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Oskarshamn site investigation

Monitoring of surface water chemistry 2006

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Medins Biologi AB

December 2008

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Keywords: Surface water, Metals, Isotopes, Nutrients.

Abstract

Within the site investigation area at Oskarshamn surface water has been sampled from November 2002. After a period of two years with basic sampling in the area the program for sampling was changed in 2005 to a program for monitoring in some of the sites. In 2006 sampling has been conducted at totally 8 sites. Five of these were sites in streams, one was a site in a lake and two were sites at sea in the inner coastal area. Sampling was performed on twelve occasions in 2006 and the water was analysed for a large number of parameters. In the lake and at sea vertical measurements were also taken by a multi parameter probe. All data collected has after an initial control been sent to SKB for storage in their database Sicada.

In this report the results from 2006 was evaluated. The results were similar to the results obtained previous years /Ericsson and Engdahl 2004ab, 2005, 2007/.

The data gathered are generally considered to be of high quality but the method used for determination of run-off is probably inexact resulting in lower quality of this data set.

The measurements of chlorophyll with the probe in Lake Frisksjön (PSM002065) are disturbed by the high concentration of humus in the water. Since both humic substances and chlorophyll have similar fluorescence in the wavelength used by the probe the concentration of chlorophyll is highly overestimated by these measurements.

The light sensor on the YSI-sonde is unable to give zero values even in a complete darkness. This results in readings (which are around 5 µmoles/second/m^2 to high) which are not compensated for in the data set.

Sammanfattning

Provtagning av ytvatten har skett inom platsundersökningsområdet vid Oskarshamn från november 2002. Efter två års basprovtagning i området övergick provtagningen under 2005 till ett program för monitering vid något färre provplatser. Under 2006 har provtagning skett vid 8 stationer. Fem av dessa var i vattendrag, en var i en sjö och två var platser i havet. Provtagning genomfördes vid tolv tillfällen under 2006 och ett stort antal parametrar analyserades. I sjön och i havet genomfördes även vertikala mätningar med en sond. Alla data som samlades in skickades efter en första kvalitetsgranskning till SKB för lagring i databasen Sicada.

I denna rapport har 2005 års resultat utvärderats. Resultaten liknade de som erhållits vid tidigare års undersökningar /Ericsson och Engdahl 2004ab, 2005, 2007/.

De data som samlats in har en generellt hög kvalitet. Tre typer av data har dock bedömts ha en lägre kvalitet.

Mätningar av vattenföring med flottörmetoden som har utförts i vattendragen första halvåret 2006. Metoden ger endast en grov uppskattning av vattenflödet.

De mätningar av klorofyll som utförts med sonden i Frisksjön (PSM002065) har blivit störda av den höga halten av humus som förekommer i vattnet. Orsaken är att både humusämnen och klorofyll fluorescerar vid den våglängd som används av sonden för att mäta klorofyllhalten. Detta har resulterat i en kraftig övervärdering av klorofyllhalten i sjön.

YSI-sondens ljussensor ger inte nollvärden i totalt mörker. Detta har resulterat i värden som är ungefär 5 µmol/sekund/m^2 för höga.

Contents

1 Introduction

This document reports the data gained by hydrogeochemical and surface ecological monitoring of surface water, which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-05-104. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Within the site investigation area surface water has been sampled from November 2002. After a period of two years with basic sampling in the area the program for sampling was changed in 2005 to a program for monitoring in some of the sites. In 2006 sampling has been conducted at 8 sites (Figure 1-1). Five of these were sites in streams, two were sites at sea in the inner coastal area, and one was a site in a lake. Sampling was performed on twelve occasions in 2006 and the water was analysed for a large number of parameters. In the lake and at sea vertical measurements were also taken by a multi parameter probe. All original results have, after an initial control, been sent to SKB for storage in their primary database Sicada. The results are traceable by the activity plan number.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	**Number**	**Version**
Hydrogeokemisk och ytekologisk monitering av ytvatten 2006	AP PS 400 05 104	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för ytvattenprovtagningar vid platsundersökningar	SKB MD 900.004	1.0

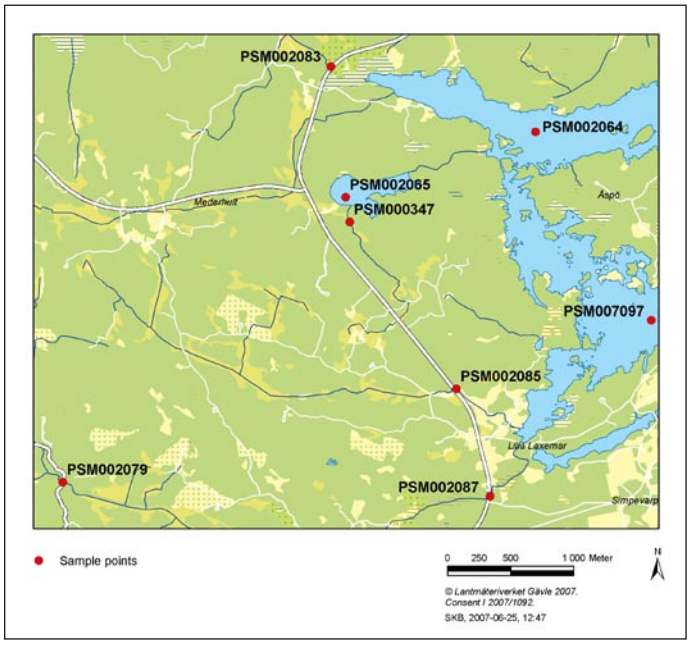

Figure 1-1. *The site investigation area and the sites sampled during 2006.*

2 Objective and scope

The purpose of monitoring is to continue to characterise the surface water at some chosen sites in the site investigation area. A number of streams, sites in the coastal area and a lake were sampled during 2006 (Figure 1-1 and Appendix 1). The sampling was performed once a month and on each sampling occasion all sites planned were sampled during a two-day period (Appendix 2).

The surface water monitoring program consisted mainly of two different programmes, the chemical programme and the ecological programme. The chemical programme included fewer working seasons in comparison with the ecological programme (Appendix 2 and Appendix 3). For the working seasons that coincided between the two programmes sampling was co-ordinated. The ecological programme as well as the chemical basically included the same parameters regardless of the type of water that was sampled (stream, lake or coastal area).

A special control programme comprising limited sites and parameters has been performed at four occasions (Appendix 3), where the accuracy of the analysing laboratories was evaluated.

A number of physical and chemical parameters were measured directly at the sampling site using a multi-parameter probe (Table 2-1). Water samples were also taken for analysis of further parameters and the samples were later sent to different laboratories.

In this report the evaluation aims to describe the quality of the data sampled in 2006.

The data gained in this activity will be used for continued advanced analysis and modelling.

Table 2-1. Parameters measured with the multi-parameter probe 2005.

Parameter	Unit	Parameter	Unit
Date/time	(Y/M/D:hh/mm)	Turbidity	(NTU)
Depth	(m)	Light	(PAR)
Water temperature	(C)	Oxygen	(mg/l)
pH		Chlorophyll	(µg/l)
Conductivity	(mS/cm)	Redox potential	(mV)
Salinity	(ppt)	Atmospheric pressure	(psi)

3 Methods

3.1 Sites and sampling frequency

Sampling was performed on twelve occasions in 2006 (Appendix 2). The total number of sampled sites during 2006 was eight (five streams, one lake and two sites in the inner coastal area).

3.2 Execution of sampling and treatment of samples

Methods used when sampling in the field, calibration procedures, treatments of samples before analysis and how samples was stored and transported to the analysing laboratories, is described in earlier P-reports /Ericsson and Engdahl 2004ab, 2005/.

During 2006 only a few changes of methods and procedures concerning sampling, sample preparations or analysis of water samples have occurred. When sampling for analysis of sulfide, the winkler bottles were filled and flowed over direct in the field, using unfiltered water, instead of bringing water to the laboratory in collecting bottles for later treatment.

Measurements of water flow in the streams were performed between January–July 2006, but the data set is not complete. Besides the usual method for flow measurements /Ericsson and Engdahl 2004a/, a device based on Doppler principals was used (provided by SKB). From August 2006 all water flow measurements were interrupted.

3.3 Analysed parameters and laboratories used

The analysed parameters and the laboratories used are shown in Table 3-1.

