P-09-75

Hydrological and meteorological monitoring at Oskarshamn, October 2008 to September 2009

Jonas Sjögren, Buban Sehalic,
Cari Andersson, Jörgen Jones
SMHI

Alf Engdahl, Medins Biologi AB

December 2009

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co

Box 250, SE-101 24 Stockholm
Phone +46 8 459 84 00

ISSN 1651-4416
SKB P-09-75

Hydrological and meteorological monitoring at Oskarshamn, October 2008 to September 2009

Jonas Sjögren, Buban Sehalic,
Cari Andersson, Jörgen Jones
SMHI

Alf Engdahl, Medins Biologi AB

December 2009

Keywords: Hydrological and meteorological stations, Discharge, Sea level, Conductivity, Water temperature, Air temperature, Precipitation, Barometric pressure, Global radiation, Wind speed, Wind direction, Snow depth, Ground frost, Accumulation and melting of ice, Calculated potential evapotranspiration, Evaporation.

Abstract

In the Simpevarp area nearby Oskarshamn meteorological monitoring has been going on since 2003 and hydrological monitoring since the beginning of 2004. Meteorological measurements are performed at two places, Äspö and Plittorp. Measured and calculated parameters at these stations are temperature, wind speed and direction, air humidity, precipitation, air pressure, global radiation and potential evapotranspiration. The Swedish Meteorological and Hydrological Institute, SMHI, has been responsible for planning and designing of the two stations used for meteorological monitoring. Furthermore, SMHI has been responsible for planning and constructing fifteen hydrological measuring stations. At these hydrological stations, water levels in lakes and in the sea are measured. Additional water temperature and electrical conductivity are measured and discharges in watercourses decided. Hydrological measurements are performed at fifteen different places.

This report also includes the registration and measurements of certain weather parameters that have been done within the area during the measurement period. Snow depth, depth of frost and ice cover break up was registered during wintertime.

The quality of meteorological and hydrological measurements during the period concerned, 2008-10-01 to 2009-09-30, has showed to be rather good. There have been interruptions in precipitations measurements according to malfunctioning equipment.

At the hydrological stations intended for discharge measurements in watercourses, the discharge has been calculated through determined rating curves. However, an important remark regarding data quality has to be announced. Most rating curves still have too few control measurements of discharge to be regarded as reliable, especially at higher water levels. Further measurements are therefore strongly recommended to make the rating curves reach an approved level of quality. Hydrological monitoring is made according to plane system RT90 and elevation system RHB70.

Sammanfattning

I Simpevarpsområdet utanför Oskarshamn har meteorologiska mätningar pågått sedan år 2003 och hydrologiska mätningar sedan början av år 2004. De meteorologiska mätningarna sker på två platser, på Äspö och i Plittorp. Här har master med registrerande instrument monterats. De meteorologiska parametrar som mäts och bestäms är temperatur, vindhastighet och riktning, luftfuktighet, nederbörd, lufttryck, globalstrålning och potentiell evapotranspiration. Sveriges Meteorologiska och Hydrologiska Institut, SMHI, har varit ansvariga för utformandet av de två meteorologiska mätstationerna. SMHI har också konstruerat och byggt 15 hydrologiska mätstationer. Vid dessa mäts vattennivåer i sjöar och i havet. Ytterligare parametrar som mäts är vattentemperatur och elektrisk konduktivitet samt bestämning av vattenföringar i vattendragen.

Under perioden har det även skett en registrering av vissa väderrelaterade parametrar. Snödjup, frostdjup, tidpunkt för isläggning samt islossning har registrerats och finns inkluderade i denna rapport.

Kvaliteten hos de meteorologiska och hydrologiska mätningarna utförda under perioden 2008-10-01 to 2009-09-30 har varit relativt god. Det har endast förekommit några avbrott i nederbördsmätningarna orsakade av fel på mätutrustningen.

Vid de hydrologiska mätstationer där vattenföringen skall bestämmas, har vattenföringen beräknats med hjälp av fastställda avbördningskurvor.

En viktig kommentar måste dock framhållas. Flera avbördningskurvor innehåller fortfarande för få uppmätta samband för att kunna anses som tillförlitliga, speciellt vid högre vattenstånd. Ytterligare mätningar rekommenderas därför starkt så att avbördningskurvorna kan uppnå en godtagbar kvalitetsnivå. Alla hydrologiska mätningar görs i plansystemet RT90 och höjdsystemet RHB70.

Contents

1	**Introduction**	**7**
2	**Objective and scope**	**9**
3	**Equipment**	**11**
3.1	Hydrological measuring stations	11
	3.1.1 Runoff stations	11
	3.1.2 Water level stations	11
	3.1.3 Calibration of equipment used at hydrological measuring stations	12
3.2	Meteorological measuring stations	12
	3.2.1 Calibration of equipment used at meteorological measuring stations	12
3.3	Winter parameters	12
	3.3.1 Depth of snow	12
	3.3.2 Depth of frost in ground	12
	3.3.3 Ice cover	13
4	**Execution**	**15**
4.1	General	15
4.2	Hydrological measurements	17
	4.2.1 Discharge in water courses	17
	4.2.2 Water temperature and electrical conductivity (EC)	18
	4.2.3 Water level	19
	4.2.4 Quality check of hydrological data	19
4.3	Meteorological measurements	20
	4.3.1 Quality check of meteorological data	20
	4.3.2 Data handling/post processing	20
4.4	Winter parameters	20
	4.4.1 Measurement of co-ordinates	20
	4.4.2 Snow depth	21
	4.4.3 Frost in ground	22
	4.4.4 Ice cover	22
	4.4.5 Data handling and documentation	22
4.5	Analyses and interpretations	22
	4.5.1 Hydrological measurements	22
	4.5.2 Meteorological measurements	22
4.6	Nonconformities	23
	4.6.1 Hydrological measurements	23
	4.6.2 Meteorological measurements	24
4.7	Missing data and system malfunctions	24
	4.7.1 Hydrological measurements	24
	4.7.2 Meteorological measurements	24
	4.7.3 Winter parameters	24
5	**Results**	**25**
5.1	Hydrological monitoring	25
	5.1.1 Discharge	25
	5.1.2 Water level	28
	5.1.3 Water temperature and electrical conductivity (EC)	28
5.2	Meteorological monitoring	34
	5.2.1 Precipitation	34
	5.2.2 Barometric pressure	37
	5.2.3 Air temperature	37
	5.2.4 Relative humidity	37
	5.2.5 Wind speed	37
	5.2.6 Wind direction	37
	5.2.7 Global radiation	37
	5.2.8 Calculated evapotranspiration	38

5.3 Winter parameters 38
5.3.1 Snow depth 38
5.3.2 Frost in ground 38
5.3.3 Ice cover 39
References 41
Appendix 1 Hydrological monitoring stations 43
Appendix 2 Rating curves for hydrological stations 45
Appendix 3 Measurements of snow cover 51
Appendix 4 Measurements of ground frost 53
Appendix 5 Meteorological monitoring 55
Appendix 6 Water level fluctuations 65

1 Introduction

This document reports the results of hydrological and meteorological measurements made in the area of Oskarshamn. The activities are performed within the site investigation at Oskarshamn and carried out in accordance to activity plan SKB AP PS 400-08-022 and SKB AP PS 400-08-023, (SKB internal controlling documents). This document also reports the data gained in “Registration of snow depth, depth of frost in the ground and time for ice cover/ice break up” which was also one of the activities performed within the site investigation at Oskarshamn. The work was carried out according to activity plan SKB AP PS 400-08-024 (SKB internal controlling document).

Hydrological measurements started in January 2004. Measured parameters are sea water level, water level in lakes and discharge in small creeks. Water temperature and conductivity are also measured at the runoff stations. At the moment hydrological measurements are made at fifteen different stations. Data presented in this document are quality checked and approved.

To characterise the investigation area regarding meteorological conditions SMHI has placed two stations with meteorological measuring equipment on the site. The results will be used for calculations of hydrological parameters.

The geographical locations of the meteorological and hydrological measuring stations can be seen on the map in Chapter 4.

This report presents the hydrological and meteorological monitoring and measurements of winter parameters during period 2008-10-01 to 2009-09-30.

Previous available monitoring reports and controlling documents used in the activity are presented in Table 1-1.

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

Activity plan	**Number**	**Version**
Ythydrologiskt moniteringsprogram	SKB AP PS 400-08-023	1.0
Meteorologiskt moniteringsprogram	SKB AP PS 400-08-022	1.0
Registrering av snödjup, tjäldjup och tider för isläggning/islossning vintern 2008/2009	SKB AP PS 400-08-024	1.0
Installation av tjäldjupsmätare	Tillägg till SKB AP PS 400-02-023	
Method descriptions and instructions	**Number**	**Version**
Meteorologiska mätningar	SKB MD 364.007	1.0
Ythydrologiska mätningar	SKB MD 364.008	1.0
Inmätning och avvägning av objekt	SKB MD 110.001	1.0
P-reports	**Number**	
Hydrological and meteorological monitoring at Oskarshamn during 2003–2004	P-05-227	
Hydrological and meteorological monitoring at Oskarshamn, November 2004–June 2005	P-06-19	
Hydrological and meteorological monitoring at Oskarshamn, July 2005–December 2006	P-07-38	
Hydrological and meteorological monitoring at Oskarshamn, January–August 2007	P-07-172	
Hydrological and meteorological monitoring at Oskarshamn, September 2007–September 2008	P-08-86	

2 Objective and scope

SKB conducts site investigations for a future deep repository for spent nuclear fuel in the Laxemar area close to Oskarshamn. To characterise the investigation area regarding the meteorological conditions SMHI has installed two stations with meteorological measuring equipment at the site. The results will be used for calculations of hydrological parameters.

Hydrological measurements are performed at fifteen stations located at different sites. Since the stations were built in a period of one year, their measurements do not all start at the same time. The first station was built in January 2004 and the last in the end of January 2005. Information about the hydrological stations and periods of measurements are given in the table in Appendix 1.

This report also comprises measurements and registrations of certain weather parameters within the Oskarshamn area, during wintertime.

The objective with this report is to present quality checked results from hydrological and meteorological monitoring made during the period 2008-10-01 to 2009-09-30.

3 Equipment

3.1 Hydrological measuring stations

Common for all stations is that the battery capacity is always measured and logged. This value is however only stored in the database at SMHI.

3.1.1 Runoff stations

The runoff stations PSM000341, PSM000343, PSM000345, PSM000347 and PSM000365 are constructed in concrete as V-notch weirs (triangular shaped outlet of water). At these stations, measurements are made with a Campbell CR10X data logger. A cellular phone and a GSM modem Siemens TC35, 9600 baud, establish communication. A dry cellular battery, CellTech (15V, 90 Ah) sustains power supply. Sensors and measured parameters are presented in Table 3-1.

At the runoff stations PSM000348, PSM000353, PSM000364 and PSM000368 discharge is measured according to a natural cross section in the watercourse. Equipment, sensors and measured parameters are the same as for the stations with constructed concrete dams. Water level is measured in meter above sea level, m.a.s.l. Sensors and measured parameters are presented in Table 3-2.

3.1.2 Water level stations

At the water level stations PSM000359 and PSM000371 measurements are carried out with a Campbell CR510 data logger. A cellular phone and a GSM modem Siemens TC35, 9600 baud, establish communication. Power supply is sustained by a charger 1.5 A, 14 VDC connected to 230 VAC. The stations are connected to ground and equipped with a lightning conductor. Sensors and measured parameters are presented in Table 3-3.

At the water level stations PSM000342, PSM000344, PSM000369 and PSM000370 the equipment is almost the same as for PSM000359 and PSM000371 but a dry cellular battery, Celltech 14V, 90 Ah sustains power supply. Sensors and measured parameters are presented in Table 3-4.

Table 3-1. Sensors and measured parameters at stations PSM000341, PSM000343, PSM000345, PSM000347 and PSM000365.

Parameters	Sensors
Water level above V-notch. (cm)	DRUCK PDCR1830, mV, range 1.5 m, vented.
Conductivity and water temperature (mS/m and °C)	Campbell CS547, range 0.5–100 mS/m with interface CampbellA547.

Table 3-2. Sensors and measured parameters at stations PSM000348, PSM000353, PSM000364 and PSM000368.

Parameters	Sensors
Water level (m.a.s.l.)	DRUCK PDCR1830, mV, range 1.5 m, vented.
Conductivity and water temperature (mS/m and °C)	Campbell CS547, range 0.5–100 mS/m with interface CampbellA547.

Table 3-3. Sensors and measured parameters at stations PSM000359 and PSM000371.

Parameters	Sensors
Water level (m.a.s.l.)	DRUCK PDCR1830, mV, range 1.5 m, vented.

Table 3-4. Sensors and measured parameters at stations PSM000369 and PSM000370.

Parameters	Sensors
Water level (m.a.s.l.)	DRUCK PDCR1830, mV, range 1.5 m, vented.

3.1.3 Calibration of equipment used at hydrological measuring stations

The manufacturers calibrate the measuring equipment. DRUCK calibrates the level pressure probes and Campbell Scientific, Inc. calibrates the conductivity and temperature probe. The function of every probe was thoroughly tested before deployment. These tests were performed by FDS mätteknik AB a sub-contractor to SMHI. Protocols from calibration have been delivered to SKB.

3.2 Meteorological measuring stations

Table 3-5 below gives technical information about the equipment. Polycarbonate cupboards house data loggers (type Campbell CR10X), modem (Siemens TC35 and COM200E) and are earthed for lightening protection.

The wind is measured at 10 meter above ground level, the other parameters at 2 meter.

3.2.1 Calibration of equipment used at meteorological measuring stations

Calibration of the instruments using data submitted by the manufactures was done by FDS along with the installation of the instruments. At 2009-05-07 the instruments at both stations, Äspö and Plitorp, were checked and calibrated by FDS.

3.3 Winter parameters

3.3.1 Depth of snow

The snow depth has been measured according to SMHI's Handbook for observers (In Swedish: SMHI:s handbok för observatörer) /2/. The measuring device has been a measuring stick graded in centimetres.

3.3.2 Depth of frost in ground

The depth of frost in the ground has been measured according to SMHI's Handbook for observers /2/. The measurements are performed with a specific measuring device. The device consists of a protective tube with a disc and a protective hood, including a measurement tube with solution. The solution consists of methylene blue and distilled water. When the water freezes the blue colour disappears and this is utilized when observing the position of frost in the ground. The measurement tube is graded in centimetres.

Table 3-5. Measuring equipment for collecting of meteorological data at the stations.

Parameters	Equipment
Wind speed and direction	RM Young Wind monitor
Air temperature	Pt100 sensor with radiation shield and ventilated Young 41004
Humidity	Rotronic HygroClip MP 100H
Precipitation	Geonor T200 complete with pedestal and wind shield
Pressure	PTB200
Global radiation at Äspö	Kipp & Zonen CM21 with warming and fan

The ground level is marked and this together with the protective hood is what is usually seen above ground. When installing the device at Oskarshamn there were some difficulties because of the large numbers of boulders in the ground. Because of this a small part of the measuring tube is also present above ground, see Figure 3-1. This has no impact on the measurements, however.

3.3.3 Ice cover

The observation of ice freeze and break up was performed by visual inspection.

Figure 3-1. *Measuring device for registration of depth of frost in the ground.*

4 Execution

4.1 General

This execution chapter is intended to describe the complete course of events, from measuring, via quality check, data handling to the storage in Sicada. On the map in Figure 4-2 it is pointed out where all monitoring stations are geographically located.

Two terms that are frequently used in this context is HMS and Sicada, SKB's data system, could therefore require a definition. HMS (Hydro Monitoring System) is SKB's network for the monitoring of hydrological, hydrogeological and meteorological parameters. This is a system for collection, calculation, and data check up and presentation. Sicada is the database that contains all of SKB's quality assured data. It is from these data the modelling and analyses are done, see Figure 4-1.

