18	781	194	117	4210	449.2	-60.1	16.9	-8	6701920.9	1632691.3	-147.5
68	KFR10	1990-12-27	1600	16.2	805	202	115	4370	349.6	-59.2	16.9	-9	6701920.9	1632691.3	-147.5

M3row	Idcode	Sampling date	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	D dev SMOW	Tr TU	O18 dev SMOW	NORTHING	EASTING	ELEVAT
69	KFR10	1992-01-10	1570	15.3	723	187	121	4030	461.2	-68.6	33.8	-8	6701920.9	1632691.3	-147.5
70	KFR10	1999-02-02	1580	13.2	690	185	126	3690	449.2	-114.8	7.4	-15.2	6701920.9	1632691.3	-147.5
71	KFR10	1999-09-30	1570	32.2	703	181	123	3860	437.2	-63.7	11.84	-7.8	6701920.9	1632691.3	-147.5
72	KFR10	2000-06-22	1470	14.9	685	163	131	3850	416	-65.9	7.1	-8.1			
73	KFR10	2000-06-28	1560	15.7	727	173	134	3890	418	-68.7	6.7	-8.1			
74	KFR10	2000-06-30	1570	16.1	737	176	133	3910	407	-71.1	6.3	-7.9			
75	KFR10	2000-07-04	1550	16	740	175	133	3970	409	-71.2	8	-7.9			
76	KFR13	1995-06-27	1129	3.9	923	79	40	3690	167.7	-114.6	12.86	-15.2	6701911.3	1633086.3	-143.1
77	KFR13	2000-06-29	1330	5	1060	91	74	3990	218	-103.9	1.8	-12.8	6701911.3	1633086.3	-168.1
78	KFR13	2000-06-29	1730	11	913	142	98	4430	319	-81.9	2.3	-10	6701911.3	1633086.3	-189.9
79	KFR19	1995-06-27	1394	8.7	281	122	114	2880	383.3	-65	17.72	-8.2	6701974.3	1633044.8	-58.2
80	KFR19	1995-06-27	1390	9.8	287	128	116	2890	374.3	-64.4	17.66	-8.4	6701953.5	1633028.4	-65.5
81	KFR19	2000-07-18	1440	11.3	312	124	117	2790	329	-73.6	16.5	-8.4	6701974.3	1633044.8	-58.2
82	KFR19	1995-06-27	1291	8	381	116	111	2930	365.3	-67	17.42	-8.6	6701987.2	1633055.0	-53.8
83	KFR19	2000-07-18	1370	9.6	364	114	114	2810	308	-69.3	18.14	-8.4	6701987.2	1633055.0	-53.8
84	KFR55	2000-05-19	1880	11.2	757	153	111	4170	349	-78.1	9.98	-9.4	6701944.3	1633083.2	-128.5
85	KFR55	2000-05-19	1740	9.2	838	138	101	4040	307	-86.4	10.76	-10.3	6701959.0	1633077.9	-131.6
86	KFR55	1995-06-27	1651	9.5	586	153	82	3861	398.3	-70.6	11.834	-9	6701971.5	1633073.3	-134.3
87	KFR55	2000-07-10	1660	9.4	667	146	108	3900	346	-78	5.5	-9.6	6701971.5	1633073.3	-134.3
88	KFR56	2000-07-10	1390	25.1	332	144	128	2840	328	-68.2	17	-8.3	6702073.1	1633102.5	-64.6
89	KFR7A	2000-07-18	1650	20.4	471	166	116	3510	380	-75.2	10.3	-9	6702031.0	1633104.5	-132.8
90	KFR7A	1989-04-04	1920	13.6	1130	258	98	5380	430	-72.4	8.4	-9.2	6702078.5	1633122.6	-134.5
91	KFR7A	1989-12-27	1840	13.9	1004	248	93	5330	404.3	-66	8.4	-9.1	6702078.5	1633122.6	-134.5
92	KFR7A	1990-06-15	1850	19.6	1040	260	94	5300	455.2	-66.3	8.4	-9	6702078.5	1633122.6	-134.5
93	KFR7A	1990-12-27	1830	14.2	1040	261	92	5280	422.4	-67.4	16.9	-9	6702078.5	1633122.6	-134.5
94	KFR7A	1992-01-10	1810	17.1	1040	268	84	5220	458.2	-73.4	16.9	-9.3	6702078.5	1633122.6	-134.5