Table 3-1. Analysed parameters and Laboratories used January–December 2006.

Components	Analysing laboratory
Alkalinity, pH, Conductivity, Anions (I-, Cl, Br, SO_4), Absorbance, HS, Fe II + Fe (tot)	Äspö Laboratory
Standard elements (Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr, TOT-S	Analycen, Lidköping (control)
Standard elements (Na, K, Ca, Mg, Si, Fe, Mn, Li, Sr, TOT-S), Iodine, Lantanoides, trace elements, environmental metals, La, In, As (Br)	Analytica, Luleå
TOC, DOC, DIC, TOT-NP, POP, PON, POC, $N0_3$, NO_2, NH_4, PO_4, Silicate, Chlorophyll, Oxygen	Department of Systems Ecology Stockholm University
Ra- and Rn-isotopes	SUERC, Scotland

3.4 Documentation

All activities were continuously documented. Notes were taken on field conditions, time of sampling, marking of samples, calibration protocols and so forth. Any deviations from the normal routines were also noted and commented in a report, which was sent to SKB after each sampling occasion. Delivery notes with instructions on which components to analyse were always sent with the samples to the different laboratories. In Table 3-2 a number of documents and files delivered to SKB after a sampling occasion can be viewed.

After analysis the data has continuously been reported from the laboratories. As a routine a first preliminary control of the data quality was performed before sending them for storage in the database Sicada.

The original results were stored in the primary database (Sicada). It is the data in this database that will be used for further interpretation (modelling). The data is traceable in Sicada by the Activity Plan number (AP PS 400-05-104).

Table 3-2. Delivery of documents and files to SKB after a sampling occasion.

Document/file	Media
WC107 – Surface water measurements	File
Activity diary	Paper
Delivery notes to the laboratories	Paper
Calibration notes for the YSI probe	File
Calibration data and additional parameters	Files
Quality checked data and signed document of field measurements	File and paper
All raw data from measurements in the field	Files
PAR profile data (Photosynthetic Active Radiation)	File
Run off data from the streams	File
Sample comments – Observations in the field	File
Deviation reports	Paper
Document of stored samples in refrigerator and freezer	File
Photos from the sites	Files
Delivery control documents (SKB and internal)	Paper

4 Nonconformities

It was not possible to sample all sites at all occasions (Appendix 4). In January one stream site was covered with ice and sampling was not possible. During summer and autumn two stream sites were dried up.

In August and September 2006 field measurements of light (PAR) with the YSI probe were not possible due to malfunction of the light sensor. In October–December PAR was measured with a separate instrument, when the probe was sent away for reparation.

Redox potential (ORP) measurements from June are probably not accurate due to malfunction of the probe. In July ORP data was excluded. ORP measurements were not possible in November and December, when the backup probe was used.

5 Results and discussion

5.1 Run-off

The run-off was measured on each sampling occasion until July when these measurements were omitted. In some of the streams and on some occasions measurements were impossible to perform due to coverage of ice or drought. The results show that the run-off in the first half of 2006 was similar to previous years (Figure 5-1).

5.2 Biochemical characterisation

5.2.1 Nutrients

Many of the streams had relatively high concentrations of nutrients (Table 5-1). Highest concentrations were generally measured downstream from farmland areas and in the larger tributaries. These results were similar to those measured in previous years /Ericsson and Engdahl 2004ab, 2005, 2007/. At many sites there was a clear tendency for the concentration of nutrient to be higher in the summer than in the winter (Figure 5-2).

Table 5-1. Average concentration of nutrients and chlorophyll a from the stream water sites, 2006.

Site number	Depth zone	NH_4-N (mg/l)	NO_3-N/NO_2-N (mg/l)	N-tot (mg/l)	P-tot (mg/l)	PO_4-P (mg/l)	POP (mg/l)	PON (mg/l)	Clorophyll a (µg/l)
PSM002079	Surface	0.061	0.294	0.993	0.030	0.003	0.015	0.111	
PSM002083	Surface	0.037	0.291	1.046	0.030	0.005	0.014	0.090	1.7
PSM002085	Surface	0.036	0.610	1.559	0.035	0.006	0.011	0.068	
PSM002087	Surface	0.055	0.416	1.137	0.029	0.004	0.013	0.148	1.5
PSM000347	Surface	0.005	0.281	0.843	0.018	0.002	0.005	0.033	

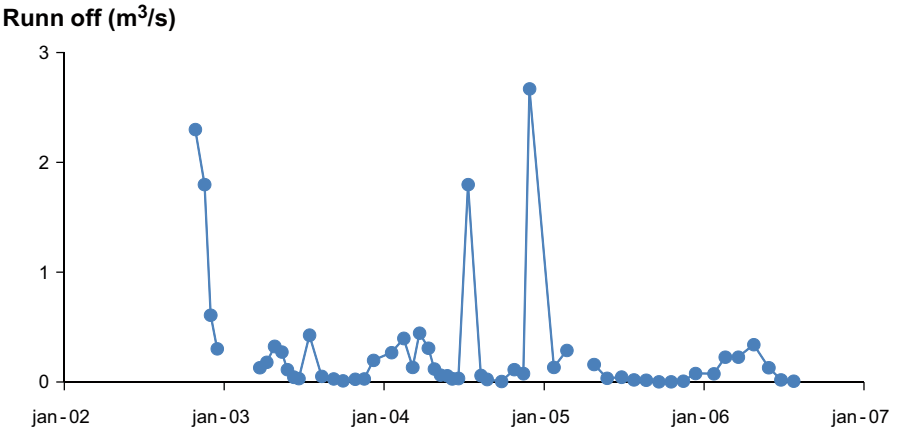

Figure 5-1. *Run-off measured in Laxemarsån (PSM002087) close to the outlet into the sea.*

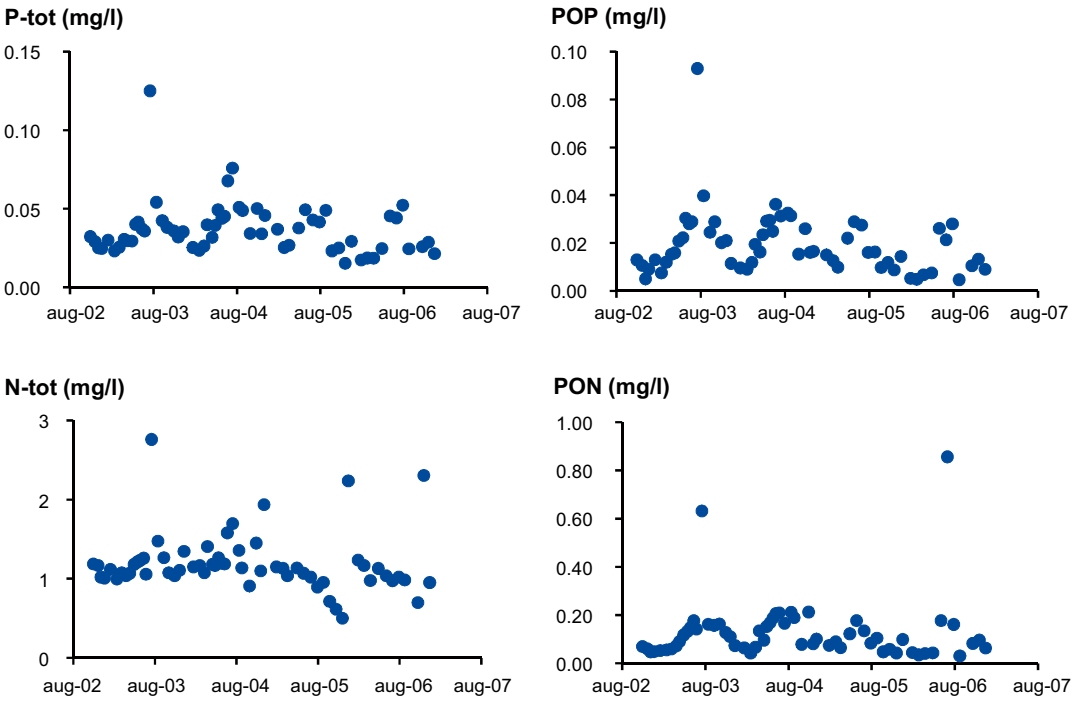

Figure 5-2. *Nutrients measured as total phosphorus, particulate phosphorus, total nitrogen and particulate nitrogen in Laxemarsån (PSM002087).*

The results from Lake Frisksjön (PSM002065) were similar to previous years (Figure 5-3 and Table 5-2). A large part of the nutrients were bound to particles (mostly plankton) in the summer month compared to the winter conditions (Figure 5-4).