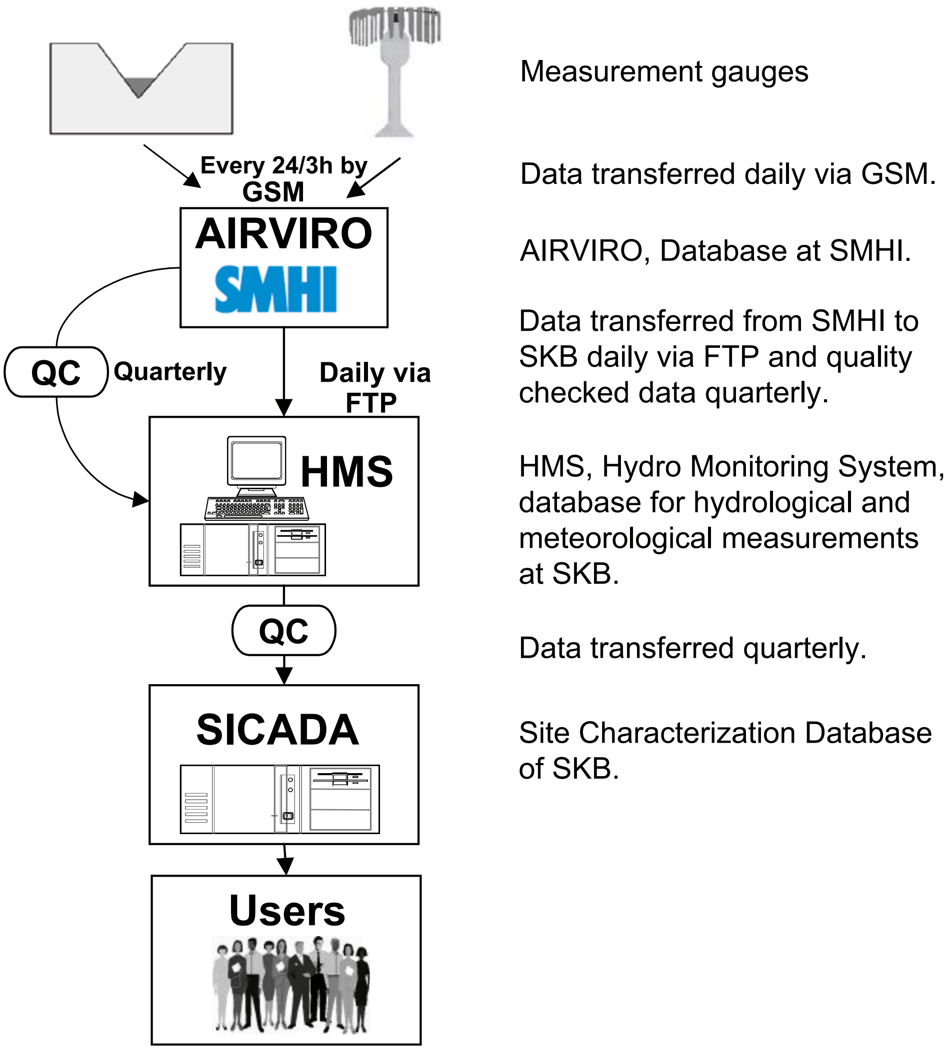


***Figure 4-1.** Flowchart – meteorological and hydrological data.*

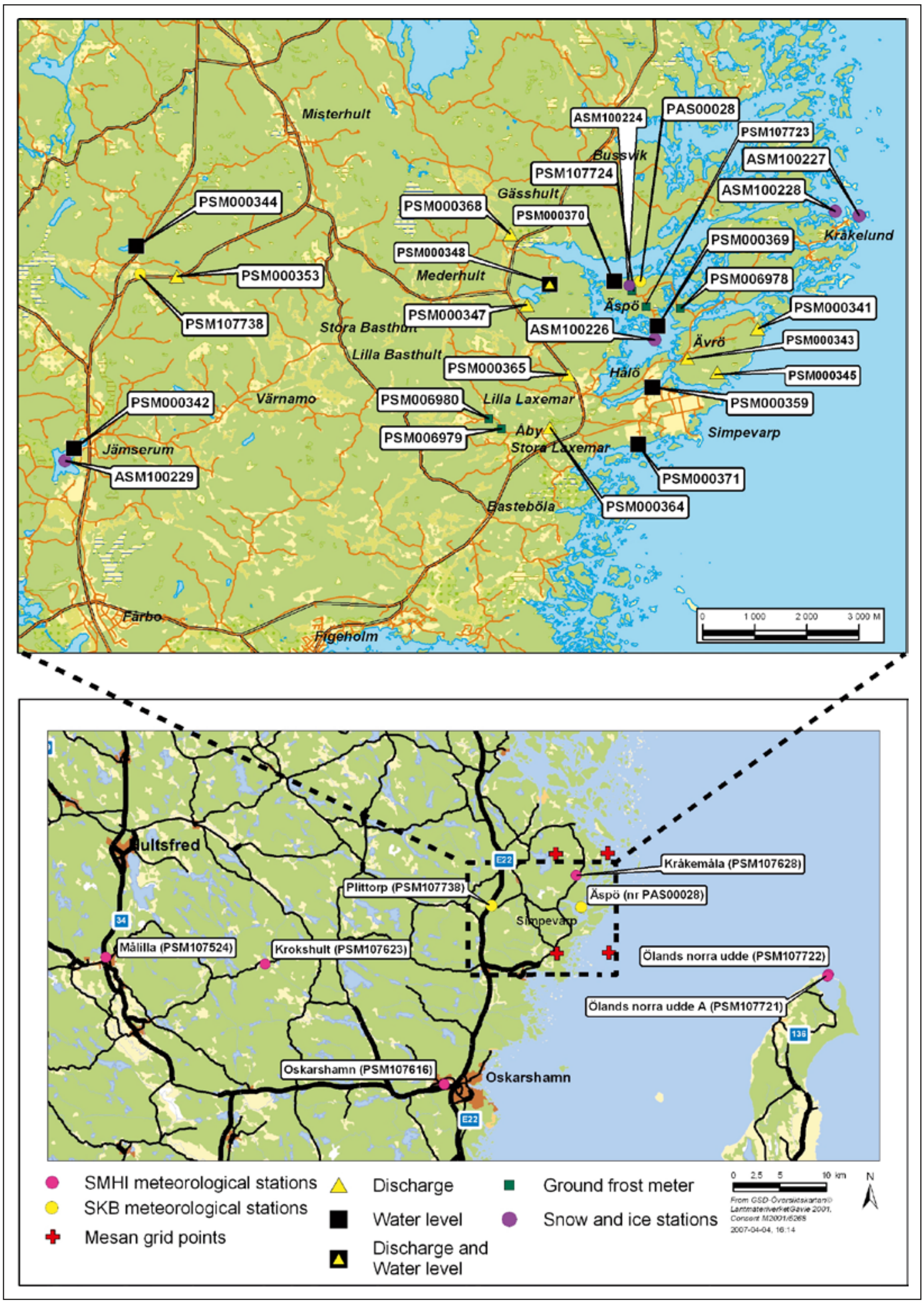


Figure 4-2. *Map showing objects of all monitoring stations except station Gladhammar (PSM107642) which is located 45 km north of Oskarshamn.*

4.2 Hydrological measurements

All sensors, probes and other equipment shall be checked and serviced once a year or if needed as soon as possible. SMHI's sub contractor, FDS Mätteknik AB will handle malfunction of equipment. During 2009-05-06 to 2009-05-08 SMHI inspected all hydrological stations in the Simpevarp area. At each station the water level sensor was checked to log correct values and the concrete dams were levelled to check that they had not moved since they were built. At all stations the sensors for temperature and conductivity were cleansed. The water temperature was checked with a reference thermometer and water specimens were sent to the SKB laboratory for conductivity analysis.

The level pressure sensors are tested by measuring the present water level. The water level is then compared to the value in the data logger. If any discrepancy is detected the logger is adjusted.

At the runoff stations, the water head above the V-notch should be set in the data logger.

The probe used for measuring conductivity and water temperature should be tested in water with known conductivity. During the inspection a simultaneous water sample was analysed at the Äspö laboratory for comparision. The water temperature should be measured with a reference thermometer. The measured value in the data logger of conductivity and temperature is then compared with the reference value.

The runoff stations need some extra care because it is very important that the flow trough the V-notch is not blocked or influenced by ice, leaves or debris. For this reason SKB have established a scheduled standard procedure for regular inspection of the stations. The inspection and cleaning records are stored in the Sicada database.

4.2.1 Discharge in water courses

Hourly measurements of discharge have been made at nine stations. Four of these stations – PSM000348, PSM000353, PSM000364 and PSM000368 – are situated at sites where a natural cross section has been used to establish the rating curves.

The other five stations – PSM000341, PSM000343, PSM000345, PSM000347 and PSM000365 – are situated at sites where concrete dams are built and where the discharge is measured with a V-notch weir. The V-notch weir is a concrete dam with a triangular, V-notch shaped, outlet. The opening angle in the V-notch varies between these stations from 45°, 60° and 120° and theoretically, the discharge (Q), could be derived from a discharge formula. The upstream level is uniquely related to the discharge over the crest where the flow passes through critical conditions. For a V-notch weir, the discharge formula becomes /1/:

$Q = 8/15 \cdot \mu \cdot (2g)1/2 \cdot h5/2 \cdot \tan\alpha/2$

Q = Discharge (m^3/s)

μ = Coefficient approximately constant, a value between 0.60 and 0.65

g = Gravity constant (9.81 m/s^2)

h = Head above the V-notch (m)

α = Angle in V-notch

The water level (head) above the V-notch point is measured. When the water stage is at the same level as the V-notch, discharge from the weir also equals zero; i.e. the level of the V-notch point is set to zero. It should be pointed out that it is the water level that is measured at the discharge stations and not directly the discharge. The discharge has to be calculated from the discharge formula. Calculations with this equation are only reliable when the weirs are built with ideal proportions. Due to conditions of local ground structure at the building site, ideal dam proportions are sometimes hard to achieve. Therefore, in most cases a rating curve has to be established before any reliable calculations of discharge can be made. Until then calculation of discharge has to be made with assumed values of parameters in the discharge formula and will be delivered as such.

At the moment discharges at station PSM000341, PSM000343 and PSM000345 are calculated from rating curves established from control measurements made by SKB and SMHI. At station PSM000347 and PSM000365 discharge is calculated with the discharge formula. In calculations at these stations the value of the coefficient μ has been set to a reasonable level of 0.60. Presently we do not know if this is a proper value of the coefficient μ for both these stations. The discharge values presented in this report are for that reason affected with a degree of uncertainty and later on adjustments in accordance to rating curves will be made.

The drainage areas where dams are built are very small. Therefore, the creeks or ditches will be dried up during main part of the year. The drainage area estimated by SKB and the opening angle in V-notch for each dam are presented in Table 4-1.

At the stations PSM000348, PSM000353, PSM000364 and PSM000368 discharge should be measured according to a natural cross-section in the watercourse, i.e. no dams are constructed. All water levels are measured in meter above sea level (m.a.s.l.) in elevation system RT90-RHB70. The drainage area estimated by SKB for each station is presented in Table 4-2.

At 2006-10-01 the rating curves for all discharge stations were determined, and discharge recalculated from station start through quality checked water level data. See the rating curves in Appendix 2. All discharge data was sent to SKB 2006-10-05. A rating curve describes the relationship between the measured water stage and the corresponding discharge. It usually takes some time to gain a reliable rating curve and until then measurements of water level are stored at these four stations. However, an important remark regarding data quality has to be made. Most rating curves still have too few control measurements of discharge to be regarded as reliable, especially at high water levels. Further measurements are therefore strongly recommended to make the rating curves reach an approved level of quality.

4.2.2 Water temperature and electrical conductivity (EC)

At all stations monitoring discharge and also the water temperature and electrical conductivity, EC, are measured. At stations where dams are constructed, temperature and EC are measured in the small basin upstream the concrete dam. At stations where natural cross sections are used the sensor is placed as deep as possible in the creek or the lake.

Table 4-1. Drainage area and V-notch angle for the dams.

Station Id	Object	Measuring place	V-notch opening angle	Drainage area (km²)
PSM000341	Ävrö NE	Dam	45°	0.29
PSM000343	Ävrö SW	Dam	45°	0.11
PSM000345	Ävrö SE	Dam	45°	0.16
PSM000347	Frisksjön (in)	Dam	60°	0.91
PSM000365	Ekerumsån	Dam	120°	2.38

Table 4-2. Drainage area for PSM000348, PSM000353, PSM000364 and PSM000368.

Station Id	Object	Measuring place	Drainage area (km²)
PSM000348	Frisksjön (out)	Lake and natural cross-section	1.88
PSM000353	Laxemarån (upper)	Natural cross-section	14
PSM000364	Laxemarån (lower)	Natural cross-section	40
PSM000368	Kärrviksån	Natural cross-section	27

4.2.3 Water level

The logged water level is an arithmetic mean value calculated from measurements made every fifth second during one hour. Hourly mean values are stored.

Sea water level

Sea water level is measured at three places in the surroundings of Äspö. The stations are PSM000369, PSM000370 and PSM000371. At these stations, measurements have been performed since January 2004. Measurements are taken in plane system RT90 and elevation system RHB70 and are expressed as meter above sea level (m.a.s.l.).

Water level measured in lakes and reservoirs

Water level is also measured at station PSM000342 and PSM000344. At PSM000342 water level is measured in lake Jämsen and at station PSM000344 in lake Plittorpsgöl. All measurements are in elevation system RT90-RHB70. At one station, PSM000359, the water level in the reservoir at Sörå is measured. This is an artificial reservoir created as a backup for the freshwater supply to the nuclear power station. Measurements are in meter above sea level, (m.a.s.l.), in plane system RT90 and elevation system RHB70.

4.2.4 Quality check of hydrological data

Before any data are finally stored in SKBs database Sicada they have to be approved. Each week SMHI performs a primary check for deviating values and every fourth month a senior hydrologist will check and approve data before the delivery for final storage in SKBs database, Sicada. Delivery of checked and approved data to SKB is carried out tertial.

Quality check of discharge stations

Weekly data is checked to limit possible disturbances and interruptions. Measurements of runoff are compared between neighbouring stations. Runoff from stations in nearby areas should mostly show the same pattern. Corrections of data are made if any disturbances or irregularities appear.

Water temperature and conductivity measurements are also compared between nearby stations. Even here, the same pattern is mostly expected. Disturbances or irregularities are corrected. Measurements of conductivity and water temperature are not approved when the water level is equal to or below the V-notch point in the dams. No water is then running in the creek and temperature and conductivity values are therefore not representative.

Quality check of water level stations

Data checks are made weekly to limit possible disturbances and interruptions.

Measurements from seawater level stations compare to each other because the same pattern is mostly expected. Corrections and adjustments of any disturbances or irregularities are made.

Water level at PSM000359, being a reservoir, does not follow the same pattern as the sea level stations. For this reason, measurements of water level at this station are judged separately. Disturbances or irregularities are corrected.

Water levels taken in lakes are compared to each other because the same behaviour is expected.

4.3 Meteorological measurements

Data are collected every half-hour. The different parameters are valid for the following time period:

- Precipitation: Accumulated sum of precipitation every 30 min. Previously the 30-min precipitation value is the difference between two adjacent accumulated precipitation sums, but FDS has inserted a filter similar to SMHI's.
- Temperature: Arithmetic mean of 1-second values for 30 minutes.
- Air pressure: Arithmetic mean of 1-second values for 30 minutes.
- Relative humidity: Arithmetic mean of 1-second values for 30 minutes.
- Wind speed and wind direction: The latest 10-minutes mean value for the actual half-hour, hence for the 10.00 data the measurement is from 09.51 to 10.00.
- Global radiation: Arithmetic mean of 1-second values for 30 minutes.

4.3.1 Quality check of meteorological data

Before any data finally will be stored in SKB's database Sicada they have to be controlled and approved by SMHI. Every week a primary check for missing and incorrect values will be performed by SMHI and every fourth month the check will be performed by a meteorologist at SMHI that will approve data, calculate potential evapotranspiration and estimate the true precipitation before delivery for final storage in SKB's database, Sicada.

4.3.2 Data handling/post processing

The data logger at the station has an internal memory to secure the data in case of communication disturbances. The system is called through SMHI's air quality system AIRVIRO, where the data is stored and the quality assurance and check is done. After this check has been performed, data is delivered to the HMS database.

SMHI has constructed a homepage according to SKB's wishes, where the results of the measurements can be shown as graphs and from which data can be extracted. The address is: http://www.airviro.smhi.se/oskarshamn/

4.4 Winter parameters

4.4.1 Measurement of co-ordinates

Coordinates for each station, Figure 4-2, were measured according to SKB's instruction SKB MD 110.001 (SKB internal controlling document). The co-ordinates were then noted in a specific protocol. Each object received a specific ID-code, see Table 4-4. For measurement of snow depth and observations of ice conditions, the objects were registered as surfaces, while the objects for frost in the ground and ice conditions were registered as points.

Table 4-4. Id-code numbers for the objects in this activity.

Measurement/observation	Id-code	Name
Snow depth	ASM100224	Grillplatsen
Frost in ground	PSM006978	Löv1
	PSM006979	Grindstugan
Ice cover	ASM100226	Äspö brygga
	ASM100227	Kråkelund yttre
	ASM100228	Kråkelund inre
	ASM100229	Jämsen

4.4.2 Snow depth

Snow depth is in this case defined as the depth of snow from snow surface to ground. The characteristics of the site for execution of the measurement are of vital importance. The site should have a fairly smooth ground surface and the snow should not fall in drifts or be blown away. The sampling station has been a forest glade (see map in Figure 4-2). The chosen areas were marked with poles of such a length that they would be seen even at maximum snow depth, Figure 4-3.

The measurement was executed once a week starting from the autumn's first snowfall until the snow surface was completely gone during springtime. The measurement was performed once a week, even if no snow had been falling, since packing, melting or evaporation should be considered as well.

The measurement was performed with a graded measuring stick, which was vertically squeezed through the snow layer until the ground was hit. The snow depth was read in centimetres. The measurement was performed at six places in the measuring area, Figure 4-4. The average snow depth was then calculated.

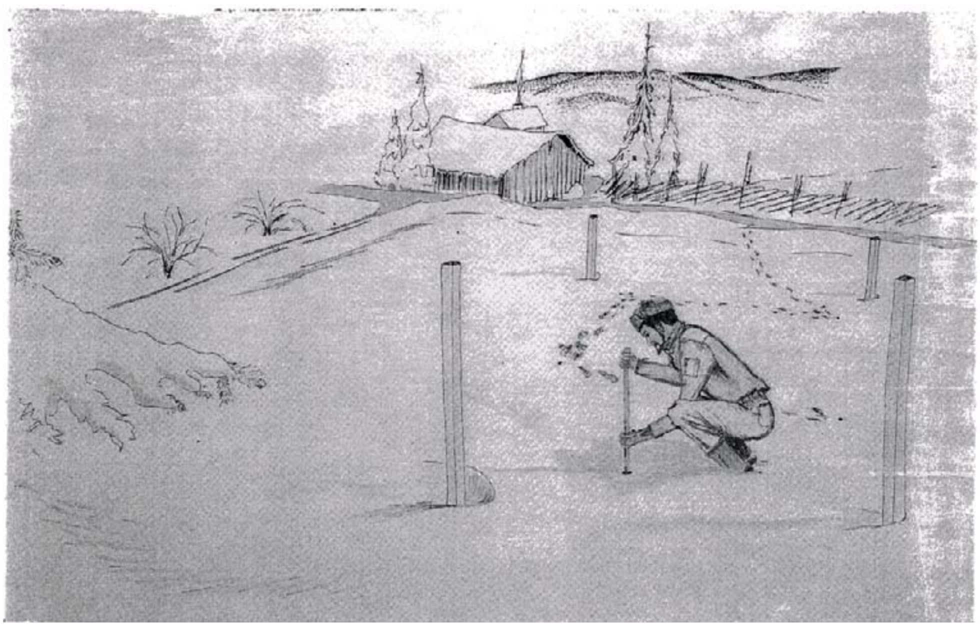


__Figure 4-3.__ Measurement of snow depth, from SMHI's Handbook for observers /2/.

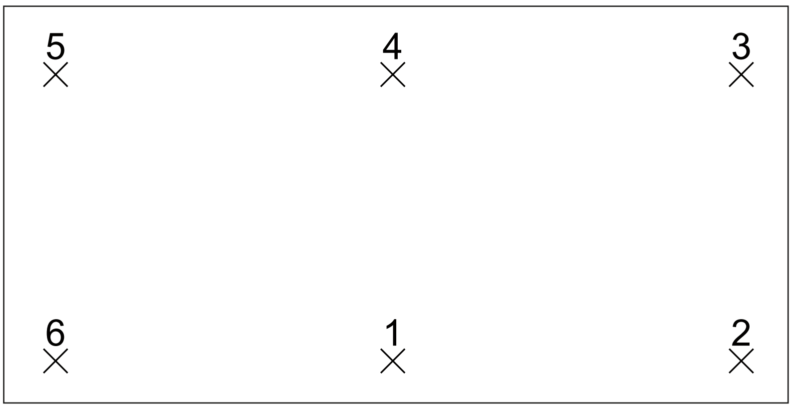


__Figure 4-4.__ Placement of the graded measuring stick in the area for measuring of snow depth. The distance between the measuring points is 1.5–2 m.

4.4.3 Frost in ground

For measurement of frost in the ground, equipment according to Section 3.3.2 was used. The measurements were carried out at two places representative for the local conditions, taking in consideration soil characteristics and topography, see Figure 4-2.

The measuring device is read by observing the uncoloured part of the tube solution, i.e. the frozen part, which shows the border between ice and water. The distance from ground surface to the frost in the ground, was received by reducing the read values with the distance from the scale zero to the ground surface. The measurements were performed once a week in connection to registration of snow depth.

4.4.4 Ice cover

The time for ice freeze up/ice break was noted for sea bays (ASM100226-ASM100228) and for lakes in the area (ASM100229), see Figure 4-2.

For the sea, ice conditions were registered every morning during working week and for the lake once a week. While ice freeze up was observed on the lake, the other lakes in the area were also observed, to check the representatively of Lake Jämsen (ASM100229).

The time for the first ice freeze up, which is important to register in the observations, is defined as the first time of the season when a lasting ice cover occurs. The time for the last ice break up is defined as the time when the ice cover from the winter season finally breaks up. Short periods in early autumn, with thin ice covers were ignored, as well as partial ice during springtime.