95	KFR7A	1992-06-29	1820	13.5	1020	265	102	5240	449.2	-72.4	8.4	-9.2	6702078.5	1633122.6	-134.5
96	KFR7A	1994-04-08	1780	13.9	986	263	96	5190	443.2	-69	3.86	-8.9	6702078.5	1633122.6	-134.5
97	KFR7A	1995-01-05	1780	16.5	955	265	98	5100	449.2	-70.8	4.4	-8.8	6702078.5	1633122.6	-134.5
98	KFR7A	1995-06-26	1759	13.9	951	269	93	5056	446.2	-69.7	4.664	-8.9	6702078.5	1633122.6	-134.5
99	KFR7A	1996-01-05	1740	14.3	930	270	88	4980	443.2	-65.2	5.12	-8.1	6702078.5	1633122.6	-134.5
100	KFR7A	1996-10-24	1802.3	14.5	931	239	92	4850	431.2	-73	5.9	-8.9	6702078.5	1633122.6	-134.5
101	KFR7A	1997-09-18	1760	14.2	878	242	98	4670	434.2	-72.3	6.98	-8.5	6702078.5	1633122.6	-134.5
102	KFR7A	1998-10-01	1780	14.9	891	235	88	4590	422.3	-70.3	7.46	-8.4	6702078.5	1633122.6	-134.5

M3row	Idcode	Sampling date	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	HCO3 mg/L	Cl mg/L	SO4 mg/L	D dev SMOW	Tr TU	O18 dev SMOW	NORTHING	EASTING	ELEVAT
103	KFR7A	1999-09-30	1760	14.9	887	229	99	4700	422.3	-70.6	6.8	-8.7	6702078.5	1633122.6	-134.5
104	KFR7A	2000-05-18	1880	16.8	860	215	116	4460	396	-73.2	8.24	-8.7			
105	KFR7A	2000-05-19	1660	14.3	798	211	116	4460	398	-71.8	8.24	-8.7			
106	KFR7A	2000-05-24	1760	14.5	842	225	117	4460	391	-72.4	8.24	-8.6			
107	KFR7A	2000-05-25	1780	14.7	852	227	114	4460	386	-74.4	8.24	-8.6			
108	KFR7C	2000-07-10	1650	15.9	570	150	113	3680	351	-73.8	8	-9			
109	Precipit		0.4	0.3	0.2	0.1	12.2	0.2	1.4	-88	0	-12.3	Meteoric	Rain	Rain old
110	Precipit		0.4	0.3	0.2	0.1	12.2	0.2	1.4	-88	22	-12.3	Meteoric	Rain	Rain
111	Precipit		0.4	0.3	0.2	0.1	12.2	0.2	1.4	-88	2008	-12.3	Meteoric	Rain	Rain'60
112	Glacial		0.2	0.4	0.2	0.1	0.1	0.5	0.5	-158	0	-21	Glacial	Glacial	Glacial
113	Sea	920828 0	1960	95	93.7	234	90	3760	503.4	-53.3	42	-5.9	Sea	Sea	PASSEA01
114	Åspö	920423 1	2140	35.1	504	195	760	4490	111.5	-60.3	17	-7.3	Åspö	Sweden	SA1094A
115	Laxemar	930803	8200	45.5	19200	2.1	14	47200	904.9	-44.9	0.2	-8.9	Åspö	Sweden	KLX02
116	Litorina		3179.8	154.1	152	379.6	146	6100	527.3	-35	0	-5			Litorina

M3row	Idcode	Sampling date	pH	Glacial %	Brine %	Litorina %	Biogenic %	Rain'60 %	dev Na mg/L	dev K mg/L	dev Ca mg/L	dev Mg mg/L	dev HCO3 mg/L	dev Cl mg/L	dev SO4 mg/L
1	KFR01	2000-07-19		9%	9%	9%	36%	36%	-496.74	-21.66	-1512.71	10.70	-167.84	-3698.97	164.82
2	KFR01	1989-04-04		12%	12%	12%	18%	44%	-260.30	-24.68	-1593.39	57.63	-75.71	-3373.55	127.65
3	KFR01	1989-12-27	7.4	12%	12%	12%	18%	45%	-300.26	-24.45	-1705.54	50.06	-74.05	-3383.63	149.39
4	KFR01	1990-06-15	7.4	13%	13%	13%	24%	38%	-464.24	-24.64	-1783.88	43.02	-119.36	-3944.68	217.63
5	KFR01	1990-12-27	7.4	12%	12%	12%	26%	39%	-395.70	-17.49	-1636.01	41.83	-138.24	-3591.88	110.84