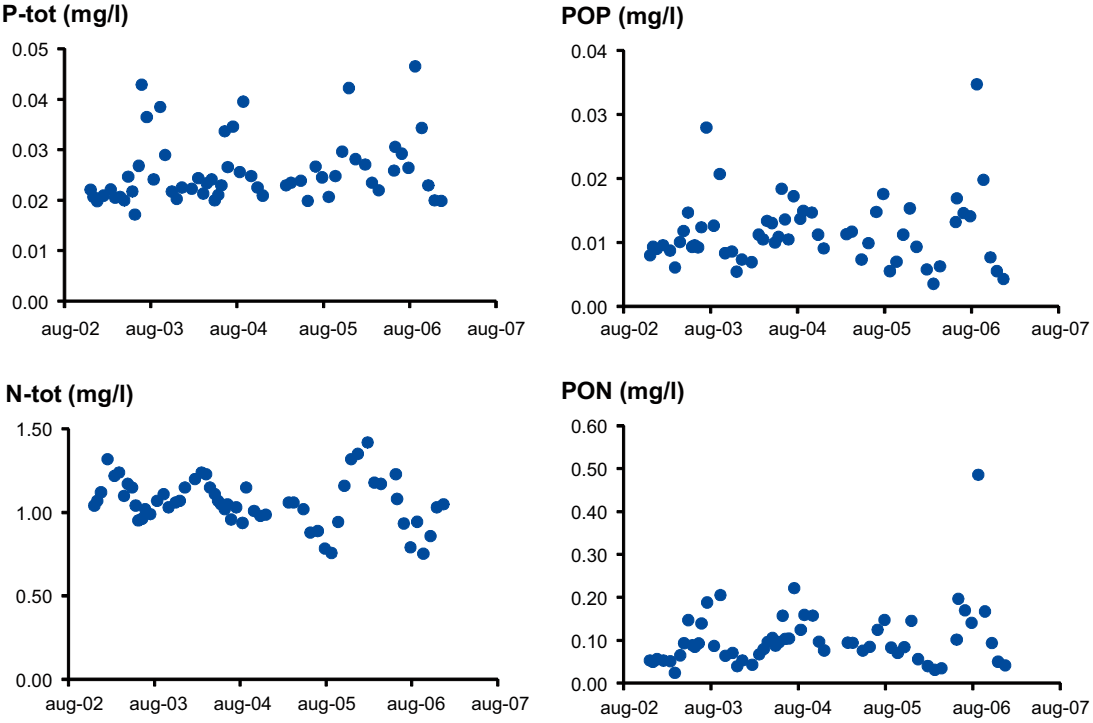

Figure 5-3. *Nutrients measured as total phosphorus, particulate phosphorus, total nitrogen and particulate nitrogen in the surface water of Lake Frisksjön (PSM002065).*

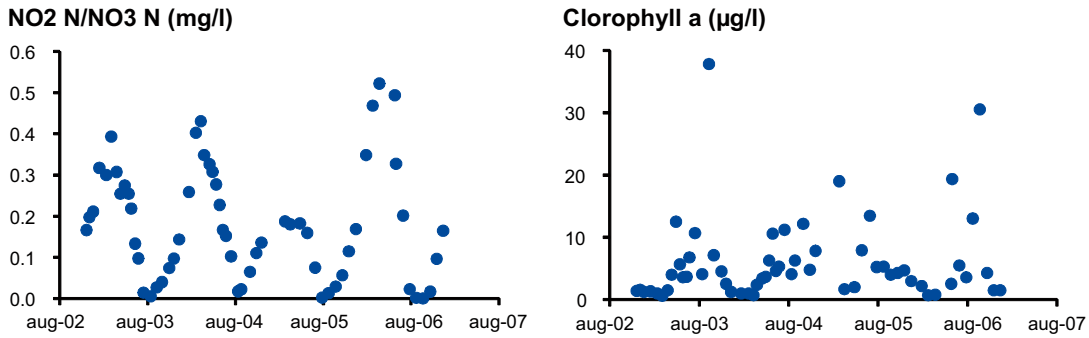

Figure 5-4. *Concentrations of chlorophyll and NO_2-N/NO_3-N in the surface water of Lake Frisksjön (PSM002065).*

Table 5-2. Average concentration of nutrients and chlorophyll a at the investigated lake, 2006.

Site number	Depth zone	NH_4-N (mg/l)	NO_3-N/NO_2-N (mg/l)	N-tot (mg/l)	P-tot (mg/l)	PO_4-P (mg/l)	POP (mg/l)	PON (mg/l)	Clorophyll a (µg/l)
PSM002065	Surface	0.129	0.222	1.037	0.027	0.002	0.012	0.130	7.1
PSM002065	Bottom	0.136	0.231	1.048	0.027	0.002	0.010	0.121	18.9

The results from the two sea sites were similar (Table 5-3). At both sites there was a tendency for the concentration of ammonium and nitrite/nitrate to be lower in the summer than in the winter (Figure 5-5). The probable reason is higher concentration of plankton in the summer but the concentration of chlorophyll a did not vary accordingly (Figure 5-5).

Table 5-3. Average concentration of nutrients and chlorophyll a at the investigated sites in the sea, 2006.

Site number	Depth zone	NH_4-N (mg/l)	NO_3-N/NO_2-N (mg/l)	N-tot (mg/l)	P-tot (mg/l)	PO_4-P (mg/l)	POP (mg/l)	PON (mg/l)	Clorophyll a (µg/l)
PSM007097	Surface	0.040	0.147	0.644	0.023	0.003	0.011	0.098	4.6
PSM007097	Bottom	0.114	0.061	0.619	0.039	0.005	0.027	0.152	6.7
PSM002064	Surface	0.022	0.064	0.490	0.020	0.003	0.008	0.058	4.0
PSM002064	Bottom	0.163	0.104	0.584	0.039	0.009	0.026	0.061	2.0

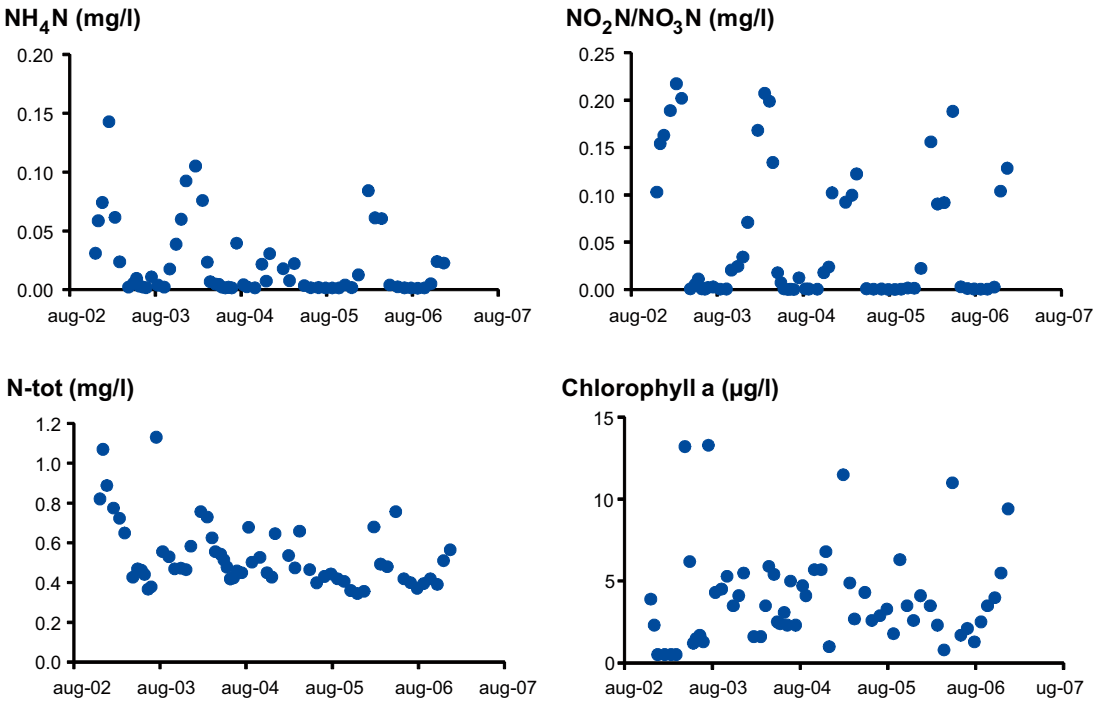

Figure 5-5. *Chlorophyll a and nutrients measured as ammonium, nitrite/nitrate and total nitrogen in the surface water of Granholmsfjärden (PSM002064).*

5.2.2 Carbon fractions

The streams in the area were humic with high concentrations of organic carbons and high absorbance (Table 5-4). At most stream sites there was a tendency of higher concentrations of organic carbon during the summer months (Figure 5-6). There was not any obvious seasonal pattern in the concentrations of DIC (dissolved inorganic carbon) which instead strongly varied with the run-off (Figure 5-7).