4.4.5 Data handling and documentation

Field personnel from the SKB executed all measurements and observations of snow depth, frost in ground and ice cover in the activity. The primary data was registered in Sicada.

4.5 Analyses and interpretations

4.5.1 Hydrological measurements

Runoff per area unit has been calculated for all discharge stations during the period 2008-10-01 to 2009-09-30, see Figure 4-5. In Figure 4-6, runoff per unit area is shown for the period 2005-02-01 to 2009-09-30. Due to data fluctuations at station PSM000341, PSM000343, PSM000345, PSM000347 and PSM000353, used data is not corrected, only pre-checked. Runoff in this part of Sweden based on measurements during the years 1961–1990 is about 5 l/(s·km^2). However, this long-term mean value is not comparable to the above period since the station period is too short.

4.5.2 Meteorological measurements

SMHI has continuously checked the collected data, i.e. checked that the data is within the limits of reason for each parameter. The data have also been compared with data from SMHI's analysing system Mesan. Mesan is an automatic system for mesoscale analysis of meteorological parameters, built on manual as well as automatic observations and including satellite- and radar information.

The values are interpolated from the nearest grid points in Mesan. The resolution of Mesan is 11×11 km and an analysis is made every hour. Corrected data has been stored in a special database. In Table 4-5 you can see the coordinates of the nearest grid points.

Table 4-5. Mesan grid points.

Latitude	Longitude
57.356	16.647
57.448	16.719
57.579	16.620
57.487	16.548

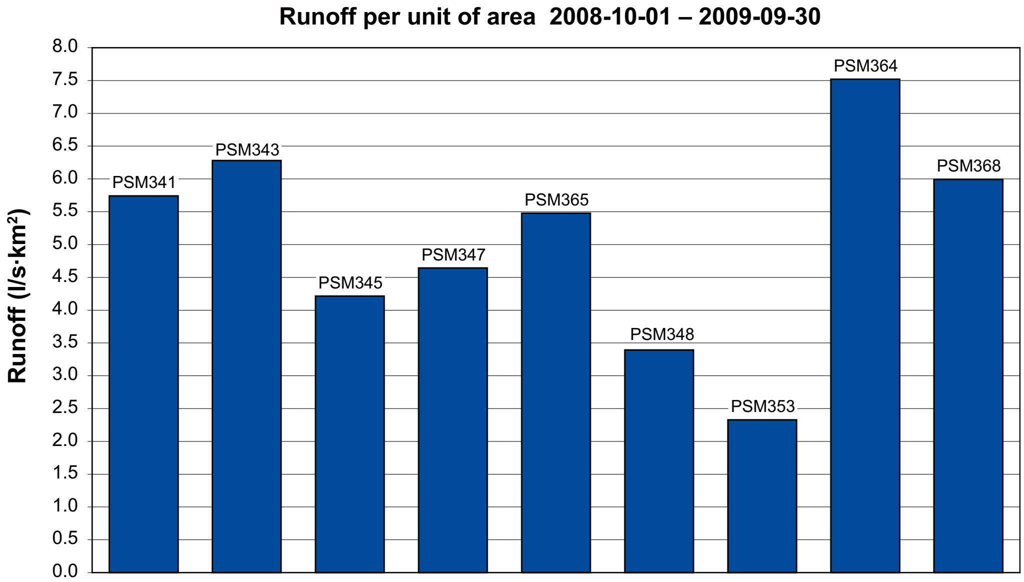


Figure 4-5. *Runoff expressed as l/s·km² during the period 2008-10-01 to 2009-09-30.*

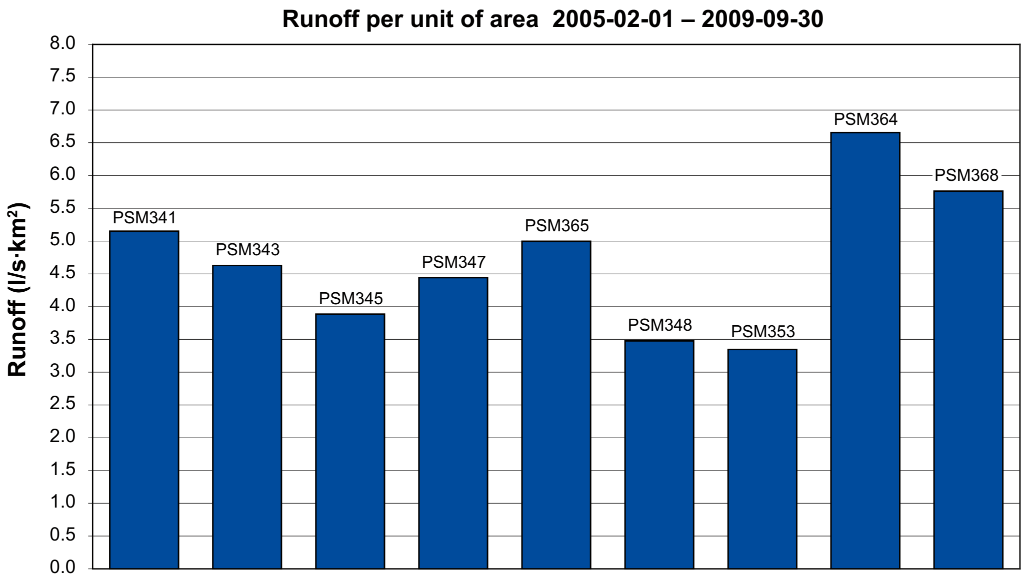


Figure 4-6. *Runoff expressed as l/s·km² during the period 2005-02-01 to 2009-09-30.*

4.6 Nonconformities

4.6.1 Hydrological measurements

At station PSM341, PSM343, PSM345, PSM347 and PSM353 daily fluctuations in water level have been recognized, some of these from station start. Investigations have been made to minimize the fluctuations which have an amplitude of at most 2 centimeters, appearing during the warm period of the year. They mainly occur during the summer season and are directly related to the daily fluctuations in temperature. There are several possible reasons to the fluctuations:

- The inflow to the station varies due to variations in evaporation in the discharge area.
- The water level in the dam varies due to higher evaporation during the warm part of the day.
- The water level in the dam varies due to varying water density related to temperature.
- The sensor is affected by temperature.

To find out if the fluctuations are related to temperature or evaporation, a study was made when the water level was low and the sensor above water level. A strong inverse correlation was then found, by SKB, between sensor value and temperature. This indicates that the fluctuations are caused by an instrument error, not by evaporation or density effects. The conclusion of the study is that the fluctuations are caused by insufficient temperature compensation in the sensor. However, at all stations except for PSM341 the fluctuations have an amplitude of 0.5 cm at most, which is negligible in relation to other fluctuations throughout the year. The error in calculated discharge on a yearly basis will therefore not be significant. At PSM341 the fluctuation amplitude of 2 cm at most was radically reduced when an extra water level sensor was installed 2009-06-23. As further investigations on data from these five stations need to be made, quality checked data will be delivered later. In order to secure correct data recording, extra water level sensors will also be added to the stations PSM000343 (Ävrö 2), PSM000345 (Ävrö 3), PSM000347 (Frisksjön in) and PSM000353 (Laxemarån övre).

During SMHI's inspection and levelling of the hydrological stations during 2009-05-06 to 2009-05-08, no significant differences since last inspection were detected.

Minor increase in water level that is hard to detect may have been caused by ice, leaves or debris. However, these nonconformities are of minor importance.

The conductivity sensors may sometimes oxidize which may result in inexplicable data peaks. These peaks may be hard to distinguish from correct data and are therefore not deleted/corrected. In the same way, thermometers may sometimes be situated just below water level which may cause unreasonable temperature levels.

For more information, see Appendix 6.

4.6.2 Meteorological measurements

No deviation reports have been sent.

There has been no major deviation.

4.7 Missing data and system malfunctions

4.7.1 Hydrological measurements

An extra water level sensor was added to station PSM000341 (Ävrö 1) 2009-05-07 since the ordinary one has shown signs to malfunction. The modem was replaced 2008-10-22 due to problem with data transmission. Transfer of data has been limited because of weak radio signal. Periodically the contact has been limited, but no data has been lost.

Two thermometers have been replaced due to malfunction. The thermometer at station PSM000348 (Frisksjön ut) was replaced 2008-10-22. At station PSM000353 (Laxemarån övre) the thermometer was replaced 2009-02-10.

Due to malfunction, the level sensor at station PSM000370 (Äspö norra) was replaced 2009-04-03. By the same reason the data logger at station PSM000371 (Clab) was corrected 2009-05-13.

4.7.2 Meteorological measurements

Due to malfunction, the precipitation measurements interrupted in late December 2008 until February, and a short period in April 2009 at Plittorp, and at Äspö in August but the total amount of precipitation during that period was measured. Otherwise, meteorological measurements have turned out to work well during the period of this report.

4.7.3 Winter parameters

During November 2008, the frost in ground device at PSM006979 was out of order. At PSM006978, the frost in ground device was out of order the first ten days in February 2009.

5 Results

5.1 Hydrological monitoring

Totally fifteen hydrological stations are built. At the discharge stations with constructed dams, quality of measured data almost exclusively depends on the maintenance of the basin upstream the dam. Therefore it is very important that the dams are cleansed from ice, leaves or debris blocking the flow through the V-notches. The water level in such situations have been interpolated between the level before and after the occasion of the peek caused by the jam.

At 2006-10-01 the rating curves for all discharge stations were determined, and discharge recalculated from station start through quality checked water level data. See the rating curves in Appendix 2. However, an important remark regarding data quality has to be made. Most rating curves still have too few control measurements of discharge to be regarded as reliable, especially at higher water levels. Further measurements are therefore strongly recommended to make the rating curves reach an approved level of quality.

During the period 2008-10-01 to 2009-09-30 daily fluctuations at five discharge stations has been observed. At all stations except one, the fluctuations are small in relation to other fluctuations throughout the year. However, to prevent error in recording of data, extra data sensors will be placed at all five stations.

Measurements of water temperature at the discharge stations seem so far to work well. Even here, only a few measured values have been corrected when making quality check of data.

Measurements of electrical conductivity, EC, have also worked well. It is very important that the temperature and conductivity sensors are kept clean. During the vegetation period, the sensors seem to be covered with organic material and for that reason, it is necessary to clean the sensors at some occasions during this period. The smallest watercourses dry up a great part of the season and the sensors must be cleansed during such periods. Otherwise, there is a risk of erroneous values when the water starts to flow again.

5.1.1 Discharge

PSM000341, PSM000343, PSM000345, PSM000347 and PSM000365

The quality checked values of discharge from the five stations with constructed dams are presented in Figure 5-1 and 5-2. Adjustments of measurements have been made to stations PSM000341, PSM000345 and PSM000347, at some occasions because the V-notches have been blocked. Due to fluctuations in recorded water level at station PSM000341, PSM000343, PSM000345 and PSM000347, data after 2009-02-01 will be investigated and delivered later.

PSM000348, PSM000353, PSM000364 and PSM000368

At four stations discharge is measured by using a natural cross-section in the watercourse, i.e. no dams are constructed. At station PSM000348 the discharge represents the outflow of lake Frisksjön. At all other places discharge is measured in the creek. The quality checked discharge from measurements of water level made during the period could be seen in Figures 5-3 to 5-5. Due to fluctuations in recorded water level at station PSM000353, data after 2009-02-01 will be investigated and delivered later.

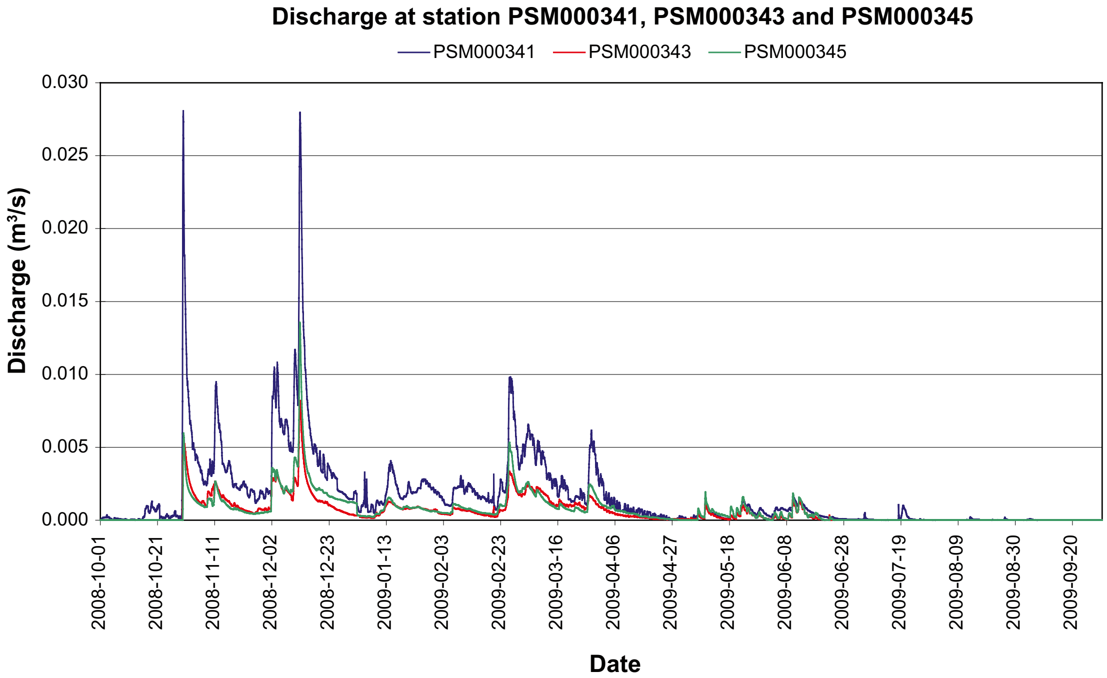


Figure 5-1. *Quality assured discharge, m³/s, at stations PSM000341, PSM000343 and PSM000345.*

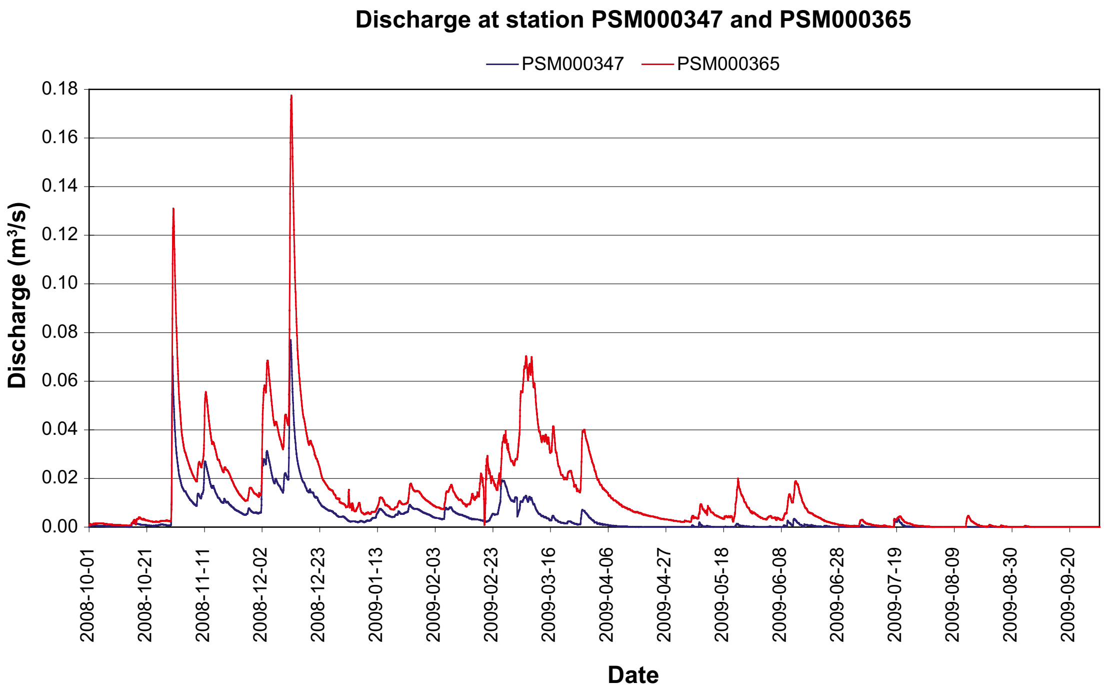


Figure 5-2. *Quality assured discharge, m³/s, for station PSM000347 and PSM000365.*

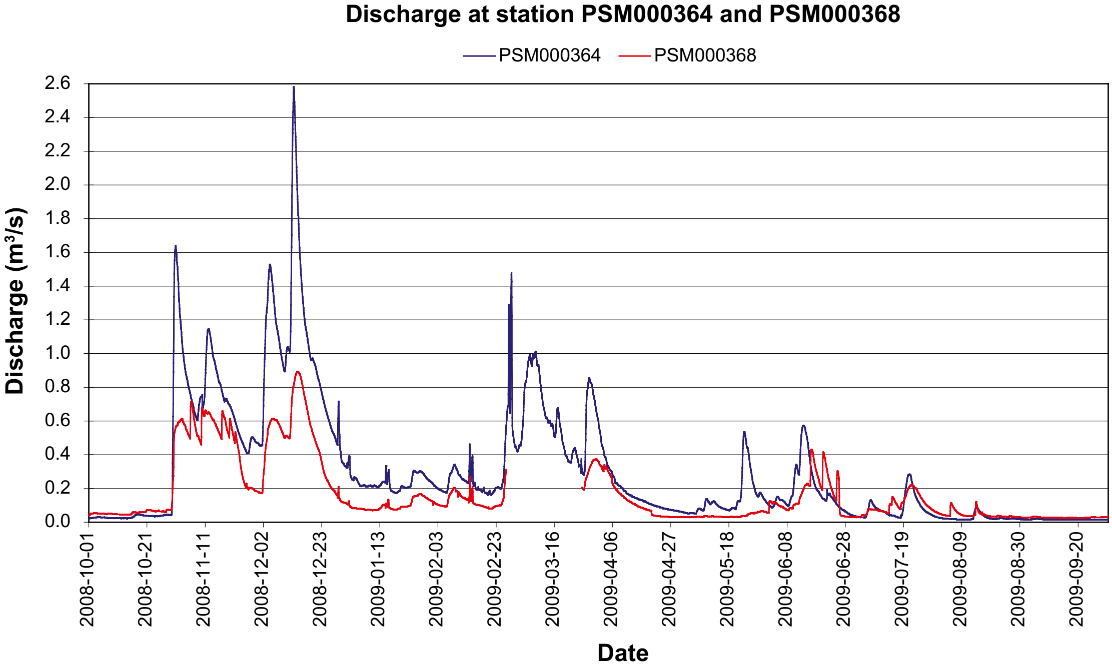


Figure 5-3. *Quality assured discharge, m³/s, for stations PSM000364 and PSM000368.*