6	KFR01	1992-01-10	7.4	13%	13%	13%	19%	43%	-386.76	-23.70	-1761.53	51.24	-82.01	-3811.63	192.68
7	KFR01	1992-06-29	7.4	12%	12%	12%	28%	37%	-416.39	-26.55	-1616.72	35.28	-141.26	-3607.73	185.21
8	KFR01	1998-10-01	7.3	12%	12%	12%	24%	40%	-333.14	-25.03	-1725.96	42.09	-112.14	-3833.85	182.43
9	KFR01	1999-09-30		12%	12%	12%	26%	40%	-326.38	-24.88	-1730.00	35.88	-119.50	-3777.84	179.12
10	KFR01	2000-07-11	7.5	11%	11%	11%	25%	41%	-345.65	-23.35	-1646.76	37.58	-114.23	-3653.93	155.82
11	KFR01	2000-07-19	7.6	11%	11%	11%	26%	40%	-366.90	-23.94	-1629.29	35.71	-123.01	-3607.54	156.02
12	KFR01	2000-07-31	7.5	10%	10%	10%	37%	34%	-481.63	-22.15	-1560.69	6.53	-174.08	-3837.63	180.72
13	KFR01	2000-08-22	7.6	11%	11%	11%	22%	45%	-350.71	-22.01	-1626.93	40.37	-87.98	-3494.10	136.50
14	KFR02	1995-06-27	7.5	38%	10%	10%	10%	33%	-150.53	-18.51	-1039.03	45.99	-24.30	-1895.48	74.22
15	KFR02	2000-06-30	7.6	43%	9%	9%	9%	30%	-40.44	-16.54	-795.25	34.88	-22.78	-1596.12	31.03
16	KFR02	1995-06-27	7.4	27%	12%	12%	12%	37%	-275.02	-23.32	-1264.62	67.88	-42.66	-2459.78	117.01
17	KFR02	2000-07-10	7.6	17%	13%	13%	13%	45%	-276.58	-23.34	-1340.25	68.87	-41.63	-2902.21	96.03
18	KFR02	1995-06-27	7.3	15%	14%	14%	14%	44%	-395.15	-26.30	-1524.25	83.29	-51.89	-3122.05	145.16
19	KFR02	2000-07-10	7.5	13%	13%	13%	16%	44%	-352.08	-24.96	-1448.19	75.91	-58.54	-3241.54	129.07
20	KFR02	1995-06-27	7.4	24%	12%	12%	12%	41%	-268.15	-22.90	-1327.71	65.43	-36.26	-2634.74	112.45
21	KFR02	2000-07-10	7.4	21%	12%	12%	12%	43%	-245.82	-22.21	-1282.29	64.17	-35.56	-2741.56	90.54
22	KFR03	1995-06-27	7.4	36%	10%	10%	10%	34%	-159.10	-17.68	-1095.68	54.35	-26.02	-2050.34	69.81
23	KFR03	2000-07-10	7.5	38%	9%	9%	9%	35%	-103.21	-14.01	-948.62	47.19	-18.88	-1855.15	16.82
24	KFR03	1995-06-27	7.3	42%	10%	10%	10%	29%	-149.15	-16.80	-968.05	58.78	-25.61	-1786.94	61.35
25	KFR03	2000-07-10	7.4	32%	10%	10%	10%	37%	-134.80	-16.62	-1033.00	55.02	-30.11	-2084.11	29.95
26	KFR03	1995-06-27	7.3	41%	10%	10%	10%	29%	-148.21	-17.70	-959.91	60.79	-25.19	-1805.51	64.72
27	KFR03	2000-07-10	7.5	24%	11%	11%	11%	42%	-122.29	-19.26	-1249.60	52.73	-34.76	-2474.50	50.08
28	KFR03	1995-06-27	7.3	26%	12%	12%	12%	39%	-206.67	-21.89	-1309.22	59.43	-37.49	-2594.38	103.14
29	KFR03	2000-07-10	7.4	23%	12%	12%	12%	43%	-104.28	-19.67	-1267.22	53.22	-36.67	-2545.76	46.70
30	KFR04	1995-06-27	7.2	34%	10%	10%	10%	37%	-175.32	-17.66	-1079.12	47.87	-24.91	-2097.35	64.87
31	KFR04	2000-07-18	7.6	28%	10%	10%	10%	41%	-132.92	-18.36	-1103.92	52.67	-25.17	-2258.77	35.98
32	KFR04	1995-06-27	7.5	12%	12%	12%	31%	32%	-294.79	-25.93	-1821.99	52.03	-148.01	-3647.66	184.89