As in the streams the water in Lake Frisksjön were strongly coloured with humus. The concentration of TOC (total organic carbon) and DOC (dissolved organic carbon) were high which led to low transparency of the water (Table 5-5). These results were similar to those measured in previous years (Figure 5-8). There was no obvious seasonal variation, neither in the concentration of DOC and TOC (dissolved organic carbon and total organic carbon) or in the transparency (Figure 5-8). A tendency of higher values of POC (particulate organic carbon) in the spring and summer month can probably be explained with higher concentrations of plankton during these months.

Table 5-4. Average concentration of carbon fractions and absorbance at the investigated stream water sites, 2006.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)
PSM002079	Surface	0.1	1.31	14.8	15.4	4.87	0.161
PSM002083	Surface	0.1	1.15	17.4	18.0	4.15	0.191
PSM002085	Surface	0.1	0.740	17.0	17.5	17.8	0.177
PSM002087	Surface	0.1	0.909	15.5	15.9	5.66	0.180
PSM000347	Surface	0.1	0.348	14.2	14.4	2.77	0.114

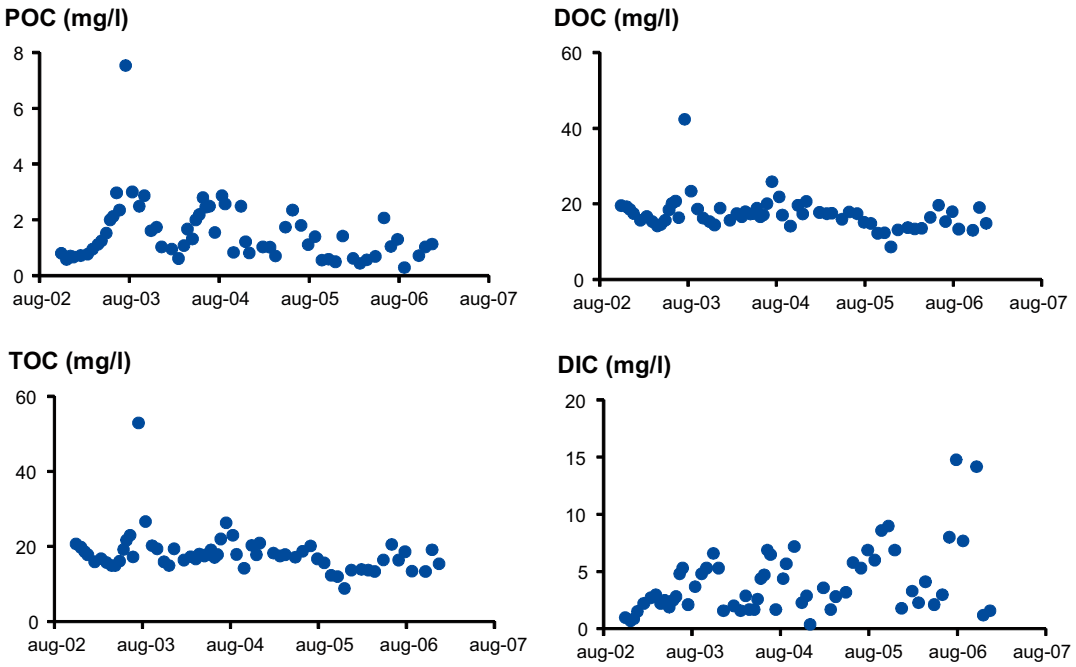

Figure 5-6. *Carbon fractions measured as particulate organic carbon (POC), dissolved organic carbon (DOC), total organic carbon (TOC) and dissolved inorganic carbon (DIC) in Laxemarsån (PSM002087).*

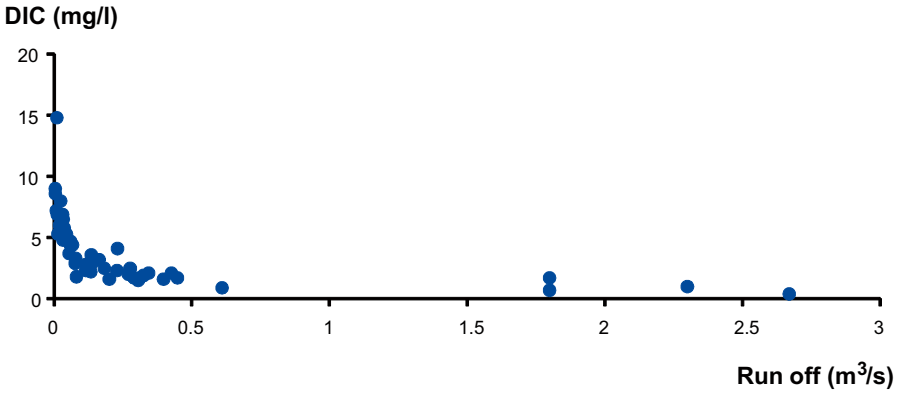

Figure 5-7. *The correlation between the concentration of DIC (dissolved organic carbon) and run-off in Laxemarsån (PSM002087).*

Table 5-5. Average concentration of carbon fractions, absorbance and transparency at the investigated lake, 2006.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Transparency (m)
PSM002065	Surface	0.5	1.05	13.8	14.1	2.98	0.123	2.19
PSM002065	Bottom	2.0	0.90	13.9	14.1	3.12	0.125	

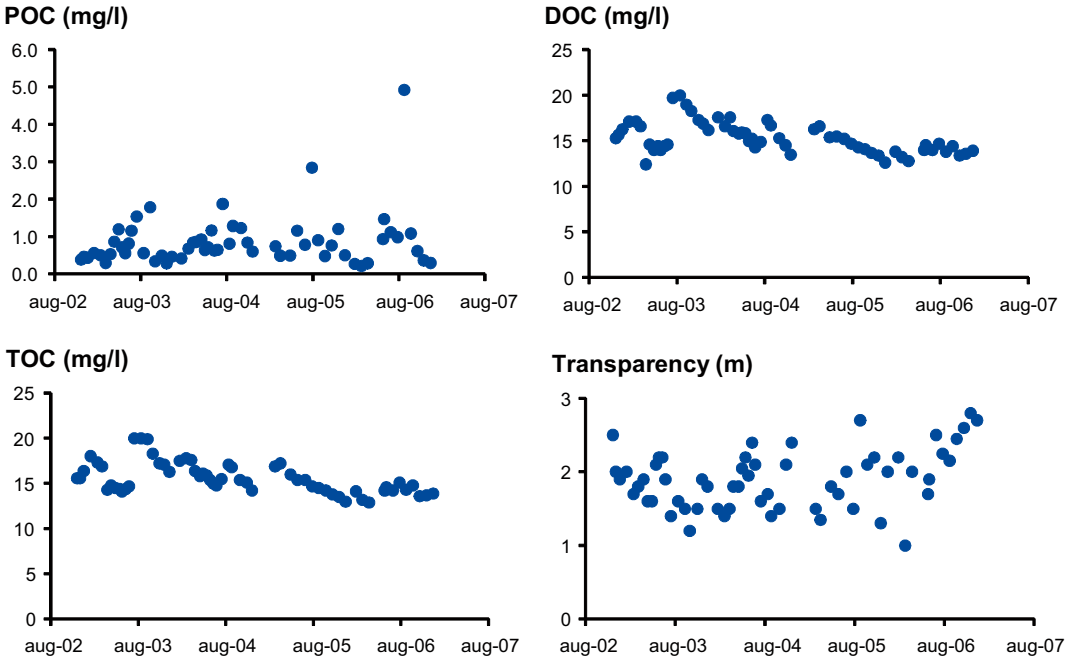

Figure 5-8. *Carbon fractions measured as particulate organic carbon (POC), dissolved organic carbon (DOC), total organic carbon (TOC) and transparency of the surface water in Lake Frisksjön (PSM002065).*

Similar to the results from previous years the concentrations of organic carbon fractions were rather high at the two sites in the sea (PSM007097 and PSM002064) (Table 5-6). As a consequence the transparency was reduced compared to what is normal for sea water in the area. As in the lakes there was no obvious seasonal pattern of the carbon fractions (Figure 5-9).