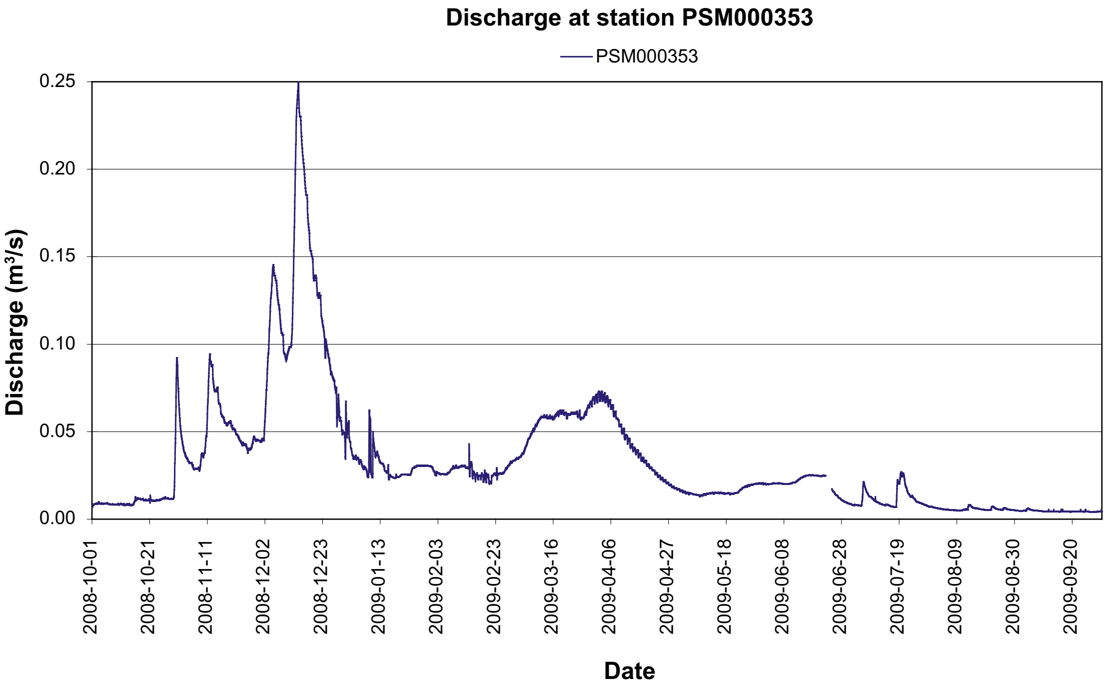


Figure 5-4. *Quality assured discharge, m³/s, for station PSM000353.*

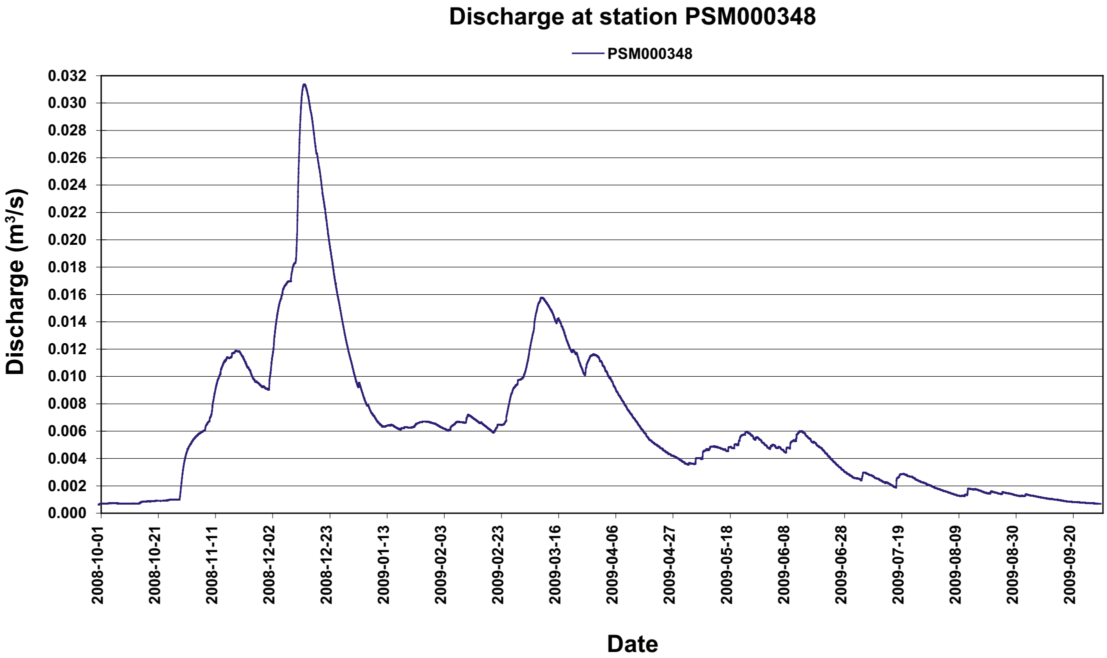


Figure 5-5. *Quality assured discharge, m³/s, for station PSM000348.*

5.1.2 Water level

Sea water level

Sea water level is measured at three places in the surroundings of Äspö. The stations are PSM000369, PSM000370 and PSM000371. Measurements are made in plane system RT90 and elevation system RHB70 and is expressed as meter above sea level (m.a.s.l.). The similarity between measurements at the three stations is good. The results are presented in Figure 5-6.

Water level measured in lakes and reservoirs

Water level is also measured at station PSM000342 and PSM000344. At PSM000342 water level is measured in lake Jämsen and at station PSM000344 in lake Plittorpsgöl. All measurements are in plane system RT90 and elevation system RHB70. No corrections of data during the period has been made. The measured water levels can bee seen in Figure 5-7.

At station PSM000359 water level is measured in the reservoir at Sörå. Measurements are in meter above sea level (m.a.s.l.), in plane system RT90 and elevation system RHB70. The measured water level can bee seen in Figure 5-8.

5.1.3 Water temperature and electrical conductivity (EC)

At all stations monitoring discharge the water temperature and electrical conductivity, EC, are measured. At the stations PSM000341, PSM000343 and PSM000345 where constructed dams are made, temperature and EC is measured in the small basin upstream the concrete dam. During drought, in periods when discharge in creeks equals zero, the water temperature in the basins will increase and the logged temperature and EC values will therefore not be representative. For this reason, all quality checked temperature and EC values are deleted when the discharge equals zero. Temperature measurements have worked well during the whole period, corrections have only been made to PSM000368 and PSM000348. At the station inspection made by SMHI in May 2009, all loggers were checked in relation to a reference thermometer and no significant errors were detected.

At station PSM000364, the temperature and conductivity sensor were found situated above water level on two occasions during August/September 2009. These data has been deleted.

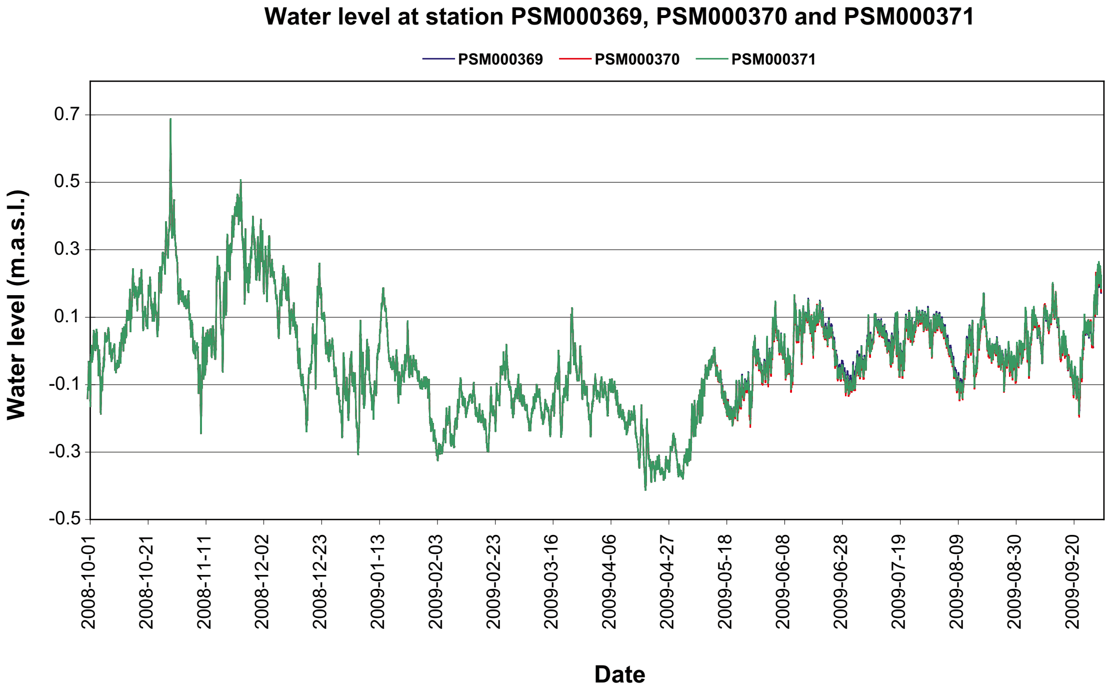


Figure 5-6. *Sea water level measured at station PSM000369, PSM000370 and PSM000371. All measurements made in plane system RT90 and elevation system RHB70.*

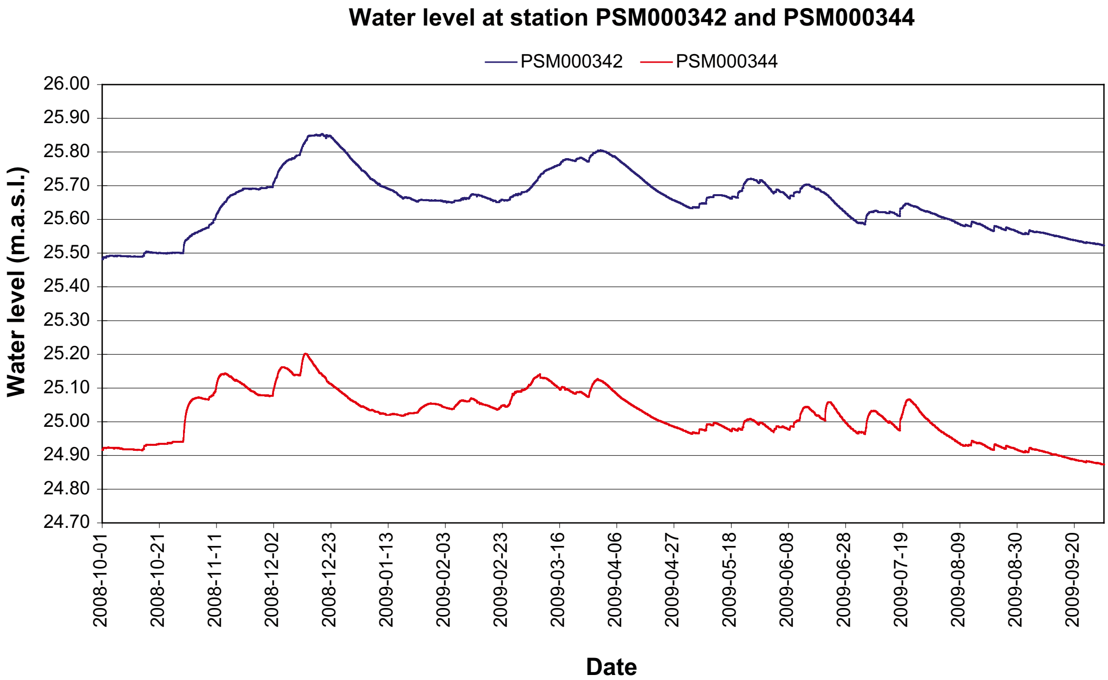


Figure 5-7. *Water level measured at station PSM000342 and PSM000344. The blue line shows the development of water level for lake Jämsen and the red line for lake Plittorpsgöl. Measurements made in meter above sea level (m.a.s.l.).*

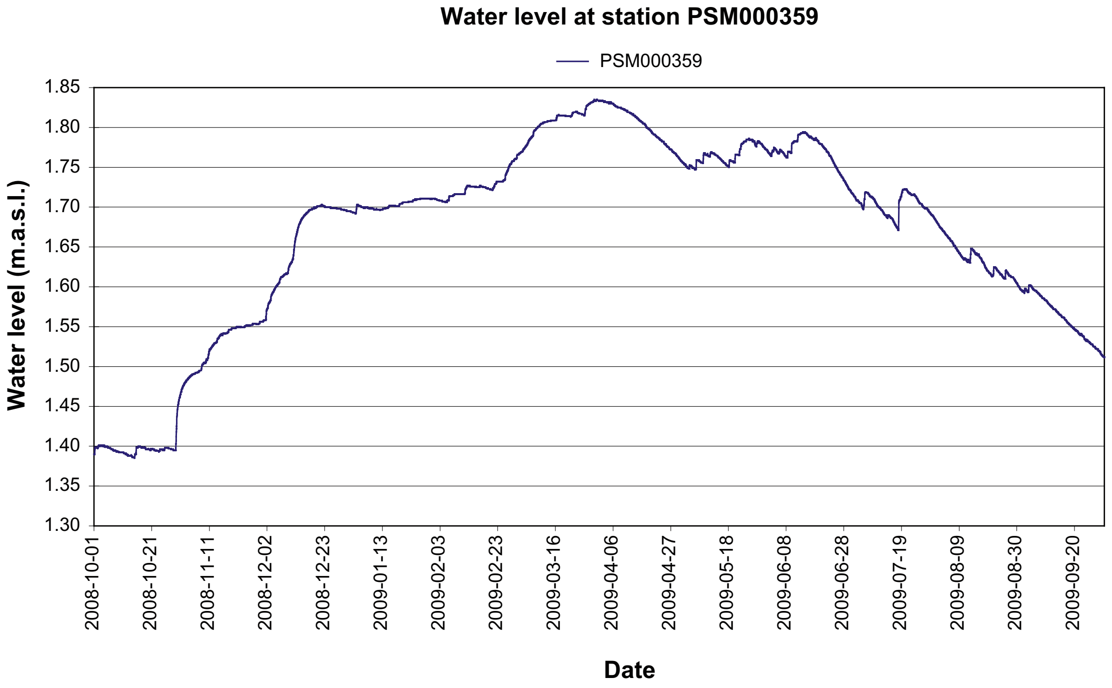


Figure 5-8. Water level measured in m.a.s.l. at station PSM000359. The blue line shows the development of water level in the reservoir at Sörå.

It has been necessary to adjust conductivity measurements at PSM000347, PSM000365 and PSM000348 when extreme values occurred. The sensors seem to be covered with organic material during the vegetation period when the biological activity is high. Because of this, it is very important to keep the sensor clean during this part of season. At the station inspection made by SMHI in May 2009, water sample were taken at all stations and later analysed by SKB laboratory regarding electrical conductivity. No significant errors were detected.

Quality checked measurements are presented in Figures 5-9 to 5-16.

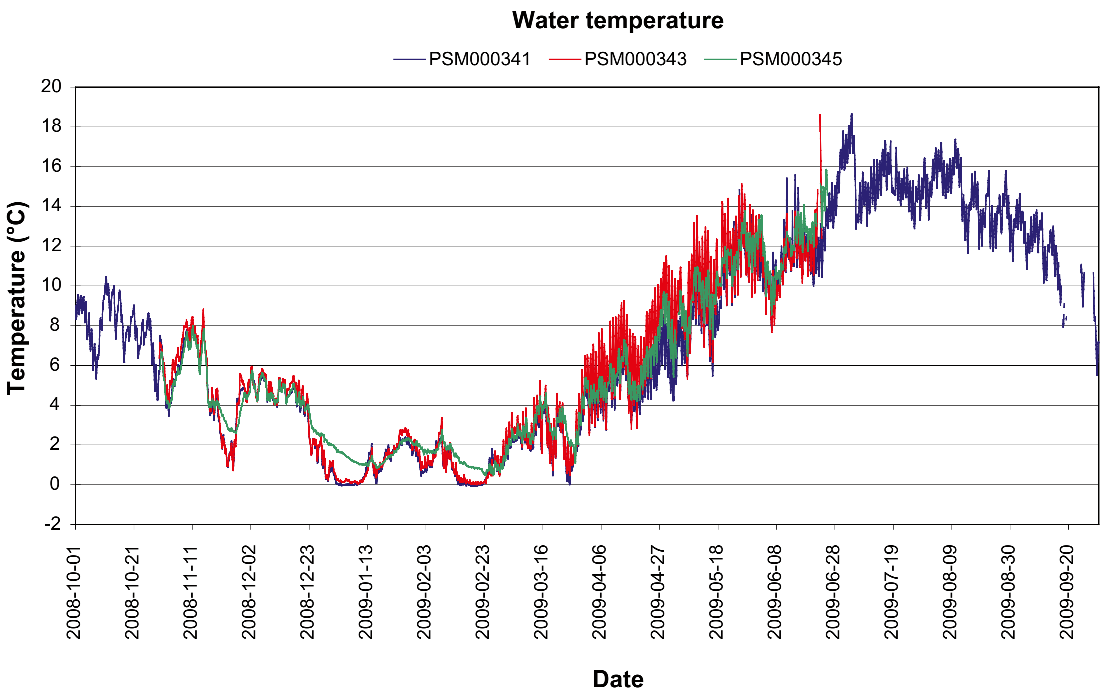


Figure 5-9. Water temperature measured at stations PSM000341, PSM000343 and PSM000345. Values deleted during periods when the discharge equals zero or when the watercourse is dried up.

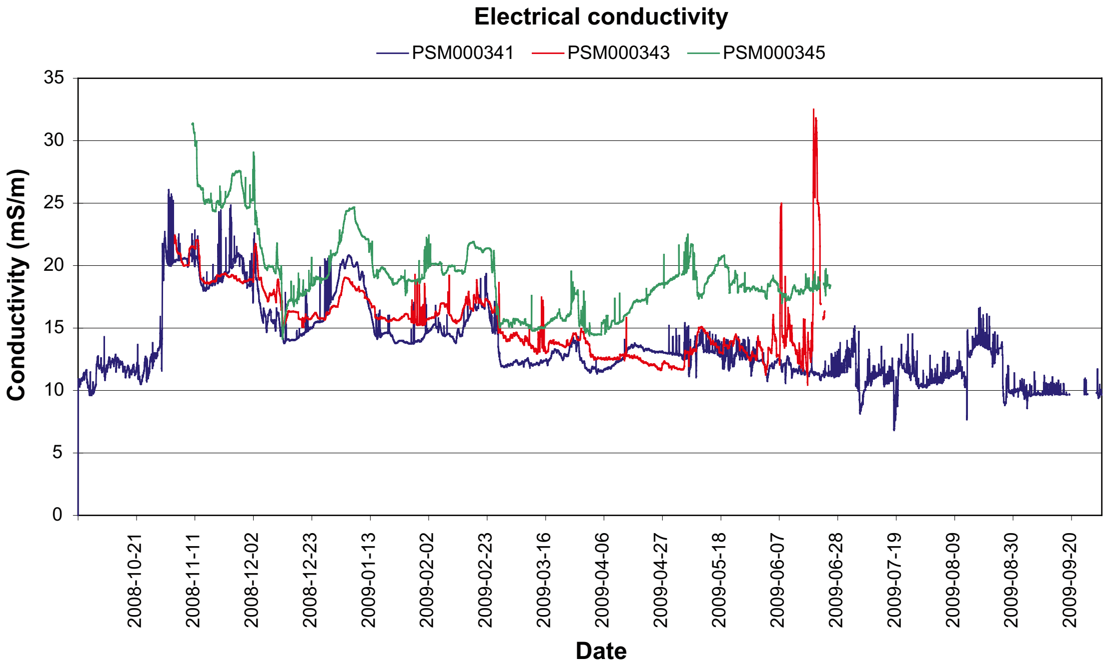


Figure 5-10. Electrical conductivity, EC, measured at stations PSM000341, PSM000343 and PSM000345. Values deleted during periods when the discharge equals zero or when the watercourse is dried up.