33	KFR04	2000-07-18	7.5	12%	12%	12%	28%	35%	-235.92	-23.70	-1707.99	53.49	-129.75	-3565.47	142.18
34	KFR04	1995-06-27	7.3	12%	12%	12%	31%	32%	-287.80	-25.47	-1860.90	54.57	-148.16	-3723.79	188.27

M3row	Idcode	Sampling date	pH	Glacial %	Brine %	Litorina %	Biogenic %	Rain'60 %	dev Na mg/L	dev K mg/L	dev Ca mg/L	dev Mg mg/L	dev HCO3 mg/L	dev Cl mg/L	dev SO4 mg/L
35	KFR04	2000-07-18	7.4	12%	12%	12%	26%	38%	-224.02	-22.96	-1694.57	52.52	-111.80	-3490.30	133.46
36	KFR05	1995-06-27	7.5	12%	12%	12%	39%	26%	-508.16	-21.62	-1929.19	37.65	-206.56	-4088.51	224.58
37	KFR05	2000-07-12	7.5	11%	11%	11%	38%	29%	-388.56	-18.59	-1768.32	38.08	-194.10	-3919.81	153.78
38	KFR08	2000-07-10	7.6	9%	9%	9%	48%	25%	-626.48	-12.87	-1639.72	13.25	-255.55	-4007.93	140.11
39	KFR08	2000-07-10	7.6	9%	9%	9%	36%	37%	-502.98	-20.71	-1410.24	15.34	-171.19	-3440.01	123.77
40	KFR08	1989-04-04		10%	10%	10%	53%	17%	-611.61	-11.78	-1854.95	-6.46	-310.20	-4416.03	180.76
41	KFR08	1989-12-27	7.3	10%	10%	10%	48%	22%	-575.09	-14.29	-1950.40	2.13	-264.09	-4422.76	217.64
42	KFR08	1990-06-15	7.3	10%	10%	10%	58%	12%	-784.19	-3.51	-1988.86	-10.81	-336.40	-4824.52	205.43
43	KFR08	1992-01-10	7.5	10%	10%	10%	54%	15%	-802.77	-4.15	-2066.80	-1.58	-311.47	-4915.06	236.89
44	KFR08	1992-06-29	7.5	10%	10%	10%	47%	23%	-617.72	-17.46	-1797.39	5.23	-248.71	-4255.74	221.24
45	KFR08	1994-04-08	7.6	10%	10%	10%	49%	22%	-706.04	-19.22	-1769.40	5.17	-276.26	-4261.88	225.08
46	KFR08	1995-01-05	7.4	10%	10%	10%	48%	23%	-674.43	-19.02	-1745.73	4.87	-263.17	-4245.37	219.64
47	KFR08	1995-06-26	7.5	10%	10%	10%	47%	25%	-654.04	-21.07	-1773.58	12.50	-253.84	-4175.06	223.02
48	KFR08	1996-01-05	7.6	11%	11%	11%	30%	37%	-470.11	-17.75	-1965.72	33.15	-134.83	-4254.10	215.10
49	KFR08	1996-10-24	7.59	10%	10%	10%	45%	26%	-561.08	-19.84	-1836.33	6.11	-242.35	-4364.03	223.43
50	KFR08	1997-09-18	7.3	10%	10%	10%	53%	19%	-684.06	-13.05	-1923.55	19.00	-296.75	-4543.90	202.24
51	KFR08	1998-10-01	7.5	10%	10%	10%	45%	26%	-522.48	-20.00	-1795.65	6.66	-246.73	-4344.27	208.94
52	KFR08	1999-09-30		10%	10%	10%	43%	27%	-603.40	-19.78	-1654.40	11.63	-233.88	-3976.21	189.94
53	KFR08	1999-11-19	6.8	10%	10%	10%	41%	30%	-582.96	-27.10	-1613.98	23.71	-219.08	-3778.67	204.28
54	KFR08	2000-07-10	7.3	10%	10%	10%	44%	27%	-571.64	-18.66	-1618.48	19.28	-233.13	-3967.73	166.08
55	KFR09	1992-06-29	7.6	10%	10%	10%	52%	19%	-708.62	-11.09	-1885.83	12.05	-279.45	-4435.46	209.49
56	KFR09	1994-04-08	7.6	9%	9%	9%	58%	14%	-844.32	-7.40	-1853.09	1.00	-333.60	-4571.68	198.56
57	KFR09	1995-01-05	7.4	9%	9%	9%	59%	12%	-864.75	-3.76	-1946.29	8.23	-339.52	-4799.27	199.63
58	KFR09	1995-06-26	7.5	9%	9%	9%	56%	16%	-806.18	-10.13	-1897.32	16.90	-317.28	-4580.20	204.63