5.2.3 Acidification

In the streams HCO_3 and pH strongly correlated with the run-off (Figure 5-10). The minimum concentration of HCO_3 and the minimum pH varied between the streams with a markedly higher value at the site PSM002085 in Ekerumsbäcken, and there is an indication of problems with acidification at the rest of the sampled sites (Table 5-7).

Similar to the results from previous years Lake Frisksjön had relatively high concentrations of HCO_3 and relatively high pH values during 2006 (Ericsson and Engdahl 2004ab, 2005, 2007 and Table 5-8).

Table 5-6. Average concentration of carbon fractions, absorbance and transparency at the investigated sea sites, 2006.

Site number	Depth zone	Depth (m)	POC (mg/l)	DOC (mg/l)	TOC (mg/l)	DIC (mg/l)	Absorbance (/5 cm, 436 nm)	Transparency (m)
PSM007097	Surface	0.5	0.738	7.93	8.23	13.7	0.041	2.79
PSM007097	Bottom	2.5	1.03	5.45	5.68	18.5	0.020	
PSM002064	Surface	0.5	0.354	6.31	6.38	15.9	0.034	4.35
PSM002064	Bottom	16	0.510	4.79	4.85	19.2	0.027	

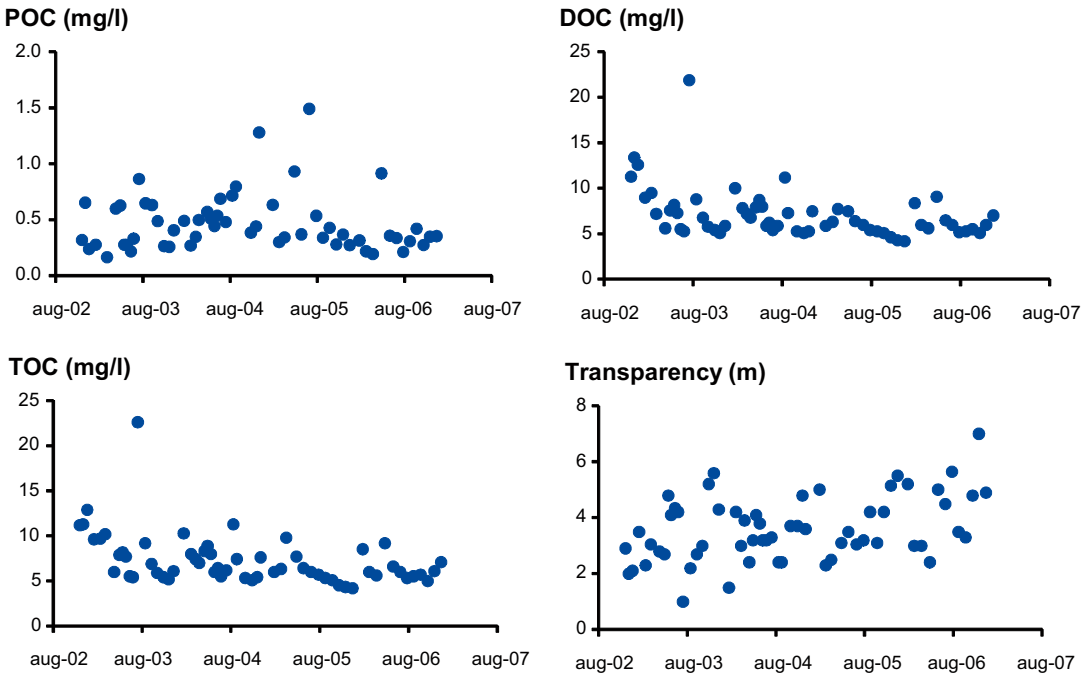

Figure 5-9. *Carbon fractions and transparency of the surface water sea site of Granholmsfjärden (PSM002064).*

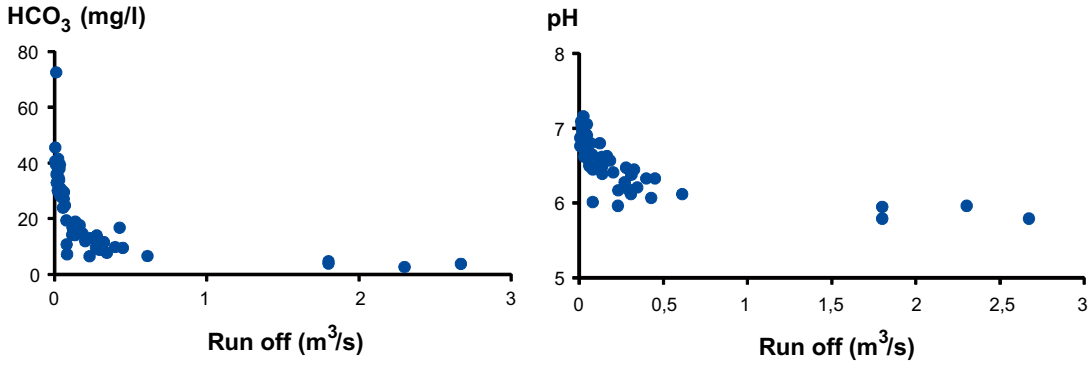

Figure 5-10. *Relation of the concentration of HCO_3 and pH to the run-off at the stream water site Laxemarsån (PSM002087).*

Table 5-7. Minimum concentration of HCO_3 and minimum pH at the stream water sites, 2006.

Site number	Depth zone	HCO_3 (mg/l)	pH
PSM002079	Surface	2.8	5.08
PSM002083	Surface	2.6	5.53
PSM002085	Surface	28.6	6.51
PSM002087	Surface	3.7	5.31
PSM000347	Surface	4.1	5.74

Table 5-8. Minimum concentration of HCO_3 and minimum pH in Lake Frisksjön, 2006.

Site number	Depth zone	Depth (m)	HCO_3 (mg/l)	pH
PSM002065	Surface	0.5	11.9	6.31
PSM002065	Bottom	2.0	12.2	6.22

5.2.4 Oxygen

The concentration of oxygen was quite low at some of the stream water sites (Table 5-9). Low concentrations of oxygen mostly appeared in the summer, partly as a consequence of high water temperature (Figure 5-11).

The oxygen concentration in the bottom water of Lake Frisksjön was occasionally very low (Table 5-10). More or less pronounced thermoclines evolved in both winter and summer. The thermocline was broken regularly in April and in late autumn but also at other times (probably as a consequence of strong winds). When the thermocline was broken a rapid raise of the oxygen concentration in the bottom water occurred (Figure 5-12).

Table 5-9. Minimum, average and maximum concentration of oxygen measured at the stream water sites, 2006.

Site number	Depth zone	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM002079	Surface	5.2	8.5	11.3
PSM002083	Surface	5.0	7.7	11.8
PSM002085	Surface	8.9	11.6	13.5
PSM002087	Surface	4.3	8.3	13.4
PSM000347	Surface	8.8	10.7	12.2

Table 5-10. Minimum, average and maximum concentration of oxygen in the surface and bottom water in Lake Frisksjön, 2006.