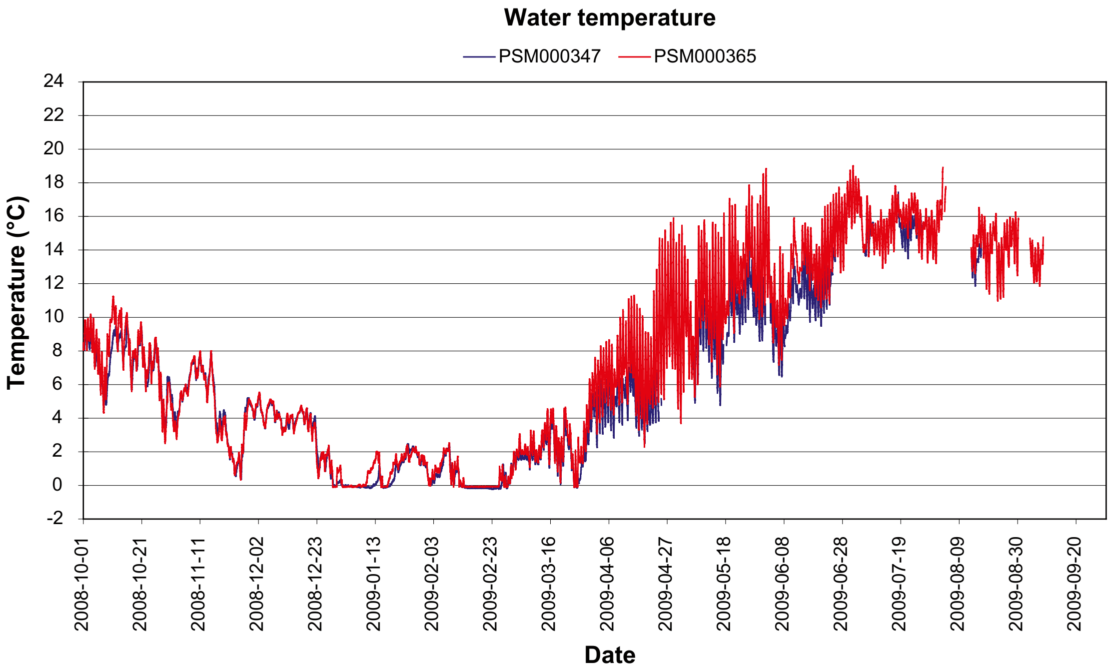


***Figure 5-11.** Water temperature measured at stations PSM000347 and PSM000365. Values deleted during periods when the discharge equals zero or when the watercourse is dried up.*

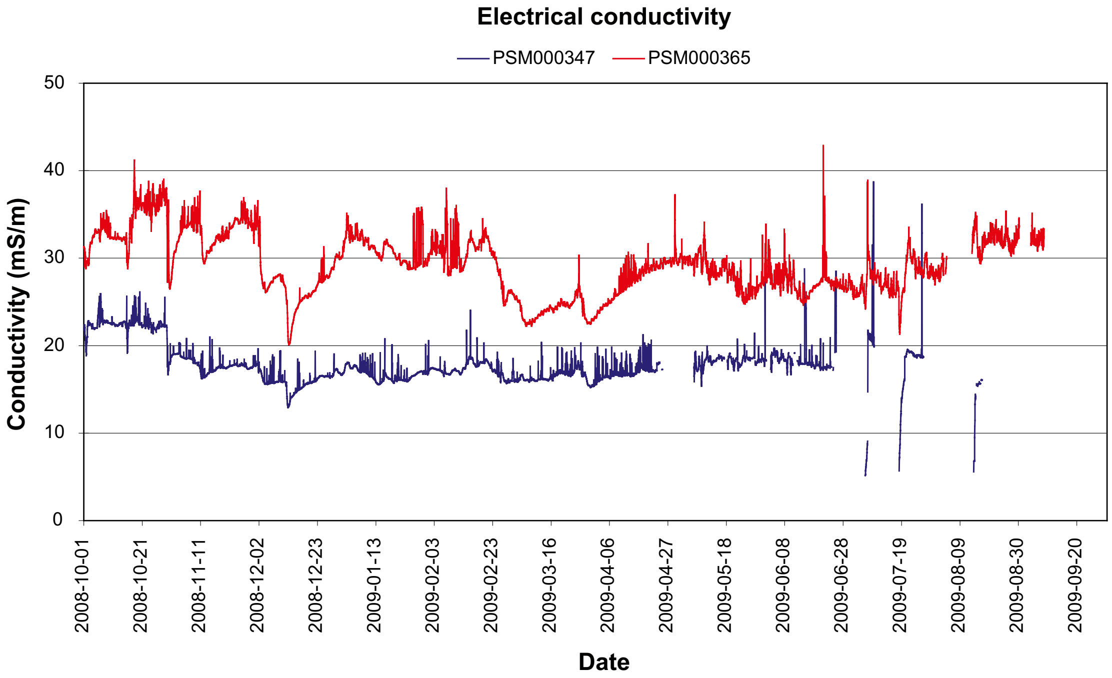


Figure 5-12. *Electrical conductivity, EC, measured at stations PSM000347 and PSM000365. Values are deleted during periods when the discharge equals zero or when the watercourse is dried up. Extremely values at station PSM000347 corrected.*

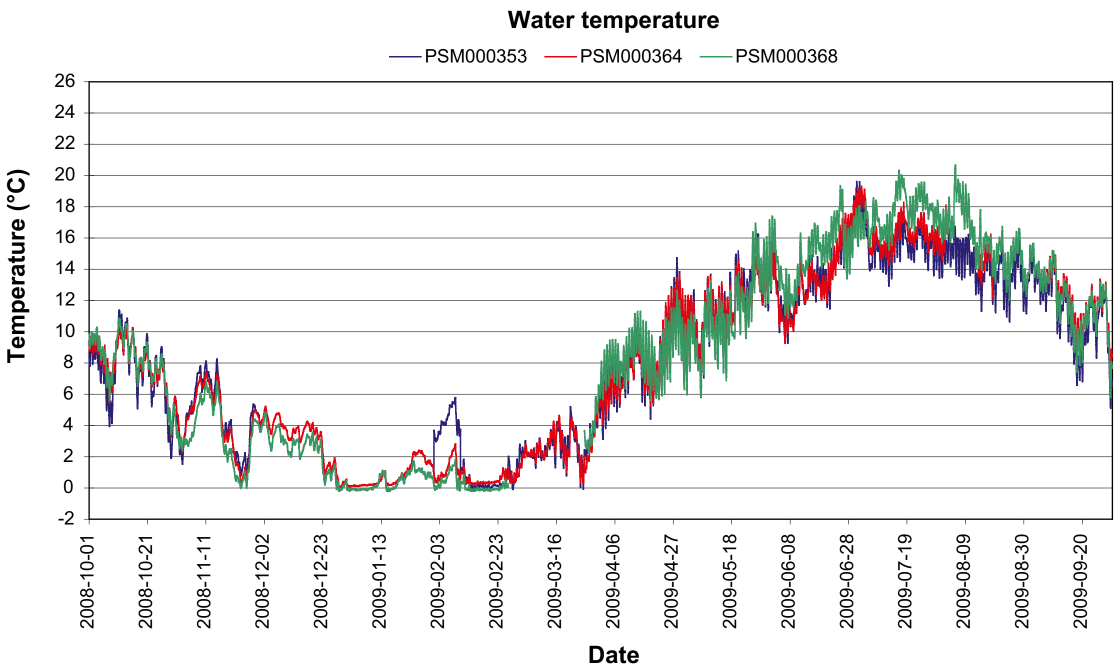


Figure 5-13. *Water temperature measured at stations PSM000353, PSM000364 and PSM000368.*

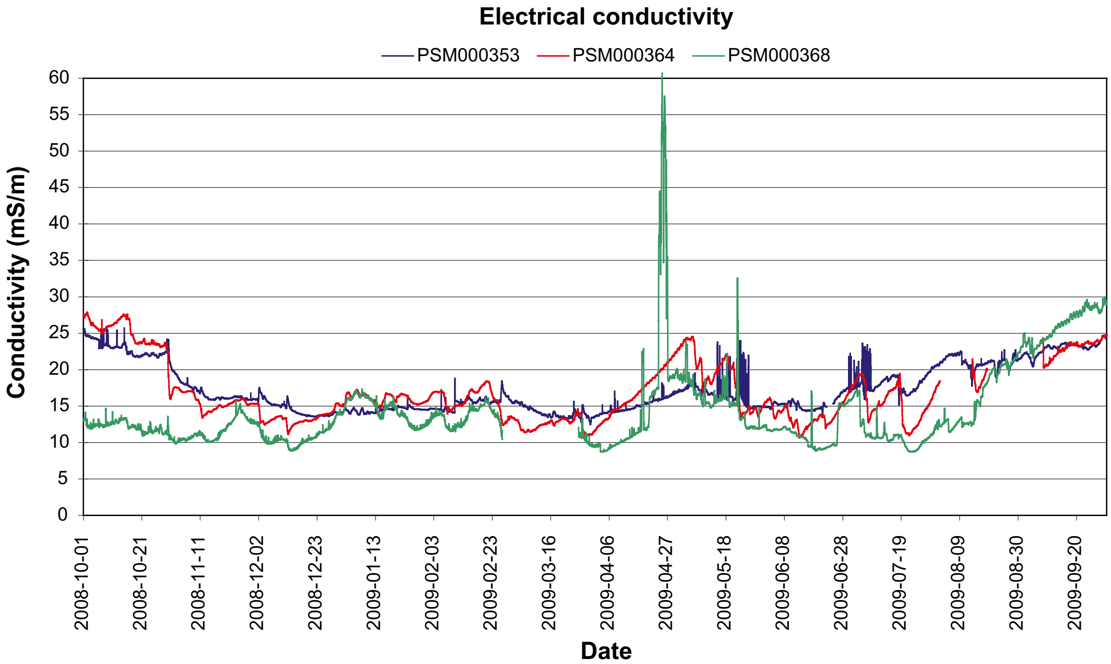


Figure 5-14. *Electrical conductivity measured at station PSM000353, PSM000364 and PSM000368.*

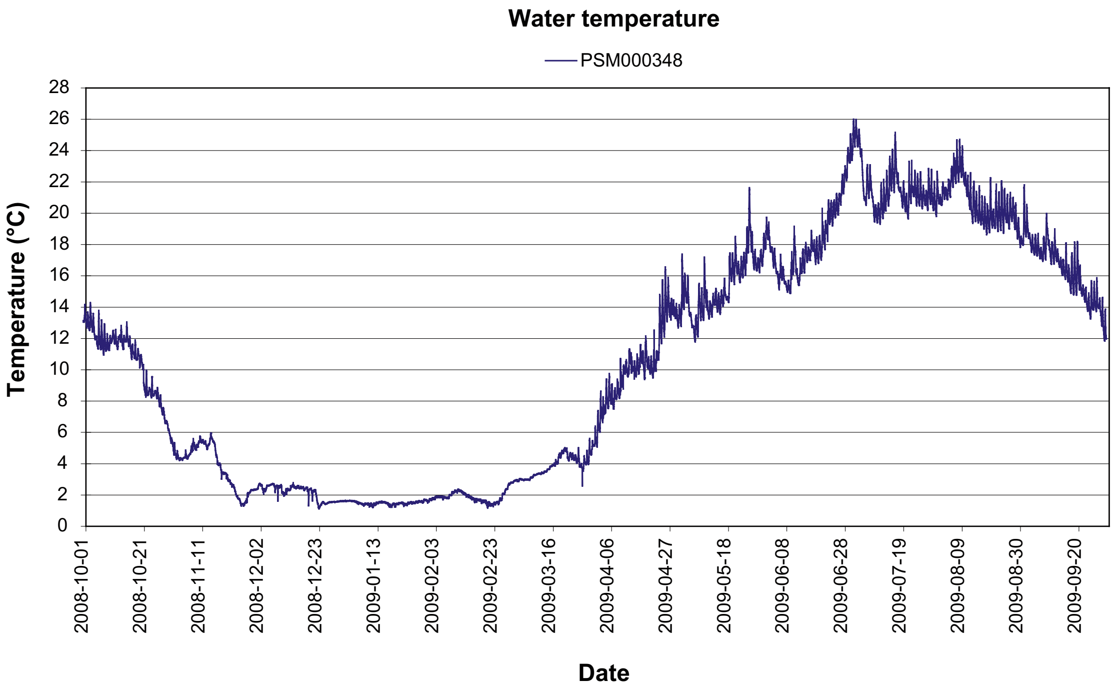


Figure 5-15. *Water temperature measured at Lake Frisksjön station PSM000348.*

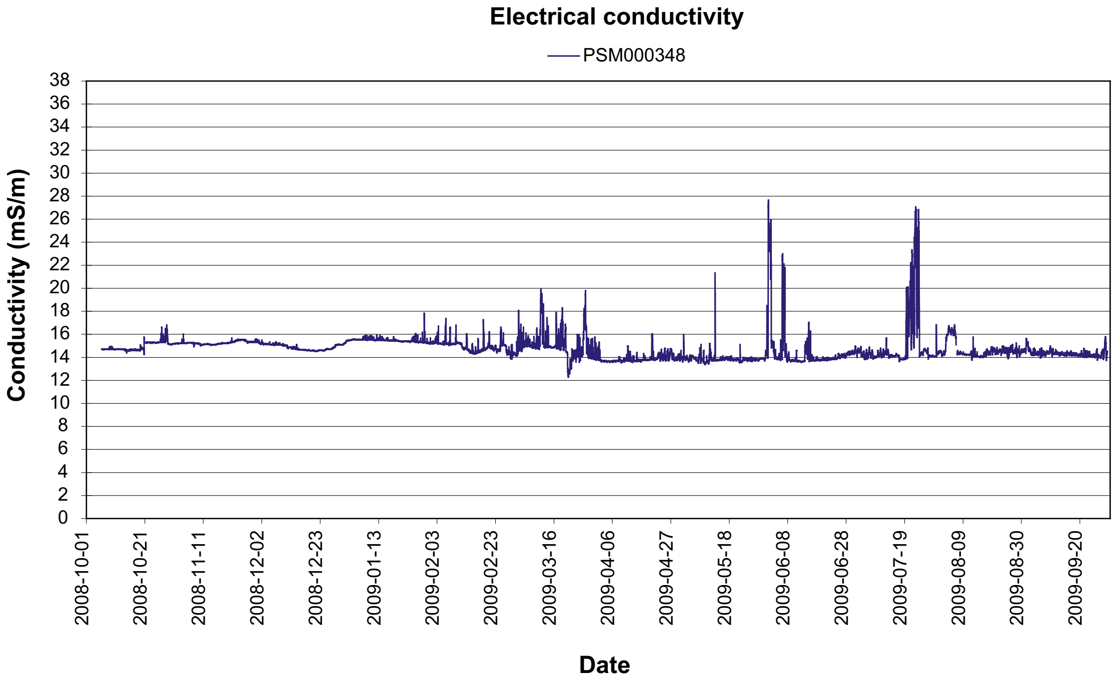


Figure 5-16. Electrical conductivity measured at Lake Frisksjön station PSM000348. Extreme values corrected or deleted.

5.2 Meteorological monitoring

Figure 4-2 shows where the two monitoring stations Plittorp and Äspö are situated. The figure also shows where the SMHI's regional precipitation stations presented in this report below are located.

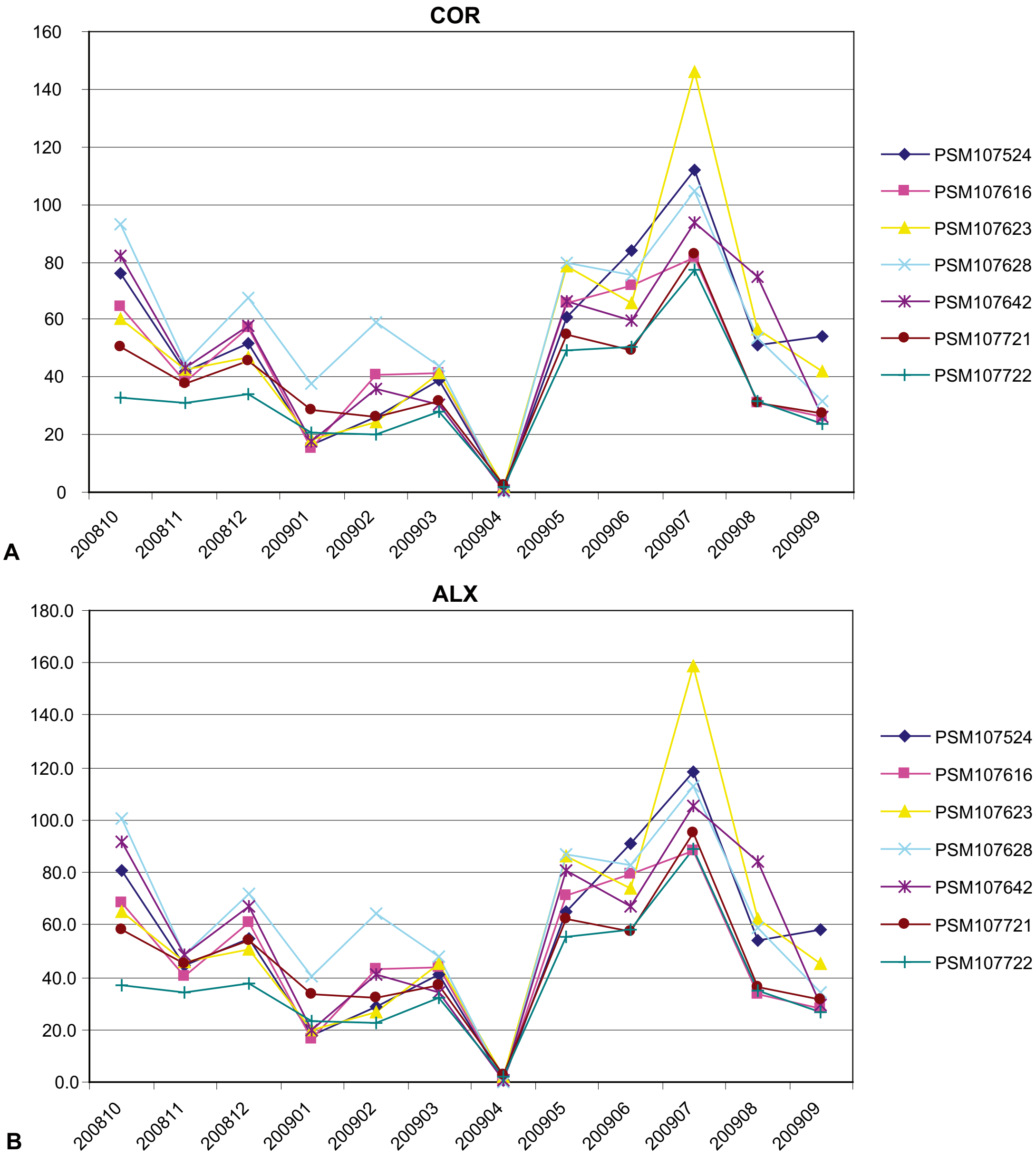
5.2.1 Precipitation

The monthly precipitations for SMHI's stations are presented in Table 5-2 and Figure 5-17. "Ölands Norra Udde A" and "Gladhammar A" are automatic stations and the others are manual stations. These precipitation values are all controlled and approved by SMHI. There are no correction for wind errors, wetting and evaporation in these values (COR) in Table 5-2a but in Table 5-2b corrected values (ALX) are presented. We see that the precipitation differs a lot between stations and between months.