59	KFR09	1996-01-05	7.6	9%	9%	9%	55%	17%	-816.94	-8.75	-1904.83	18.49	-317.13	-4635.03	196.49
60	KFR09	1996-10-24	7.56	10%	10%	10%	55%	16%	-740.52	-6.61	-1932.08	13.31	-314.16	-4769.11	189.64
61	KFR09	1997-09-18	7.3	9%	9%	9%	54%	18%	-684.94	-13.51	-1881.29	17.35	-300.46	-4599.12	204.38
62	KFR09	1998-10-01	7.3	10%	10%	10%	54%	17%	-729.11	-6.19	-1956.65	13.35	-307.83	-4768.71	181.34
63	KFR09	1999-02-02	7	9%	9%	9%	57%	16%	-761.33	-6.58	-1861.04	6.26	-320.48	-4721.60	183.63
64	KFR09	2000-06-28	7.6	9%	9%	9%	55%	17%	-743.58	-3.74	-1840.38	3.21	-307.27	-4452.55	155.21
65	KFR10	1989-04-04		11%	11%	11%	50%	16%	-669.09	-29.39	-1517.69	73.50	-284.27	-3740.46	196.78
66	KFR10	1989-12-27	7.2	12%	12%	12%	46%	18%	-676.22	-23.57	-1703.24	48.86	-258.14	-4011.52	229.25
67	KFR10	1990-06-15	7	11%	11%	11%	52%	15%	-776.15	-22.68	-1660.45	50.42	-294.63	-4113.34	230.00
68	KFR10	1990-12-27	6.9	11%	11%	11%	48%	19%	-658.48	-22.34	-1520.82	66.69	-271.78	-3534.43	141.30

M3row	Idcode	Sampling date	pH	Glacial %	Brine %	Litorina %	Biogenic %	Rain'60 %	dev Na mg/L	dev K mg/L	dev Ca mg/L	dev Mg mg/L	dev HCO3 mg/L	dev Cl mg/L	dev SO4 mg/L
69	KFR10	1992-01-10	7.2	11%	11%	11%	45%	20%	-704.55	-23.59	-1718.90	54.63	-245.45	-4106.32	246.40
70	KFR10	1999-02-02	6.6	46%	12%	12%	12%	17%	-81.83	-15.88	-1750.55	114.06	10.79	-3413.02	259.00
71	KFR10	1999-09-30		11%	11%	11%	55%	11%	-885.31	-9.98	-1712.70	29.21	-318.14	-4536.18	215.03
72	KFR10	2000-06-22	7.2	11%	11%	11%	46%	22%	-710.76	-22.34	-1579.83	33.09	-238.48	-3816.00	213.86
73	KFR10	2000-06-28	7.4	11%	11%	11%	45%	22%	-648.41	-22.04	-1606.61	43.02	-230.76	-3943.90	211.29
74	KFR10	2000-06-30	7.4	11%	11%	11%	45%	22%	-634.86	-21.58	-1592.49	46.21	-231.27	-3910.67	200.64
75	KFR10	2000-07-04	7.4	11%	11%	11%	45%	22%	-651.42	-21.62	-1590.64	45.60	-229.62	-3846.92	202.71
76	KFR13	1995-06-27		54%	8%	8%	8%	21%	-0.68	-15.99	-735.98	30.75	-39.46	-1138.27	38.17
77	KFR13	2000-06-29	7.7	35%	10%	10%	10%	35%	-57.52	-19.33	-977.63	31.75	-24.66	-1940.28	58.94
78	KFR13	2000-06-29	7.5	13%	13%	13%	22%	40%	-185.10	-22.21	-1641.31	50.12	-97.27	-3299.78	112.73
79	KFR19	1995-06-27		9%	9%	9%	42%	30%	-549.21	-24.49	-1708.70	5.12	-223.12	-3900.70	204.47
80	KFR19	1995-06-27		9%	9%	9%	42%	30%	-561.33	-23.52	-1698.92	10.15	-225.28	-3897.69	195.34
81	KFR19	2000-07-18	7.6	9%	9%	9%	38%	34%	-424.80	-20.62	-1669.68	14.67	-190.31	-3844.60	153.67
82	KFR19	1995-06-27		9%	9%	9%	38%	34%	-579.03	-24.01	-1603.83	6.27	-197.69	-3718.95	189.61
83	KFR19	2000-07-18	7.6	9%	9%	9%	39%	35%	-463.21	-21.74	-1531.07	4.44	-200.56	-3618.58	138.30
84	KFR55	2000-05-19	7.6	12%	12%	12%	29%	34%	-134.62	-23.58	-1758.72	49.62	-133.39	-3659.15	140.74