Site number	Depth zone	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM002065	Surface	7.9	9.5	11.2
PSM002065	Bottom	0.4	6.4	11.1

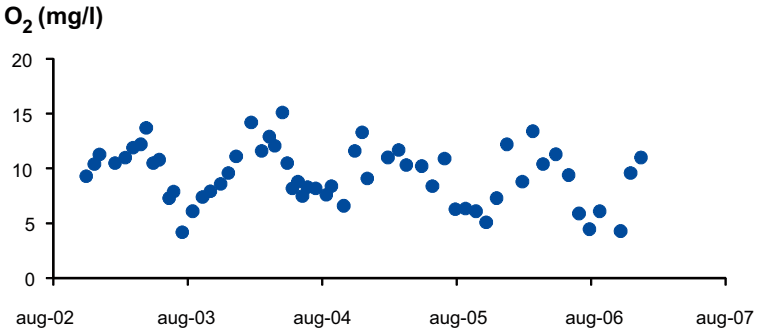

Figure 5-11. *Concentration of oxygen at the stream water site Laxemarsån (PSM002087).*

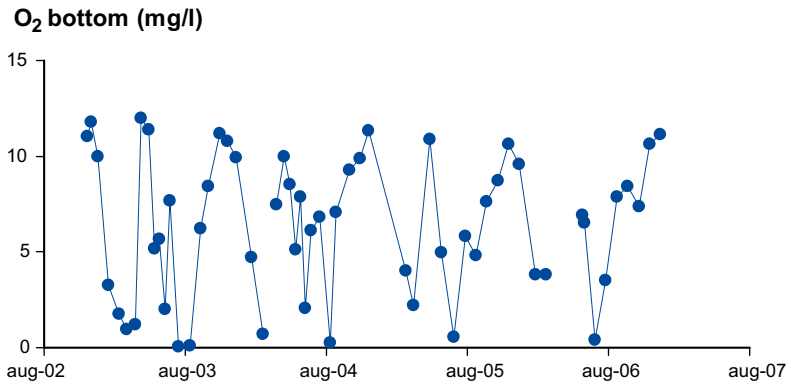

Figure 5-12. *Concentration of oxygen in the bottom water of Lake Frisksjön (PSM002065).*

At the sea sites the concentration of oxygen in the bottom water was occasionally very low (Table 5-11). Especially the site in Granholmsfjärden showed a similar pattern of thermocline build up and breakage as Lake Frisksjön.

5.3 Chemical characterisation

5.3.1 Major ions and conductivity

The concentration of major ions and the conductivity is presented in Tables 5-12, 5-13 and 5-14. The site PSM002085 differed with markedly higher concentrations and higher conductivity than the other streams suggesting different composition of the bedrock in the tributary. The concentration of most ions correlated well to the run off (Figure 5-13).

Table 5-11. Minimum. average and maximum concentration of oxygen in the surface and bottom water at the sea water sites. 2006.

Site number	Depth zone	Oxygen (min) (mg/l)	Oxygen (average) (mg/l)	Oxygen (max) (mg/l)
PSM007097	Surface	6.9	10.0	12.2
PSM007097	Bottom	0.1	3.6	10.9
PSM002064	Surface	9.1	10.3	12.6
PSM002064	Bottom	0.1	4.0	10.0

Table 5-12. Average concentration of major ions and conductivity at the stream water sites, 2006. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Br (mg/l)	Conductivity (mS/m)
PSM002079	Surface	0.1	16.5	2.3	15.5	4.1	21.9	26.7	26.1	*0.200*	20.7
PSM002083	Surface	0.1	10.9	1.8	15.1	3.3	17.2	13.0	31.0	*0.2*	17.1
PSM002085	Surface	0.1	44.6	1.4	37.7	5.4	86.7	52.4	54.0	*0.3*	45.3
PSM002087	Surface	0.1	19.5	2.4	17.3	4.4	26.2	29.0	33.5	*0.2*	24.6
PSM000347	Surface	0.1	17.4	1.7	11.9	3.2	10.2	27.5	25.2	*0.2*	19.2

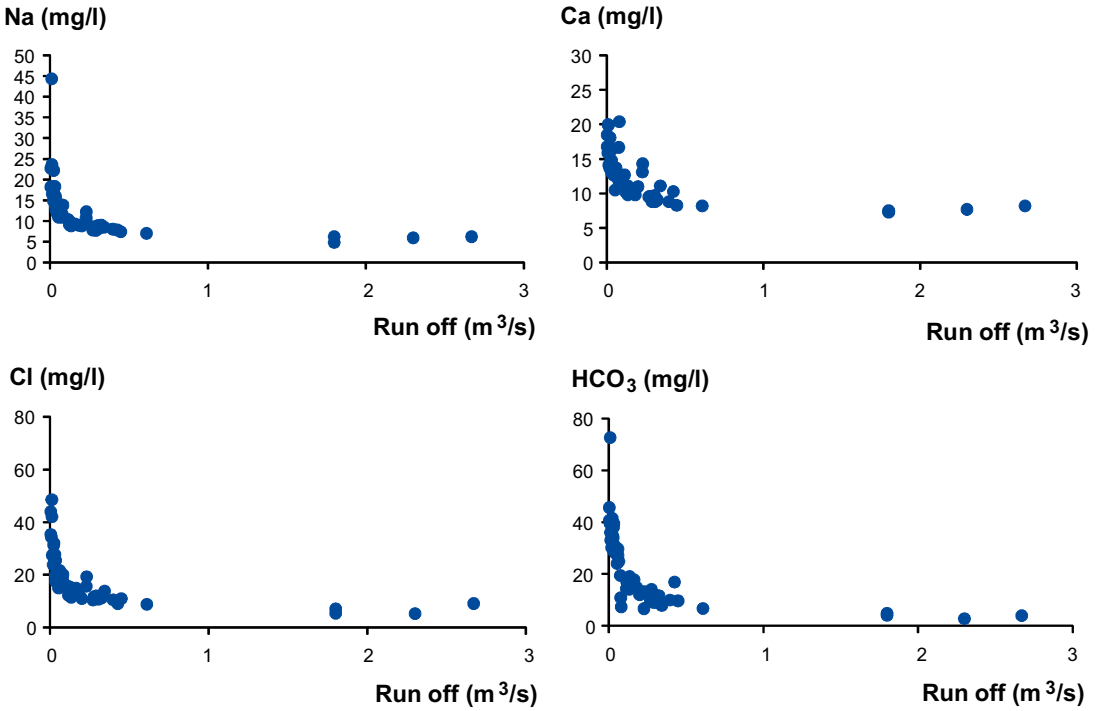

Figure 5-13. *Relation of the concentration of some major ions to the run-off at the stream water site Laxemarsån (PSM002087).*

Table 5-13. Average concentration of major ions and conductivity in Lake Frisksjön 2006. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Br (mg/l)	Conductivity (mS/m)
PSM002065	Surface	0.5	12.9	1.8	8.5	2.8	14.7	20.3	14.6	*0.2*	15.0
PSM002065	Bottom	2.0	12.5	1.8	8.5	2.8	15.0	17.9	14.4	*0.2*	14.8

Table 5-14. Average concentration of major ions and conductivity at the sea water sites, 2006.

Site number	Depth zone	Depth (m)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Br (mg/l)	Conductivity (mS/m)
PSM007097	Surface	0.5	1,577	62.0	82.0	190	76.8	2,990	417	10.0	947
PSM007097	Bottom	2.5	1,923	75.6	97.8	237	95.6	3,599	499	12.1	1,133
PSM002064	Surface	0.5	1,782	69.9	89.8	218	83.2	3,297	459	10.8	1,043
PSM002064	Bottom	16	1,989	79.8	100.8	245	98.8	3,734	515	12.6	1,171

In Lake Frisksjön the concentrations of ions and the conductivity was slightly lower than in the streams (Table 5-13).

At the sea sites the surface water differed from the bottom water with lower average concentrations of ions and lower average conductivity. This was probably a consequence of the outflow of fresh water and poor turn over at the sites which are secluded from the open sea. The periodic variation in the outflow of fresh water caused a marked variation in the surface waters of the ion concentration at the sea sites (Figure 5-14).