The ALX-correctionsfactors of precipitation is listed below in Table 5-1.

Table 5-1. ALX-Corrections in percent of SMHI's stations according to reference /5/.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Målilla	7	9	6	8	7	8	6	7	7	6	6	6	7
Oskarshamn	6	6	6	8	8	11	8	7	7	7	6	6	7
Krokshult	9	11	9	8	10	12	9	10	8	8	8	8	9
Kråkemåla	7	9	9	8	9	10	8	9	8	8	7	6	8
Ölands norra A	18	22	16	16	13	16	15	16	16	16	18	18	17
Ölands norra	13	14	17	12	13	16	15	11	12	14	11	11	13
Gladhammar A	13	15	14	14	22	12	13	13	13	12	13	16	13



Figur 5-17. *Monthly precipitation in mm at SMHI's stations, (COR) corrected (ALX).*

Table 5-2a. Monthly precipitation in mm at SMHI's stations, uncorrected (COR).

Station	Year	1	2	3	4	5	6	7	8	9	10	11	12
PSM107524	2008										76.3	41.8	51.7
Målilla	2009	16.5	26.3	39.0	0.9	60.7	84.1	111.8	50.8	54.3			
PSM107616	2008										64.2	38.4	57.4
Oskarshamn	2009	15.5	40.9	41.1	0.9	65.9	71.5	81.5	31.2	26			
PSM107623	2008										60.4	42.7	46.8
Krokshult	2009	18.5	24.2	41.3	1.9	78.4	65.8	145.9	56.6	42.1			
PSM107628	2008										93.1	45.1	67.7
Kråkemåla	2009	37.8	59.1	43.8	0.2	79.5	75.5	104.7	53.7	31.7			
PSM107642	2008										82.1	43.3	57.7
Gladhammar	2009	17.4	35.9	30.2	0.6	66.1	59.7	93.4	74.7	26.1			
PSM107721	2008										50.3	38	45.8
Ölands N A	2009	28.3	26.1	31.9	2.6	54.9	49.3	82.8	31.2	27.3			
PSM107722	2008										32.7	30.9	34.1
Ölands N	2009	20.8	19.9	27.7	2	49.3	50.4	77.5	31.6	23.6			

Table 5-2b. Monthly precipitation in mm at SMHI's stations, corrected (ALX).

Station	Year	1	2	3	4	5	6	7	8	9	10	11	12
PSM107524	2008										80.9	44.3	54.8
Målilla	2009	17.7	28.7	41.3	1.0	64.9	90.8	118.5	54.4	58.1			
PSM107616	2008										68.7	40.7	60.8
Oskarshamn	2009	16.4	43.4	43.6	1.0	71.2	79.4	88.0	33.4	27.8			
PSM107623	2008										65.2	46.1	50.5
Krokshult	2009	20.2	26.9	45.0	2.1	86.2	73.7	159.0	62.3	45.5			
PSM107628	2008										100.5	48.3	71.8
Kråkemåla	2009	40.4	64.4	47.7	0.2	86.7	83.1	113.1	58.5	34.2			
PSM107642	2008										92.0	48.9	66.9
Gladhammar	2009	19.7	41.3	34.4	0.7	80.6	66.9	105.5	84.4	29.5			
PSM107721	2008										58.3	44.8	54.0
Ölands N A	2009	33.4	31.8	37.0	3.0	62.0	57.2	95.2	36.2	31.7			
PSM107722	2008										37.3	34.3	37.9
Ölands N	2009	23.5	22.7	32.4	2.2	55.7	58.5	89.1	35.1	26.4			

The monthly precipitation at Plittorp and Äspö are presented in Table 5-4. "COR" means corrected and approved value by SMHI, "MES" means analysed values from Mesan. ALX is the correction for wind errors, wetting and evaporation.

ALX is estimating the true precipitation. It is based on photographs of the surroundings and maps of the stations and the same method is used as for the other SMHI stations. The Table 5-3 below gives the corrections in percent for each month. More information about the estimated true precipitation can be found in reference /4/ and /5/.

The registered 30-minutes precipitation values have to be filtered before storing. That is because the instrument is very sensitive and registers incorrect small values of precipitation.

If we compare the ALX values from Plittorp and Äspö with the values from the closest SMHI stations Kråkemåla and Oskarshamn we see that the yearly precipitation at Plittorp and Äspö are quite similar to Oskarshamn.

Table 5-3. ALX-Corrections in percent of SKB's stations according to reference /6/.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Äspö	21	21	19	16	14	14	14	14	14	16	17	20	17
Plittorp	12	13	12	10	10	9	9	10	10	10	10	12	11

Table 5-4. Monthly precipitation in mm at SKB's stations. "COR" means corrected and approved value by SMHI and "MES" means analysed values from Mesan. ALX is the new estimation of the true precipitation.

Station	Year	1	2	3	4	5	6	7	8	9	10	11	12
PAS000028	2008										84.7	38.4	65.4
Äspö ALX	2009	29.3	49.2	41.6	2.0	86.9	59.7	97.1	66.0	24.7			
PSM107738	2008										56.5	33.1	50.3
Plittorp ALX	2009		42.0	45.9	1.1	73.0	100.4	108.3	63.7	22.1			
PAS000028	2008										73.0	32.8	54.5
Äspö COR	2009	24.2	40.7	35.0	1.7	76.2	52.4	85.2	57.9	21.7			
PSM107738	2008										51.4	30.1	44.9
PlittorpCOR	2009		37.2	41.0	1.0	66.4	92.1	99.4	57.9	20.1			
Mesan	2008										53.4	40.3	50.7
	2009	13.1	29.0	25.5	4.6	96.0	75.1	78.8	43.5	20.0			

Figure A5-1 in Appendix 5 shows the accumulated sum of precipitation during the period. From the figure, we see that the precipitation gauge was emptied at two moments.

5.2.2 Barometric pressure

Graphs of the barometric pressure are presented in Figure A5-2 in Appendix 5. Values from Plittorp, Äspö are presented. Figure A5-10 shows 30-min values for March 2009 where we can see that the measured value from Plittorp is lower than the Mesan-value, which is valid for the sea surface. The pressure decreases in theory about 1 hPa per 8 meter and the value from Plittorp is therefore correct.

5.2.3 Air temperature

Graphs of daily temperature are presented in Figure A5-3 in Appendix 5. Values from Plittorp, Äspö and Mesan-values are presented. We see that the three curves follow each other very well.

Figure A5-11 shows 30-min values for March 2009. We notice that Äspö is more influenced of the sea because the lowest temperatures are several degrees higher compared to Plittorp

5.2.4 Relative humidity

Graphs of daily relative humidity are presented in Figure A5-4 in Appendix 5. Values from Plittorp, Äspö and Mesan-values are presented. We see that the three curves follow each other very well. In Figure A5-12, 30-min values for March 2009 are presented.

5.2.5 Wind speed

Graphs of the wind speed (daily mean) are presented in Figure A5-5 in Appendix 5. Values from Plittorp, Äspö and Mesan-values are presented. We see that the wind speeds are higher at Äspö compared to Plittorp but that the curves follow each other quite well.

The measured wind speed at Plittorp is clearly lower than the Mesan analysis. This depends on the surroundings of the site (not very open area) and that Mesan overestimates the wind speed at sites close to the sea. The measured wind speed at Plittorp is also lower than the values from Äspö. The reason is of course that Äspö is closer to the sea.

Figure A5-13 shows measurements March 2009 for the 30-min mean wind speed. The gust wind speed is approximately 2–3 times higher than the mean wind speed presented here. The gust wind speed is not presented in the figure.

5.2.6 Wind direction

Graphs of windroses are presented in Figure A5-6 in Appendix 5. Values from Äspö, Plittorp are presented. We see that for both station the most winds blow from the sector south to west. Figure A5-13 shows 30-min values for March 2009.

5.2.7 Global radiation

Graphs of the daily sum of global radiation are presented in Figure A5-7 in Appendix 5. Global radiation is measured only at Äspö. Values from Äspö and Strång-values are presented. Analysed global radiation from the SMHI radiation model Strång, which uses data from Mesan, corresponds well to measured global radiation at Äspö. 30-min values for March 2009 are presented in Figure A5-14.

5.2.8 Calculated evapotranspiration

The potential evapotranspiration E_p "new calculation method" is derived from the Penman equation:

$$E_P = (\frac{\Delta \cdot (R_n - G)}{(\Delta + \gamma) \cdot L} + \frac{\gamma \cdot f(u) \cdot (e_s - e)}{(\Delta + \gamma)}) \cdot tstep$$

where

Δ	proportionality constant
R_n	net radiation flux density
G	heat flux density into ground
γ	psychrometric constant
$f(u)$	function of wind speed
e_s	saturated water vapor pressure
e	water vapor pressure
L	latent heat of vaporization
tstep	time step

The method is described in detail in /3/. Measured data every 30-minutes of temperature, relative humidity, wind speed and global radiation were required as input data to the equation to calculate the potential evapotranspiration. The wind speed was measured at 10 m above the ground but for the estimation of potential evapotranspiration the wind speed was re-calculated to a value representing 2 m above the ground by multiplying by a factor 0.8. The net radiation was calculated from the measured global radiation and the albedo was set to 0.12 when the ground was not covered in snow and to 0.5 when there was a snow cover. The applied method included heat storage in the ground.

Graph of the potential evapotranspiration is presented in the Figure A5-8 in Appendix 5. The 30-min values for March 2009 are presented in Figure A5-15 in Appendix 5.

5.3 Winter parameters

5.3.1 Snow depth

The average snow depth at the one station for snow depth measurement consists of only two values; 3.7 cm snow depth dated 2008-11-24 and 17.8 cm snow depth dated 2009-02-12. All data is listed in Appendix 3.

5.3.2 Frost in ground

The frost in ground data at the two measurement sites are shown in Table 5-5. The frost in ground devices was out of order for some time during the winter (see Section 4.7.3). All data is listed in Appendix 4.

Table 5-5. Frost in ground at the two measurement sites.

Site	Date	Ground frost (cm)
PSM006978	2008-11-21	1.0
PSM006978	2008-11-24	1.0
PSM006979	2009-02-09	3.0
PSM006979	2009-02-11	1.0
PSM006979	2009-03-02	2.0
PSM006979	2009-03-19	2.0

5.3.3 Ice cover

Ice conditions observed in the Oskarshamn area are shown in Table 5-6.

Table 5-6. Time for ice freeze up and ice break up in a lake and sea at Oskarshamn area.

Site	Ice freeze up	Ice break up	Period with ice cover (days)
Äspös brygga (ASM10226)	2002-12-19	2003-03-27	99
	2004-01-07	2004-03-10	62
	2005-03-08	2005-04-01	25
	2005-12-20	2006-04-18	119
	2007-01-23	2007-03-15	50
	2007-12-10	2008-01-01	19
	2009-01-29	2009-03-02	32
Kråkelund yttre (ASM100227)	*no ice cover during 2003–2004*		
	no ice cover during 2004–2005		
	no ice cover during 2005–2006		
	no ice cover during 2006–2007		
	no ice cover during 2007–2008		
	no ice cover during 2008–2009		
Kråkelund inre (ASM100228)	2003-01-10	2003-03-21	71
	no ice cover during 2004–2005		
	2006-01-02	2006-01-12	10
	2006-01-26	2006-02-03	8
	2006-03-17	2006-03-29	12
	no ice cover during 2006–2007		
	no ice cover during 2007–2008		
	no ice cover during 2008–2009		
Jämsen (ASM100229)	2002-11-19	2002-11-22	3
	2002-12-19	2003-03-28	100
	2004-01-07	2004-03-10	64
	2004-11-22	2005-03-30	129
	2005-11-22	2006-04-18	147
	2007-01-15	2007-03-15	58
	2007-12-10	2008-01-14	34
	2009-01-20	2009-03-19	59

References

/1/ **SMHI/Naturvårdsverket, 1979.** Vattenföringsbestämning vid vattenundersökningar.

/2/ **SMHI.** Handbok för observatörer. Internt document.

/3/ **Eriksson B, 1981.** Den ”potentiella” evapotranspirationen i Sverige. Eriksson, B. (1981) RMK28.

/4/ **Alexandersson, 2003.** Meteorologi, Nr 111. Korrektion av nederbörd enligt enkel klimatologisk metodik.

/5/ **Alexandersson, 2005.** Enkel bedömning av nederbördsmätförluster på fyra automatstationer.

Appendix 1

Hydrological monitoring stations

Station Id	Object	Place	Variables	Instrumentation	Time interval of measurements	QC_OK
PSM000341	Ävrö NE	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-03-18 00:00 Stop: 2009-10-01 00:00	OK
PSM000342	Jämsen	Lake	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-07-24 15:00 Stop: 2009-10-01-00:00	OK
PSM000343	Ävrö SW	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-03-18 00:00 Stop: 2009-10-01 00:00	OK
PSM000344	Plittorpsgöl	Lake	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-07-24 15:00 Stop: 2009-10-01 00:00	OK
PSM000345	Ävrö SE	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-03-18 00:00 Stop: 2009-10-01 00:00	OK
PSM000347	Frisksjön (in)	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-11-30 13:00 Stop: 2009-10-01 00:00	OK
PSM000348	Frisksjön (out)	Lake, Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-07-24 01:00 Stop: 2009-10-01 00:00	OK
PSM000353	Laxemarån (upper)	Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-09-02 15:00 Stop: 2009-10-01 00:00	OK
PSM000359	Sörå-magasinet	Lake	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2009-10-01 00:00	OK
PSM000364	Laxemarån (lower)	Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-09-02 11:00 Stop: 2009-10-01 00:00	OK
PSM000365	Ekerumsån	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2005-02-01 13:00 Stop: 2009-10-01 00:00	OK
PSM000368	Kärrviksån	Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-07-24 10:00 Stop: 2009-10-01 00:00	OK
PSM000369	Äspö S	Sea	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2009-10-01 00:00	OK
PSM000370	Äspö N	Sea	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2009-10-01 00:00	OK
PSM000371	Clab	Sea	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2009-10-01 00:00	OK

Rating curves for hydrological stations

Rating curves where concrete V-notch is used

The following rating curves are based on control measurements made by SKB and SMHI and were determined 2006-10-01. Since then additional control measurements have been made by SKB. However, these have not given any occasion to adjust existing curves, but further control measurements of discharge are required to increase the accuracy of the rating curves. The names of the five stations are PSM000341, PSM000343, PSM000345, PSM000347 and PSM000365.

For all stations the discharge has been theoretically calculated as:

$Q = 8/15 \cdot \mu \cdot (2g)^{1/2} \cdot h^{5/2} \cdot \tan\alpha/2$

Q = Discharge (m^3/s)

μ = Coefficient approximatively constant

g = Constant of gravity (9,815 m/s^2)

h = Water level above V-notch (m)

α = opening angle

PSM000341

The rating angle is 45° and μ is set to 0.7. This value of μ is somewhat high because the water speed is high through the dam. The diagram below shows how the control measurements fit to the theoretically calculated discharge Q.

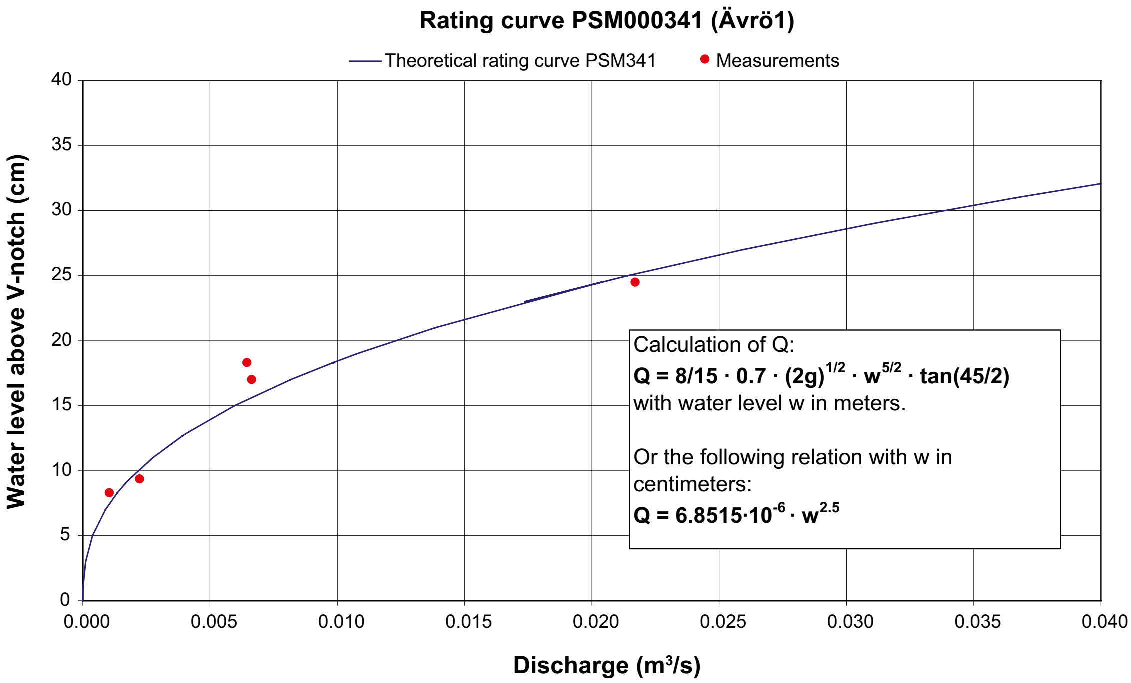


Figure A2-1. *Made control measurements in relation to the theoretically calculated discharge at PSM000341.*

PSM000343

The rating angle is 45° and μ is set to 0,6. The diagram below shows how the control measurements fit to the theoretically calculated discharge Q.

PSM000345

The rating angle is 45° and μ is set to 0.6. The diagram below shows how the control measurements fit to the theoretically calculated discharge Q.