85	KFR55	2000-05-19	7.6	13%	13%	13%	18%	44%	-73.24	-22.34	-1673.66	54.66	-62.98	-3443.10	106.92
86	KFR55	1995-06-27		12%	12%	12%	34%	31%	-406.53	-25.91	-1857.97	42.49	-196.31	-3913.76	191.98
87	KFR55	2000-07-10	7.4	12%	12%	12%	28%	37%	-261.16	-23.78	-1729.47	47.31	-126.20	-3561.42	147.47
88	KFR56	2000-07-10	7.6	9%	9%	9%	49%	24%	-685.21	-10.20	-1652.86	13.68	-263.56	-4154.30	144.19
89	KFR7A	2000-07-18	7.4	11%	11%	11%	39%	27%	-464.45	-15.86	-1898.33	46.85	-202.55	-4228.83	175.20
90	KFR7A	1989-04-04		14%	14%	14%	39%	19%	-503.99	-28.08	-1771.31	128.69	-222.63	-3818.56	186.06
91	KFR7A	1989-12-27	7	13%	13%	13%	43%	18%	-571.77	-27.46	-1749.12	114.09	-256.94	-3586.47	168.33
92	KFR7A	1990-06-15	7	14%	14%	14%	45%	14%	-681.52	-24.52	-1821.19	117.84	-271.16	-4012.25	206.16
93	KFR7A	1990-12-27	6.9	13%	13%	13%	44%	17%	-615.87	-27.74	-1754.48	125.30	-262.16	-3766.87	182.99
94	KFR7A	1992-01-10	7.1	14%	14%	14%	40%	18%	-653.15	-25.25	-1904.96	136.47	-242.35	-4121.50	210.50
95	KFR7A	1992-06-29	7.1	14%	14%	14%	40%	19%	-600.53	-28.09	-1837.48	134.31	-227.36	-3875.39	207.61
96	KFR7A	1994-04-08	7.2	13%	13%	13%	43%	17%	-665.52	-28.04	-1810.32	127.40	-257.59	-3859.51	203.71
97	KFR7A	1995-01-05	7	13%	13%	13%	44%	16%	-687.82	-25.81	-1853.43	127.64	-261.80	-4008.41	208.22
98	KFR7A	1995-06-26	7.2	13%	13%	13%	44%	17%	-685.03	-28.01	-1837.67	133.25	-261.76	-3977.51	207.16
99	KFR7A	1996-01-05	7.2	13%	13%	13%	49%	13%	-760.15	-29.01	-1748.78	123.92	-308.37	-3956.81	205.23
100	KFR7A	1996-10-24	7.24	13%	13%	13%	40%	20%	-558.97	-26.06	-1838.67	110.81	-233.72	-4010.69	196.39
101	KFR7A	1997-09-18	6.9	13%	13%	13%	43%	19%	-609.60	-26.43	-1809.70	109.75	-250.03	-4060.07	203.21
102	KFR7A	1998-10-01	7.2	13%	13%	13%	44%	18%	-597.67	-25.84	-1782.56	101.39	-266.55	-4128.69	191.70

M3row	Idcode	Sampling date	pH	Glacial %	Brine %	Litorina %	Biogenic %	Rain'60 %	dev Na mg/L	dev K mg/L	dev Ca mg/L	dev Mg mg/L	dev HCO3 mg/L	dev Cl mg/L	dev SO4 mg/L
103	KFR7A	1999-09-30		13%	13%	13%	42%	20%	-587.21	-25.35	-1781.13	98.23	-244.51	-3957.83	193.18
104	KFR7A	2000-05-18	7.6	12%	12%	12%	42%	21%	-425.47	-22.74	-1757.41	86.43	-222.37	-4038.10	171.10
105	KFR7A	2000-05-19	7.7	12%	12%	12%	42%	23%	-581.12	-24.11	-1705.45	84.41	-222.72	-3728.69	181.41
106	KFR7A	2000-05-24	7.6	12%	12%	12%	43%	21%	-522.19	-24.60	-1695.90	95.64	-230.34	-3858.60	171.04
107	KFR7A	2000-05-25	7.6	12%	12%	12%	42%	22%	-495.12	-24.30	-1708.05	99.22	-225.37	-3885.79	165.20
108	KFR7C	2000-07-10	7.6	11%	11%	11%	37%	30%	-388.13	-19.09	-1749.94	36.57	-186.14	-3843.24	151.71
109	Precipit			8%	5%	5%	5%	77%	-651.14	-11.27	-956.38	-27.76	-41.54	-2783.58	-74.08