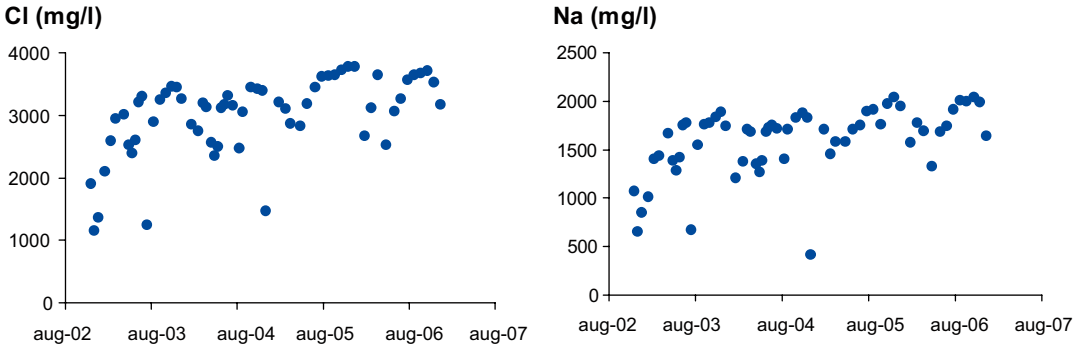

Figure 5-14. *Concentration of Na and Cl in the surface water at the secluded sea site Granholmsfjärden (PSM002064).*

5.3.2 Heavy metals and trace elements

The concentrations of metals are presented in Table 5-15, 5-16 and 5-17. Most metals differ between the sites at sea and the sites in the lake and streams with lower concentrations in the sea. At sea most metal concentrations are similar between the two sites. Likewise most inland sites had similar concentrations of metals.

Table 5-15. Average concentration of heavy metals and trace elements at the stream water sites, 2006. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Al (ug/l)	As (ug/l)	Ba (ug/l)	Cd (ug/l)	Ce (ug/l)	Co (ug/l)	Cr (ug/l)	Cs (ug/l)	Cu (ug/l)	Dy (ug/l)
PSM002079	Surface	498.3	0.4	33.3	0.076	6.4	1.0	0.7	*0.032*	2.6	0.450
PSM002083	Surface	820.5	0.4	26.1	0.115	6.3	0.9	0.9	*0.031*	2.4	0.414
PSM002085	Surface	244.7	0.4	30.4	0.088	3.5	0.8	1.3	*0.030*	6.2	0.312
PSM002087	Surface	458.7	0.4	45.4	0.079	6.0	0.9	0.7	*0.032*	3.3	0.432
PSM000347	Surface	602.0	0.4	28.2	0.076	6.9	0.5	1.1	*0.031*	4.0	0.431

Site number	Depth zone	Er (ug/l)	Eu (ug/l)	Gd (ug/l)	Hf (ug/l)	Hg (ug/l)	Ho (ug/l)	I (ug/l)	La (ug/l)	Lu (ug/l)	Mo (ug/l)
PSM002079	Surface	0.291	0.103	0.592	0.022	*0.003*	0.096	*0.1*	3.7	0.044	0.4
PSM002083	Surface	0.286	0.093	0.511	0.044	*0.004*	0.087	*0.1*	3.2	0.055	0.6
PSM002085	Surface	0.217	0.079	0.397	0.038	*0.003*	0.066	*0.1*	2.1	0.038	2.8
PSM002087	Surface	0.284	0.097	0.564	0.023	*0.004*	0.090	*0.1*	3.5	0.043	0.5
PSM000347	Surface	0.284	0.121	0.592	0.033	*0.004*	0.088	*0.1*	3.8	0.045	1.2

Site number	Depth zone	Nb (ug/l)	Nd (ug/l)	Ni (ug/l)	Pb (ug/l)	Pr (ug/l)	Rb (ug/l)	Sb (ug/l)	Sc (ug/l)	Sm (ug/l)	Tb (ug/l)
PSM002079	Surface	0.0	3.7	3.1	0.1	0.951	3.8	0.1	0.2	0.654	0.074
PSM002083	Surface	0.1	3.3	3.2	0.2	0.835	3.6	0.1	0.2	0.589	0.065
PSM002085	Surface	0.1	2.5	7.0	0.1	0.594	2.1	0.1	0.2	0.456	*0.050*
PSM002087	Surface	0.1	3.5	3.4	0.1	0.873	4.0	0.1	0.2	0.612	0.070
PSM000347	Surface	0.1	4.2	3.0	0.1	1.044	3.3	0.1	0.2	0.731	0.072

Site number	Depth zone	Th (ug/l)	Tl (ug/l)	Tm (ug/l)	U (ug/l)	V (ug/l)	Y (ug/l)	Yb (ug/l)	Zn (ug/l)	Zr (ug/l)
PSM002079	Surface	0.1	0.017	0.040	0.3	0.8	3.5	0.285	12.6	0.7
PSM002083	Surface	0.2	0.015	0.043	0.6	0.9	3.1	0.327	17.5	1.2
PSM002085	Surface	0.2	0.017	0.032	1.4	1.0	2.3	0.236	6.7	1.4
PSM002087	Surface	0.1	0.017	0.039	0.3	0.7	3.2	0.280	16.3	0.7
PSM000347	Surface	0.2	0.023	0.041	0.5	0.9	2.9	0.305	10.7	0.9

Table 5-16. Average concentration of heavy metals and trace elements in Lake Frisksjön, 2006. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Al (ug/l)	As (ug/l)	Ba (ug/l)	Cd (ug/l)	Ce (ug/l)	Co (ug/l)	Cr (ug/l)	Cs (ug/l)	Cu (ug/l)	Dy (ug/l)
PSM002065	Surface	227.0	0.6	16.5	0.019	2.9	0.2	0.6	*0.030*	2.1	0.155
PSM002065	Bottom	241.0	0.6	15.5	0.017	3.0	0.3	0.5	*0.031*	2.1	0.161

Site number	Depth zone	Er (ug/l)	Eu (ug/l)	Gd (ug/l)	Hf (ug/l)	Hg (ug/l)	Ho (ug/l)	I (ug/l)	La (ug/l)	Lu (ug/l)	Mo (ug/l)
PSM002065	Surface	0.102	0.044	0.210	0.017	*0.002*	0.031	*0.1*	1.4	0.016	1.1
PSM002065	Bottom	0.106	0.046	0.219	0.018	*0.003*	0.034	*0.1*	1.5	0.018	1.1

Site number	Depth zone	Nb (ug/l)	Nd (ug/l)	Ni (ug/l)	Pb (ug/l)	Pr (ug/l)	Rb (ug/l)	Sb (ug/l)	Sc (ug/l)	Sm (ug/l)	Tb (ug/l)
PSM002065	Surface	0.0	1.6	1.6	0.8	0.404	3.9	0.2	0.1	0.263	*0.031*
PSM002065	Bottom	0.0	1.6	1.6	0.7	0.416	4.0	0.1	0.1	0.273	*0.031*

Site number	Depth zone	Th (ug/l)	Tl (ug/l)	Tm (ug/l)	U (ug/l)	V (ug/l)	Y (ug/l)	Yb (ug/l)	Zn (ug/l)	Zr (ug/l)
PSM002065	Surface	0.1	0.010	0.015	0.3	1.3	1.0	0.106	4.4	0.5
PSM002065	Bottom	0.1	0.011	0.015	0.3	1.3	1.1	0.110	4.1	0.5

Table 5-17. Average concentration of heavy metals and trace elements at the sea water sites, 2006. Figures in italic indicate that some individual values in the calculation were below the detection limit of the analysis.

Site number	Depth zone	Al (ug/l)	As (ug/l)	Ba (ug/l)	Cd (ug/l)	Ce (ug/l)	Co (ug/l)	Cr (ug/l)	Cs (ug/l)	Cu (ug/l)	Dy (ug/l)
PSM007097	Surface	63.5	*0.9*	22.4	*0.027*	0.6	0.2	0.3	*0.100*	1.1	*0.054*
PSM007097	Bottom	16.3	*1.0*	22.0	*0.024*	0.2	0.3	0.2	*0.104*	0.5	*0.025*
PSM002064	Surface	66.7	*0.9*	19.5	*0.026*	0.4	0.2	0.2	*0.100*	1.1	*0.035*
PSM002064	Bottom	7.6	*0.9*	18.1	*0.024*	0.1	0.2	0.1	*0.100*	0.6	*0.020*