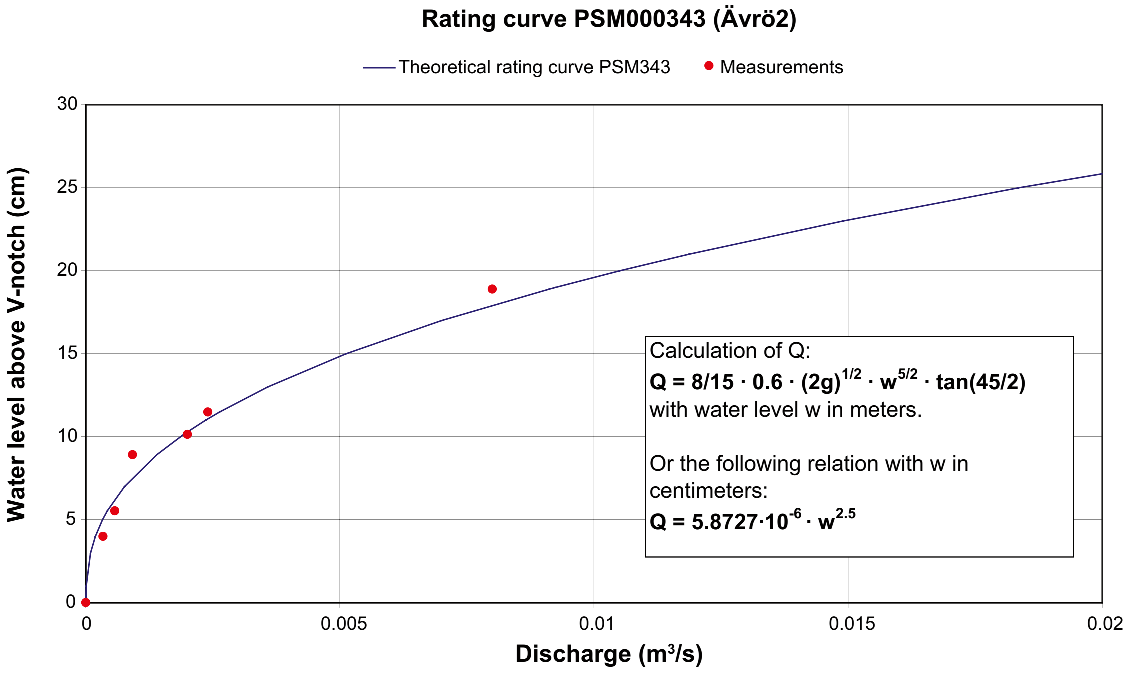


Figure A2-2. Made control measurements in relation to the theoretically calculated discharge at PSM000343.

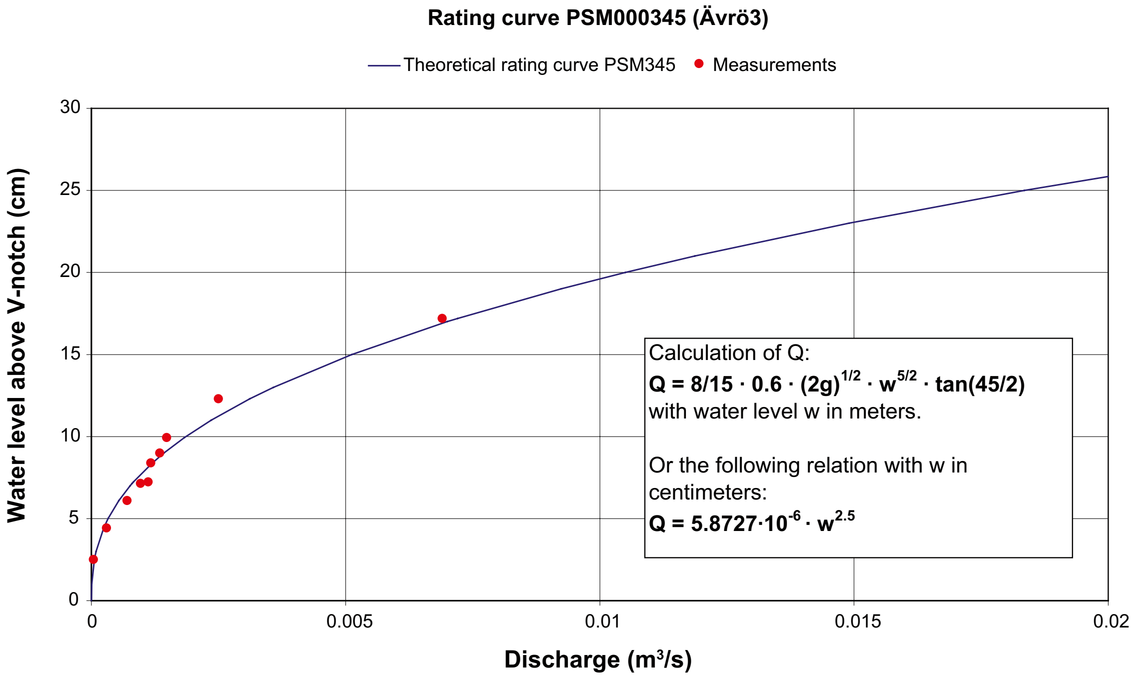


Figure A2-3. Made control measurements in relation to the theoretically calculated discharge at PSM000345.

PSM000347

The rating angle is 60° and μ is set to 0.6. The diagram below shows how the control measurements fit to the theoretically calculated discharge Q.

PSM000365

The rating angle is 120° and μ is set to 0.6. The diagram below shows how the control measurements fit to the theoretically calculated discharge Q.

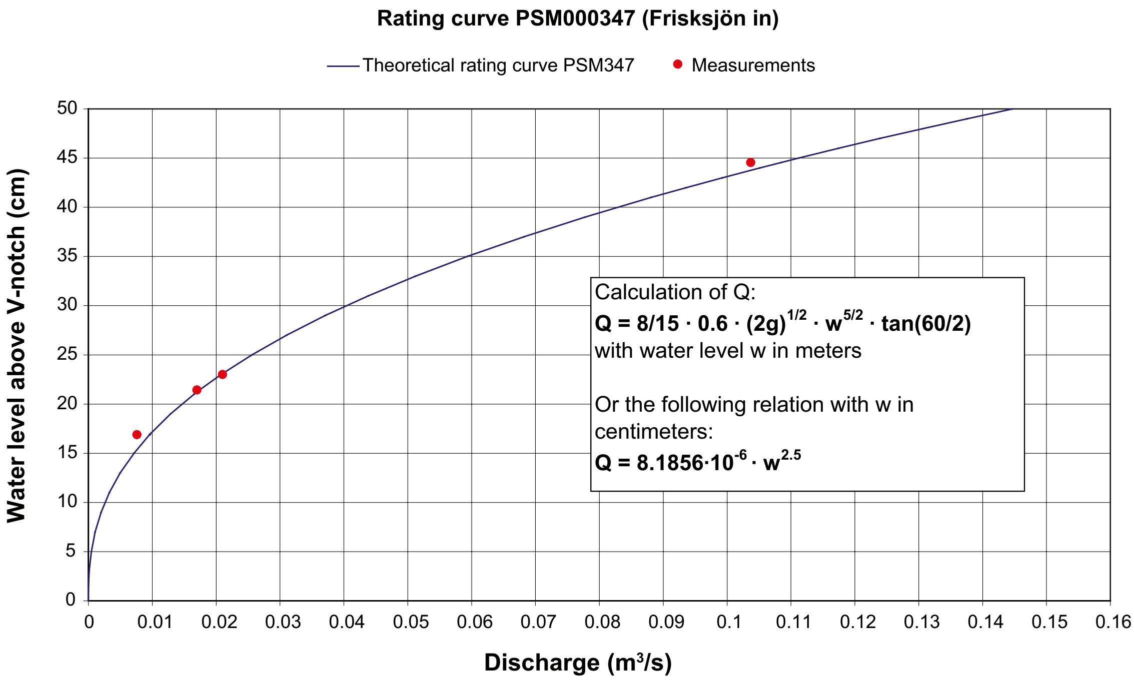


Figure A2-4. Made control measurements in relation to the theoretically calculated discharge at PSM000347.

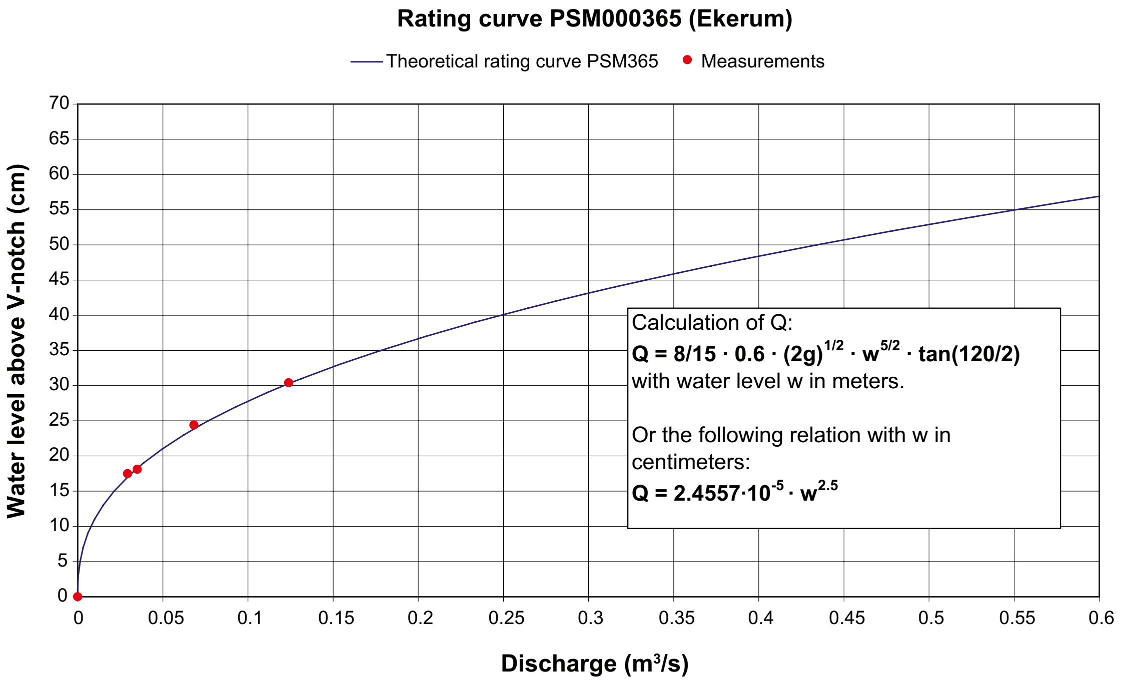


Figure A2-5. Made control measurements in relation to the theoretically calculated discharge at PSM000365.

Rating curves where natural cross section is used. The following rating curves are based on control measurements made by SKB and SMHI to describe the discharge at the SKB hydrological stations where a natural cross section in the watercourse is used. The rating curves were determined 2006-10-01. Since then additional control measurements have been made by SKB. However, these have not given any occasion to adjust existing curves, but further control measurements of discharge are required to increase the accuracy of the rating curves. The names of the four stations are PSM000348, PSM000353, PSM000364 and PSM000368.

PSM000348

The discharge from lake Frisksjön is determined by using the lake´s natural outlet as cross section. The rating curve below has been established based on control measurements made up to 2006-10-01.

PSM000353

The discharge in Laxemarån upper is determined by using the natural sections (Equation 1) and the contraction made by the road culvert just downstream the station (Equation 2). The discharge is for the present calculated with two rating equations. The first is valid up to the water level +10.23 m.a.s.l. and the other for higher levels. The following rating curves have been established based on control measurements made up to 2006-10-01.

PSM000364

The discharge in Laxemarån lower is determined by using the threshold and contraction made by the earlier concrete construction. The discharge is for the present calculated by the following rating curve.

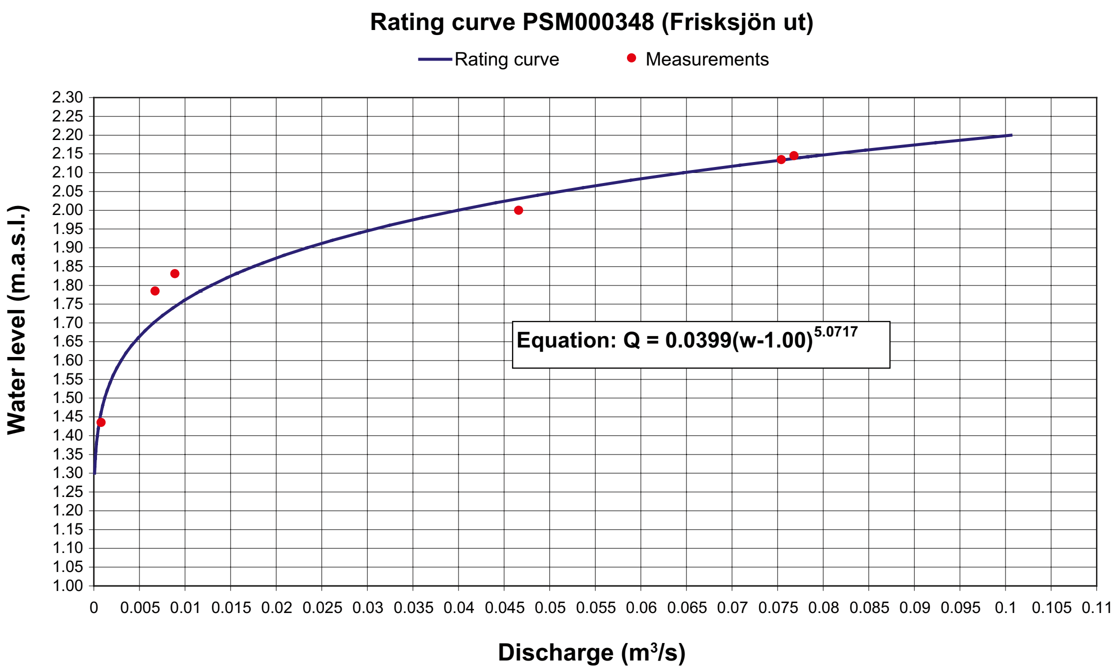


Figure A2-6. Rating curve for PSM000348 Frisksjön out based on made control measurements.

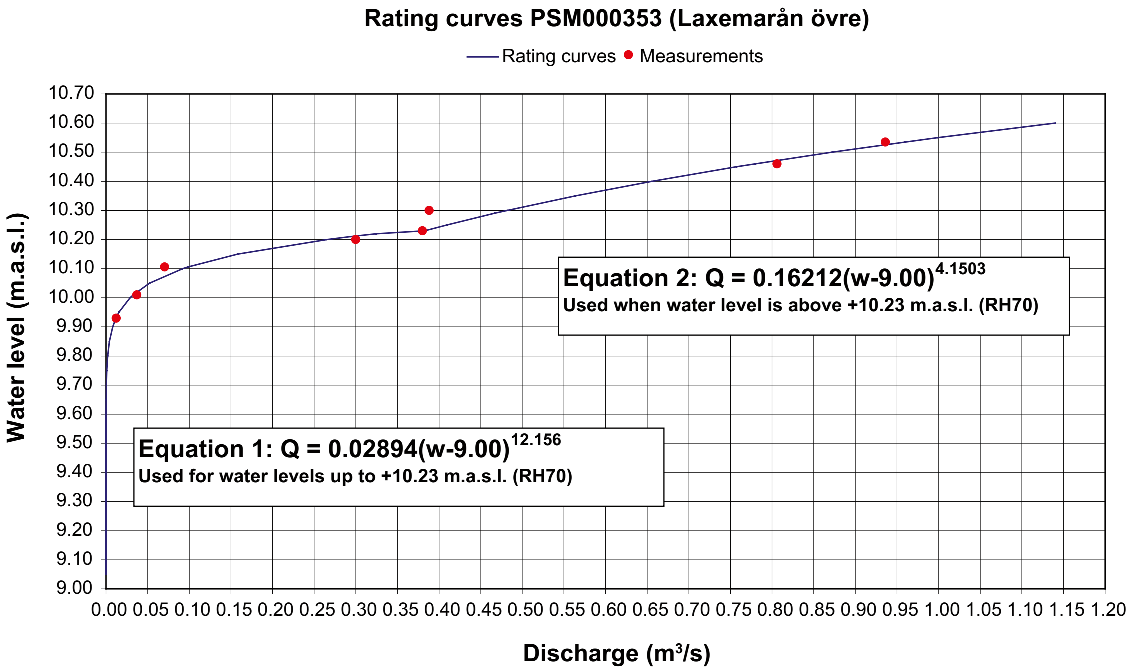


Figure A2-7. *Rating curve for PSM000353 Laxemarån upper based on control measurements made up to 2006-10-01.*

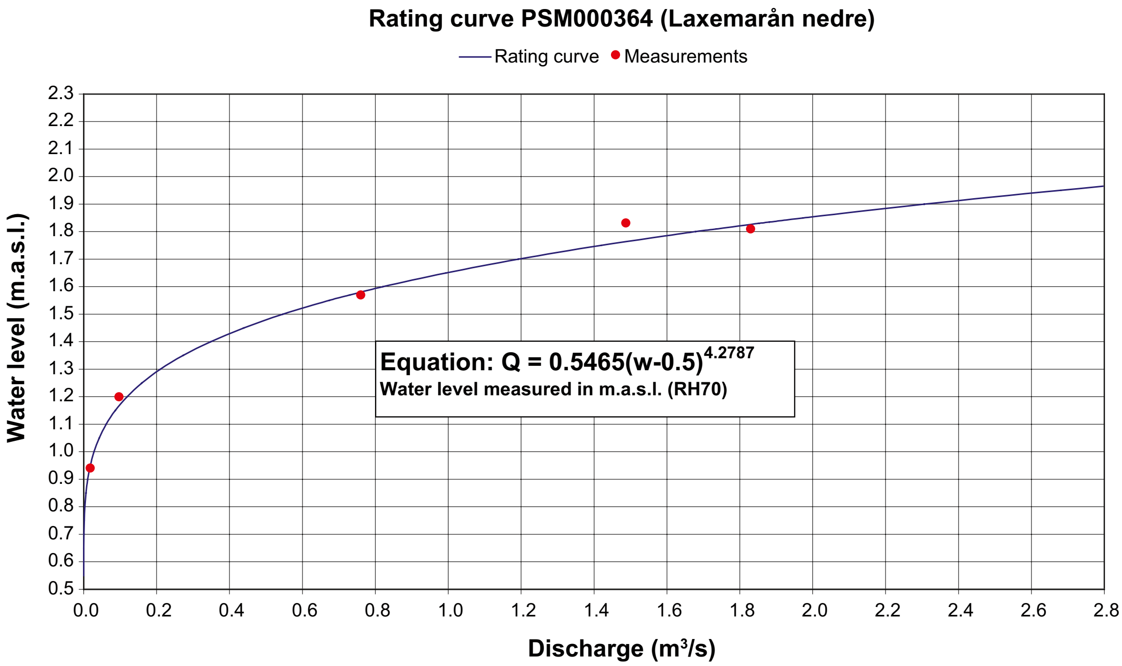


Figure A2-8. *Rating curve for PSM000364 Laxemarån lower based on control measurements made up to 2006-10-01.*

PSM000368

The discharge in Kärrviksån is determined by using downstream sections and contractions in the watercourse. The discharge is for the present calculated by two rating curves, since control measurements have shown that different sections is determining the discharge in different rating registers. The first is valid up to water level +1.94 m.a.s.l. and the other for higher water levels. The following rating curve has been established based on control measurements made up to 2006-10-01.