110	Precipit			8%	5%	5%	5%	77%	-644.00	-11.15	-945.90	-27.46	-41.08	-2753.09	-73.27
111	Precipit			0%	0%	0%	0%	100%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
112	Glacial			100%	0%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
113	Sea	920828 0		5%	5%	49%	35%	5%	-786.53	4.81	-1201.54	-19.71	-246.34	-3356.69	156.97
114	Åspö	920423 1		0%	0%	0%	100%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
115	Laxemar	930803		0%	100%	0%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00
116	Litorina			0%	0%	100%	0%	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00

M3row	Idcode	Sampling date	dev D dev SMOW	dev Tr TU	dev O18 dev SMOW
1	KFR01	2000-07-19	3.17	-709.97	1.61
2	KFR01	1989-04-04	0.67	-875.58	0.23
3	KFR01	1989-12-27	0.85	-891.44	0.27
4	KFR01	1990-06-15	3.62	-757.59	0.56
5	KFR01	1990-12-27	0.72	-768.04	0.48
6	KFR01	1992-01-10	-1.93	-848.09	0.58
7	KFR01	1992-06-29	2.90	-727.29	1.35
8	KFR01	1998-10-01	-1.05	-799.68	1.14
9	KFR01	1999-09-30	0.90	-787.27	1.09
10	KFR01	2000-07-11	-1.11	-814.20	1.12
11	KFR01	2000-07-19	0.25	-801.88	1.15
12	KFR01	2000-07-31	5.00	-682.86	1.57
13	KFR01	2000-08-22	-3.38	-900.40	0.90
14	KFR02	1995-06-27	-1.41	-652.42	0.17
15	KFR02	2000-06-30	-6.40	-608.39	0.98
16	KFR02	1995-06-27	-2.34	-730.36	0.30
17	KFR02	2000-07-10	-6.26	-897.80	0.54
18	KFR02	1995-06-27	-2.17	-883.56	0.05
19	KFR02	2000-07-10	-5.99	-883.17	0.64
20	KFR02	1995-06-27	-3.67	-807.76	0.30
21	KFR02	2000-07-10	-6.04	-861.99	0.51
22	KFR03	1995-06-27	-2.21	-668.32	-0.02
23	KFR03	2000-07-10	-6.62	-706.25	0.28
24	KFR03	1995-06-27	-2.10	-579.36	-0.05
25	KFR03	2000-07-10	-6.10	-740.15	0.35
26	KFR03	1995-06-27	-1.91	-581.18	-0.03
27	KFR03	2000-07-10	-6.52	-843.63	0.55
28	KFR03	1995-06-27	-3.10	-778.78	0.30
29	KFR03	2000-07-10	-5.55	-857.74	0.44
30	KFR04	1995-06-27	-3.82	-721.46	0.26
31	KFR04	2000-07-18	-5.75	-824.48	0.36
32	KFR04	1995-06-27	2.86	-646.27	1.01
33	KFR04	2000-07-18	-0.10	-709.95	0.94
34	KFR04	1995-06-27	2.75	-637.59	0.92

M3row	Idcode	Sampling date	dev D dev SMOW	dev Tr TU	dev O18 dev SMOW
35	KFR04	2000-07-18	-1.67	-761.59	0.88
36	KFR05	1995-06-27	4.06	-521.62	1.32
37	KFR05	2000-07-12	0.95	-579.91	1.29
38	KFR08	2000-07-10	4.20	-501.30	1.50
39	KFR08	2000-07-10	3.76	-731.53	1.42
40	KFR08	1989-04-04	11.45	-340.24	1.43
41	KFR08	1989-12-27	8.82	-404.34	1.31
42	KFR08	1990-06-15	9.29	-238.78	1.21
43	KFR08	1992-01-10	5.54	-259.24	1.27
44	KFR08	1992-06-29	8.86	-446.82	1.45
45	KFR08	1994-04-08	10.97	-429.23	1.65
46	KFR08	1995-01-05	8.50	-459.60	1.81
47	KFR08	1995-06-26	8.20	-484.88	1.78
48	KFR08	1996-01-05	-1.32	-726.94	0.77
49	KFR08	1996-10-24	6.97	-503.80	1.78
50	KFR08	1997-09-18	4.95	-367.88	1.68