Site number	Depth zone	Er (ug/l)	Eu (ug/l)	Gd (ug/l)	Hf (ug/l)	Hg (ug/l)	Ho (ug/l)	I (ug/l)	La (ug/l)	Lu (ug/l)	Mo (ug/l)
PSM007097	Surface	*0.038*	*0.021*	*0.072*	*0.020*	*0.002*	*0.020*	*0.2*	0.4	*0.020*	1.8
PSM007097	Bottom	*0.021*	*0.020*	*0.027*	*0.020*	*0.002*	*0.020*	*0.2*	0.1	*0.020*	1.8
PSM002064	Surface	*0.029*	*0.020*	*0.045*	*0.020*	*0.002*	*0.020*	*0.2*	0.2	*0.023*	1.8
PSM002064	Bottom	*0.020*	*0.020*	*0.020*	*0.020*	*0.002*	*0.020*	*0.2*	0.1	*0.020*	1.8

Site number	Depth zone	Nb (ug/l)	Nd (ug/l)	Ni (ug/l)	Pb (ug/l)	Pr (ug/l)	Rb (ug/l)	Sb (ug/l)	Sc (ug/l)	Sm (ug/l)	Tb (ug/l)
PSM007097	Surface	0.0	0.4	1.4	*0.3*	*0.099*	18.4	*0.1*	*0.4*	*0.073*	*0.020*
PSM007097	Bottom	0.0	0.1	0.9	*0.4*	*0.036*	21.9	*0.1*	*0.4*	*0.029*	*0.020*
PSM002064	Surface	0.0	0.3	1.1	*0.3*	*0.064*	20.3	*0.1*	*0.4*	*0.047*	*0.020*
PSM002064	Bottom	0.0	0.1	1.0	*0.3*	*0.022*	22.5	*0.1*	*0.4*	*0.020*	*0.020*

Site number	Depth zone	Th (ug/l)	Tl (ug/l)	Tm (ug/l)	U (ug/l)	V (ug/l)	Y (ug/l)	Yb (ug/l)	Zn (ug/l)	Zr (ug/l)
PSM007097	Surface	*0.2*	*0.030*	*0.020*	0.7	0.4	0.4	*0.038*	4.9	*0.1*
PSM007097	Bottom	*0.2*	*0.030*	*0.020*	0.8	*0.3*	0.2	*0.022*	4.3	*0.1*
PSM002064	Surface	*0.2*	*0.030*	*0.020*	0.7	0.3	0.3	*0.030*	10.5	*0.1*
PSM002064	Bottom	*0.2*	*0.030*	*0.020*	0.7	0.2	0.1	*0.020*	3.4	*0.1*

5.3.3 Isotopes

The results of the measurements of isotopes are presented in Table 5-18, 5-19 and 5-20. For radium all sites had values below the detection limit. These results are considerably lower than the results obtained previous years /Ericsson and Engdahl 2004a, 2007/. The measurements of radon varied between the two streams were measurements were performed with a markedly higher value at the stream site PSM002083. This result was similar to previous years /Ericsson and Engdahl 2004a, 2005/.

Table 5-18. Isotope data from the investigated sites in the streams 2006. Figures in italic indicate that some individual values were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn (Bq/l)
PSM002079	Surface	0.1	*0.015*	0.098
PSM002083	Surface	0.1	*0.015*	1.448
PSM002085	Surface	0.1	–	–
PSM002087	Surface	0.1	*0.015*	0.132
PSM000347	Surface	0.1	–	–

Table 5-19. Isotope data from Lake Frisksjön 2006. Figures in italic indicate that some individual values were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn (Bq/l)
PSM002065	Surface	0.5	*0.015*	*0.015*
PSM002065	Bottom	2.0	*0.015*	*0.015*

Table 5-20. Isotope data from the investigated sea sites 2006. Figures in italic indicate that some individual values were below the detection limit of the analysis.

Site number	Depth zone	Depth (m)	^{226}Ra (Bq/l)	^{222}Rn (Bq/l)
PSM007097	Surface	0.5	*0.015*	*0.015*
PSM007097	Bottom	2.5	*0.015*	0.0115
PSM002064	Surface	0.5	*0.015*	*0.015*
PSM002064	Bottom	16	*0.015*	*0.015*

5.4 Effect on the results of methodological changes

No major change of methods that could have an effect on the results occurred in 2006.

5.5 Accuracy of data

Data has continuously been assessed after analysis and before storage into Sicada. Generally very few analysing errors or indications of contaminations have been detected and it is our opinion that the data is of high quality.

Two sets of data are of lower quality. The first is the measurements of the run-off at the stream sites. These measurements have been performed with a float method (BIN HR 013) (see methods) which, for many reasons, has been the only possible way to perform measurements of the run-off. The accuracy of this method is quite low compared to measurements with discharge weirs and gauges. The difficulties with measurement of run-off when the stream sites are covered with ice during winter also cause loss of data. The second data set with lower quality is the measurements of chlorophyll performed in Lake Frisksjön by the multi parameter probe. This problem is known from previous years and the problem seems to be that both humic substances and chlorophyll have similar fluorescence in the wavelength used by the probe. Since the inland waters contains high concentrations of humic substances the probe to large proportion measure humic substances as chlorophyll.

Another problem with the probe data is that the sensor measuring photosynthetically active radiation (PAR) is unable to give a zero value, when it is completely dark. The lowest PAR value that the sensor can show seems to be around 5 µmoles/second/m^2. The manufacturer says that this error is due to an electronic mismatch between the probe port and the light sensor and suggests that the offset could be subtracted.

6 References

Ericsson U, Engdahl A, 2004a. Oskarshamn site investigation. Surface water sampling in Simpevarp 2002–2003. SKB P-04-13, Svensk Kärnbränslehantering AB.

Ericsson U, Engdahl A, 2004b. Oskarshamn site investigation. Surface water sampling in Oskarshamn October 2003 to February 2004. SKB P-04-75, Svensk Kärnbränslehantering AB.

Ericsson U, Engdahl A, 2005. Oskarshamn site investigation. Surface water sampling at Simpevarp 2004. SKB P-05-118, Svensk Kärnbränslehantering AB.

Ericsson U, Engdahl A, 2007. Oskarshamn site investigation. Surface water sampling at Simpevarp 2005. SKB P-06-155, Svensk Kärnbränslehantering AB.

Appendix 1

Sites, co-ordinates and sampling depths

Sites, depths and co-ordinates 2006

ID-code	Name	Type of water	Co-ordinate X	Co-ordinate Y	Sampling depth (m)
PSM007097	Borholmsfjärden	Sea	636714	155156	0.5–7.0
PSM002064	Granholmsfjärden	Sea	636862	155052	0.5–17
PSM002065	Frisksjön	Lake	636810	154901	0.5–3.0
PSM002079	Kvarnstugan	Stream	636583	154674	0.1
PSM002083	Smedtorpet	Stream	636912	154888	0.1
PSM002085	Ekerum	Stream	636656	154986	0.1
PSM002087	Ekhyddan	Stream	636570	155012	0.1
PSM000347	Frisksjöns inlopp	Stream	636791	154904	0.1

Appendix 2

Schedule – Surface water sampling, weekly working seasons

Sampling occasions and programme 2006

Month	Jan	Feb	Mar	Apr	May	June
Programme	**Week nr**					
Ecological	4	8	12	17	22	26
Chemical class 5 (reduced)			12		22	
Chemical class 5 (full)						
Control programme (Br and std elements)			12		22	

Month	July	Aug	Sept	Oct	Nov	Dec
Programme	**Week nr**					
Ecological	30	34	38	42	46	50
Chemical class 5 (reduced)						50
Chemical class 5 (full)		34				
Control programme (Br and std elements)		34				50

Appendix 3

Programmes performed at the different sites

Sites and programmes 2006

ID-code	Name	Type of water	Ecological programme	Chemical programme	Control programme
PSM007097	Borholmsfjärden	Sea	X	X	X
PSM002064	Granholmsfjärden	Sea	X	X	X
PSM002065	Frisksjön	Lake	X	X	X
PSM002079	Kvarnstugan	Stream	X	X	
PSM002083	Smedtorpet	Stream	X	X	X
PSM002085	Ekerum	Stream	X	X	
PSM002087	Ekhyddan	Stream	X	X	X
PSM000347	Frisksjöns inlopp	Stream	X	X	

Appendix 4

Sampling sites and weeks when not sampled

Sites and weeks not sampled 2006

ID-code	Name	Type of water	Weeks when not sampled	Comment
PSM002085	Ekerum	Stream	4	Ice covered
PSM002085	Ekerum	Stream	34, 38, 42	Dried up
PSM000347	Frisksjöns inlopp	Stream	26, 30, 34, 38, 42	Dried up