51	KFR08	1998-10-01	6.77	-498.98	1.87
52	KFR08	1999-09-30	6.30	-533.17	1.73
53	KFR08	1999-11-19	8.07	-589.40	1.85
54	KFR08	2000-07-10	5.19	-537.08	1.61
55	KFR09	1992-06-29	4.79	-363.84	1.51
56	KFR09	1994-04-08	8.42	-274.60	1.49
57	KFR09	1995-01-05	5.80	-240.11	1.34
58	KFR09	1995-06-26	7.12	-310.55	1.41
59	KFR09	1996-01-05	5.25	-326.21	1.45
60	KFR09	1996-10-24	4.95	-308.58	1.34
61	KFR09	1997-09-18	5.75	-355.65	1.72
62	KFR09	1998-10-01	11.25	-329.69	0.39
63	KFR09	1999-02-02	4.95	-311.23	1.57
64	KFR09	2000-06-28	3.89	-340.63	1.35
65	KFR10	1989-04-04	10.66	-329.51	1.66
66	KFR10	1989-12-27	9.41	-362.18	1.35
67	KFR10	1990-06-15	10.68	-285.63	1.50
68	KFR10	1990-12-27	12.61	-381.01	0.67

M3row	Idcode	Sampling date	dev D dev SMOW	dev Tr TU	dev O18 dev SMOW
69	KFR10	1992-01-10	3.82	-379.90	1.80
70	KFR10	1999-02-02	-9.83	-339.03	-0.83
71	KFR10	1999-09-30	5.85	-219.20	1.48
72	KFR10	2000-06-22	6.60	-451.45	1.69
73	KFR10	2000-06-28	3.90	-443.16	1.71
74	KFR10	2000-06-30	1.52	-445.97	1.92
75	KFR10	2000-07-04	1.48	-448.00	1.93
76	KFR13	1995-06-27	0.93	-406.99	0.50
77	KFR13	2000-06-29	-4.35	-694.00	0.90
78	KFR13	2000-06-29	-3.40	-799.84	0.93
79	KFR19	1995-06-27	8.99	-601.86	1.82
80	KFR19	1995-06-27	9.44	-592.80	1.59
81	KFR19	2000-07-18	1.48	-678.90	1.82
82	KFR19	1995-06-27	8.02	-673.64	1.61
83	KFR19	2000-07-18	5.61	-684.99	1.78
84	KFR55	2000-05-19	-1.34	-682.57	1.20
85	KFR55	2000-05-19	-6.71	-881.05	0.84
86	KFR55	1995-06-27	5.01	-618.37	1.38
87	KFR55	2000-07-10	-0.73	-747.39	1.08
88	KFR56	2000-07-10	3.82	-469.91	1.36
89	KFR7A	2000-07-18	-0.96	-542.84	1.12
90	KFR7A	1989-04-04	1.17	-382.38	0.87
91	KFR7A	1989-12-27	6.67	-353.97	0.79
92	KFR7A	1990-06-15	5.34	-272.57	0.73
93	KFR7A	1990-12-27	5.07	-322.86	0.86
94	KFR7A	1992-01-10	-0.09	-346.87	0.73
95	KFR7A	1992-06-29	0.90	-373.83	0.82
96	KFR7A	1994-04-08	3.49	-336.76	0.96
97	KFR7A	1995-01-05	1.45	-317.35	1.02
98	KFR7A	1995-06-26	2.75	-335.34	0.95
99	KFR7A	1996-01-05	5.59	-255.40	1.45
100	KFR7A	1996-10-24	0.53	-411.25	1.15
101	KFR7A	1997-09-18	0.51	-379.44	1.40
102	KFR7A	1998-10-01	2.29	-367.06	1.46

M3row	Idcode	Sampling date	dev D dev SMOW	dev Tr TU	dev O18 dev SMOW
103	KFR7A	1999-09-30	2.40	-396.54	1.24
104	KFR7A	2000-05-18	0.04	-422.74	1.27
105	KFR7A	2000-05-19	1.55	-455.57	1.28
106	KFR7A	2000-05-24	0.60	-424.14	1.32
107	KFR7A	2000-05-25	-1.13	-437.24	1.37
108	KFR7C	2000-07-10	1.20	-607.55	1.25
109	Precipit		-0.09	-1550.12	-0.03
110	Precipit		-0.09	-1533.13	-0.03
111	Precipit		0.00	0.00	0.00
112	Glacial		0.00	0.00	0.00
113	Sea	920828 0	0.60	-73.30	1.38
114	Áspö	920423 1	0.00	0.00	0.00
115	Laxemar	930803	0.00	0.00	0.00
116	Litorina		0.00	0.00	0.00