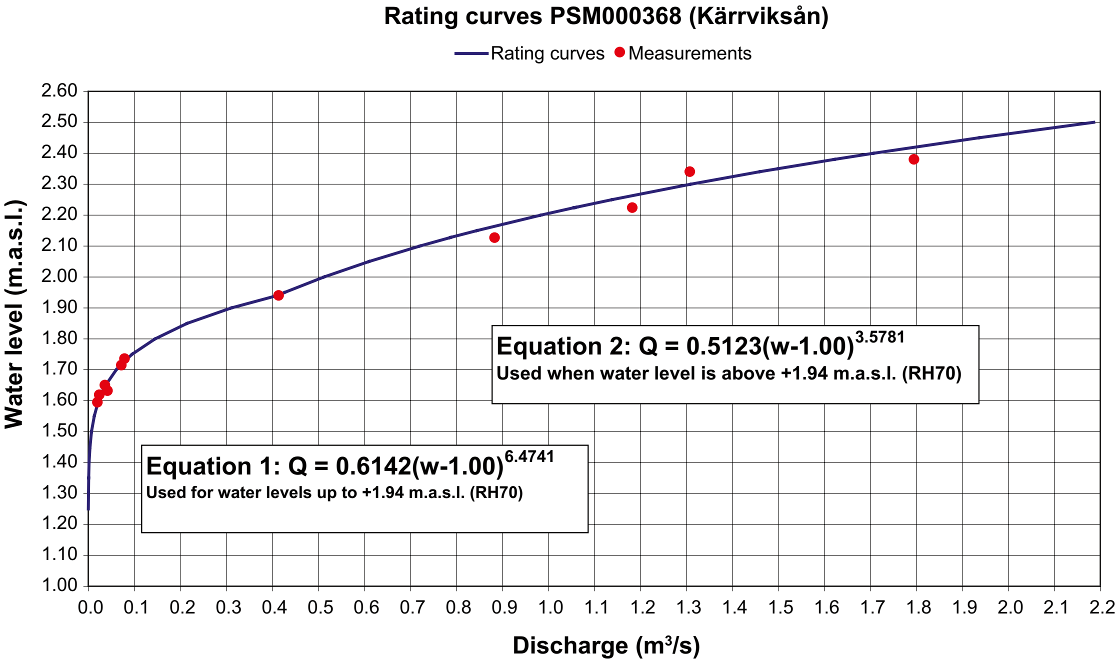


Figure A2-9. *Rating curve for PSM000368 Kärrviksån based on control measurements made up to 2006-10-01.*

Appendix 3

Measurements of snow cover

Primary data from snow depth measurements during the winter 2008/2009

The data collected during the snow depth measurements are presented below as individual measurements as well as the calculated average snow depth and a visual estimate of the coverage degree. S = completely or almost covered ground, SB = more than half of the ground snow covered but not completely covered, BS = more than half of the ground free of snow but not completely, B = the ground completely or almost completely free of snow.

Table A3-1. Snow depth at "Grillplatsen" (ASM100224) during the winter 2008/2009.

Start date	Stop date	Point 1 (cm)	Point 2 (cm)	Point 3 (cm)	Point 4 (cm)	Point 5 (cm)	Point 6 (cm)	Average snow cover (cm)	Snow coverage
2008-11-03	2008-11-03								B
2008-11-21	2008-11-21								BS
2008-11-24	2008-11-24	4	4	3	3	4	4	3.7	S
2008-12-02	2008-12-02								B
2008-12-08	2008-12-08								B
2008-12-18	2008-12-18								B
2009-01-13	2009-01-13								B
2009-01-29	2009-01-29								B
2009-02-04	2009-02-04								B
2009-02-09	2009-02-09								B
2009-02-12	2009-02-12	18	18	17	17	18	19	17.8	S
2009-03-02	2009-03-02								BS
2009-03-19	2009-03-19								B
2009-04-03	2009-04-03								B

Measurements of ground frost

Primary data from measurement of frost in the ground during the winter 2008/2009

The data collected during the measurements of ground frost are presented below. As the whole device was not situated within the ground, the levels for ground surface are above the 0-level. The upper registration is the level of the upper border of the ground frost read from the device whereas the lower registration is the lower border. The upper and lower levels of ground frost are calculated using the level of the ground surface and the upper and lower registrations, respectively. From these two levels the distribution of ground frost has been calculated.

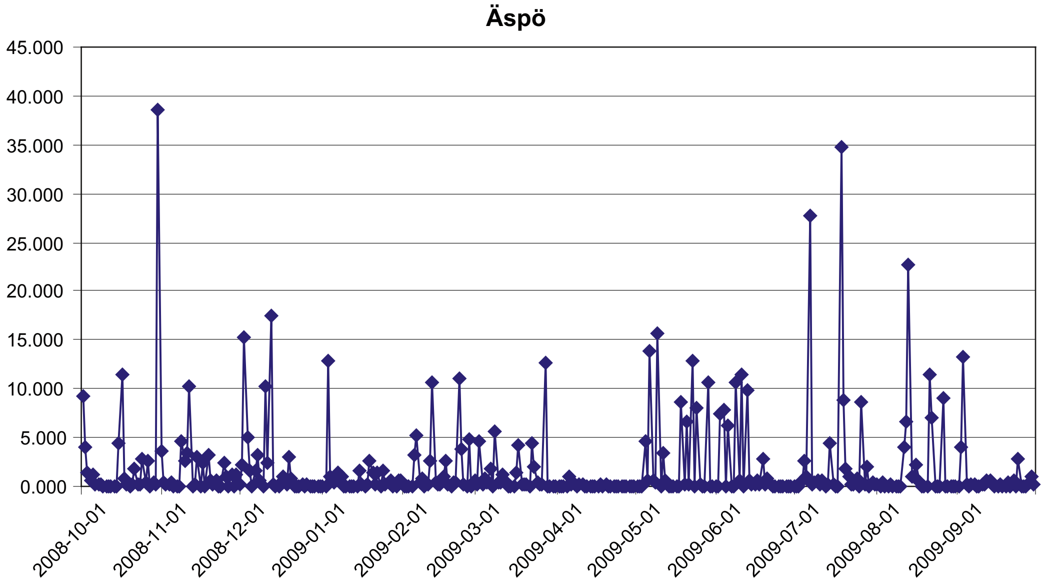
Table A4-2. Frost in ground during the winter 2008/2009 at Äspö (PSM6978).

Start Date	Stop Date	Ground surface (cm)	Upper reg (cm)	Lower reg (cm)	Upper level of ground frost (cm)	Lower level of ground frost (cm)	Ground frost distribution (cm)
2008-11-03	2008-11-03	102.0					
2008-11-14	2008-11-14	102.0					
2008-11-21	2008-11-21	102.0		103.0		1.0	1.0
2008-11-24	2008-11-24	102.0		103.0		1.0	1.0
2008-12-08	2008-12-08	102.0					
2009-01-13	2009-01-13	102.0					
2009-01-29	2009-01-29	102.0					
2009-02-11	2009-02-11	102.0					
2009-02-13	2009-02-13	102.0					
2009-02-23	2009-02-23	102.0					
2009-03-02	2009-03-02	102.0					
2009-03-19	2009-03-19	102.0					
2009-04-03	2009-04-03	102.0					

Table A4-3. Frost in ground during the winter 2008/2009 at Grindstugan (PSM6979).

Start Date	Stop Date	Ground surface (cm)	Upper reg (cm)	Lower reg (cm)	Upper level of ground frost (cm)	Lower level of ground frost (cm)	Ground frost distribution (cm)
2008-11-03	2008-11-03	105.0					
2008-11-14	2008-11-14	105.0					
2008-12-08	2008-12-08	105.0					
2009-01-13	2009-01-13	105.0					
2009-01-29	2009-01-29	105.0					
Device was exchanged 2009-02-06							
2009-02-06	2009-02-06	110.0					
2009-02-09	2009-02-09	110.0		113.0		3.0	3.0
2009-02-11	2009-02-11	110.0	110.0	111.0	0.0	1.0	1.0
2009-02-23	2009-02-23	110.0					
2009-03-02	2009-03-02	110.0		112.0		2.0	2.0
2009-03-19	2009-03-19	110.0		112.0		2.0	2.0
2009-04-03	2009-04-03	110.0					

Meteorological monitoring



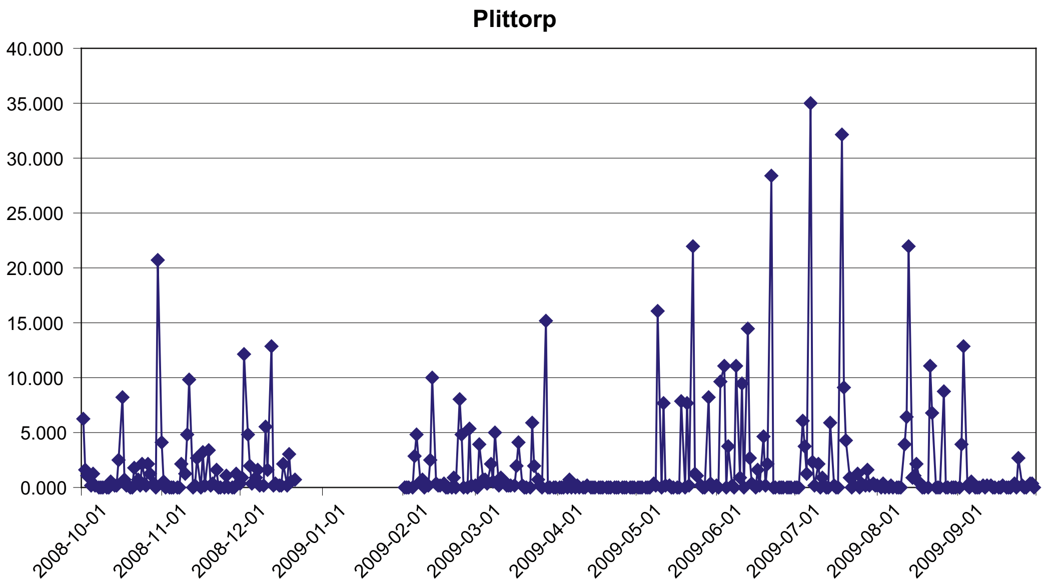


Figure A5-1a. *Precipitation (COR) in mm, daily values. October 2008–September 2009.*

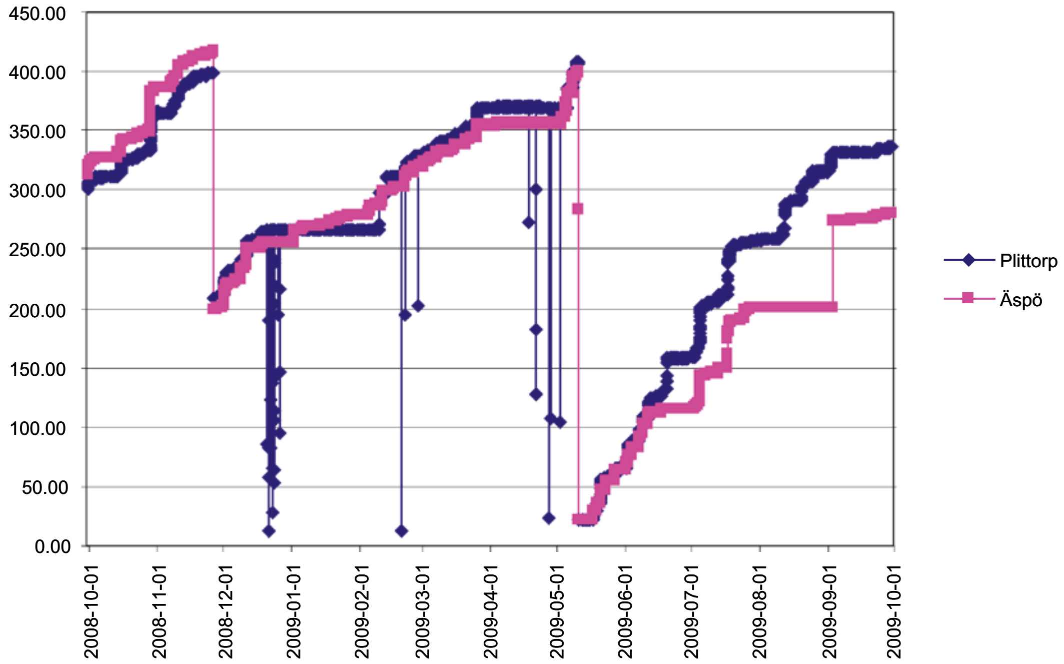


Figure A5-1b. *Precipitation in mm, daily values 30 min values. October 2008–September 2009.*

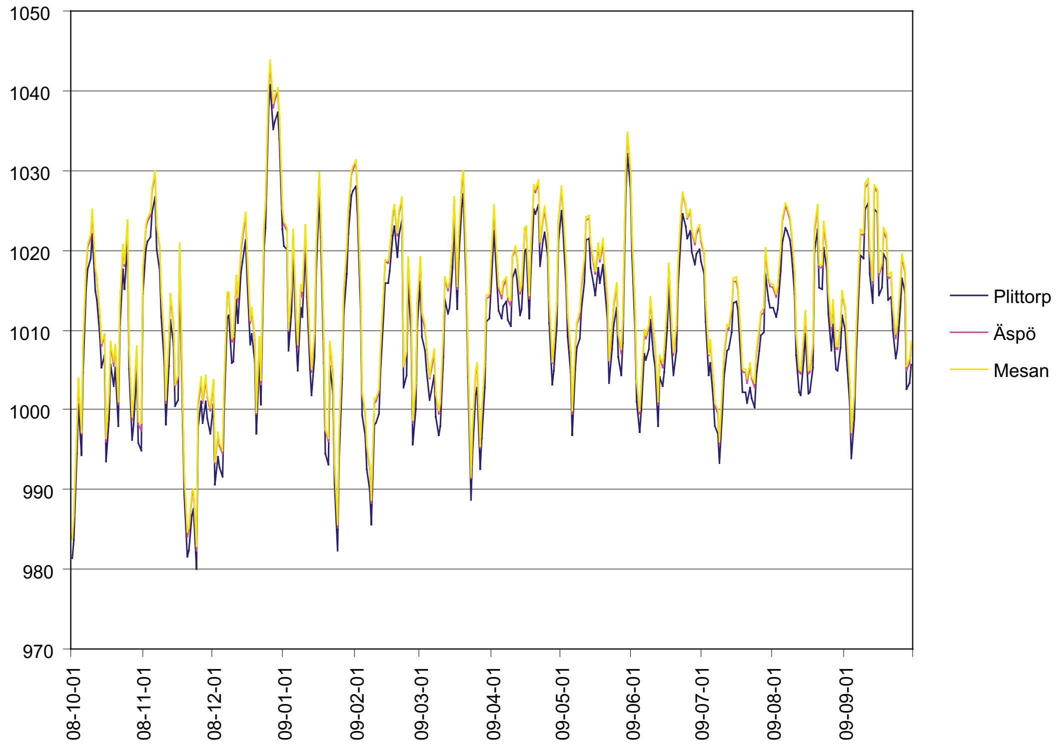


Figure A5-2. *Barometric pressure in hPa, daily values. October 2008–September 2009.*

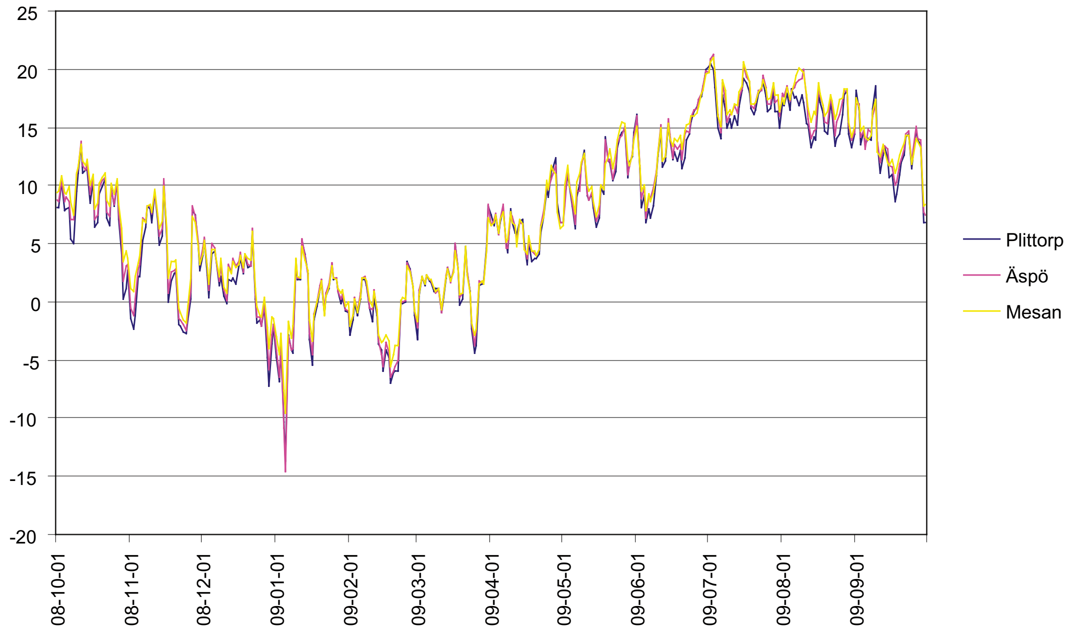


Figure A5-3. *Temperature in °C, daily values. October 2008–September 2009.*

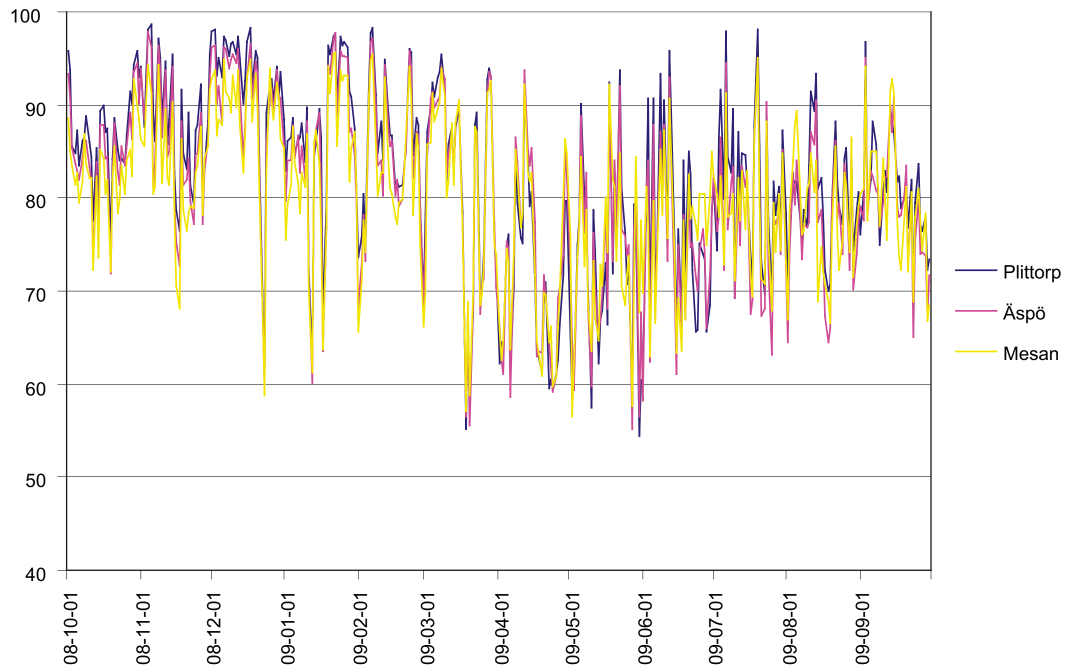


Figure A5-4. *Relative humidity in %, daily values. October 2008–September 2009.*

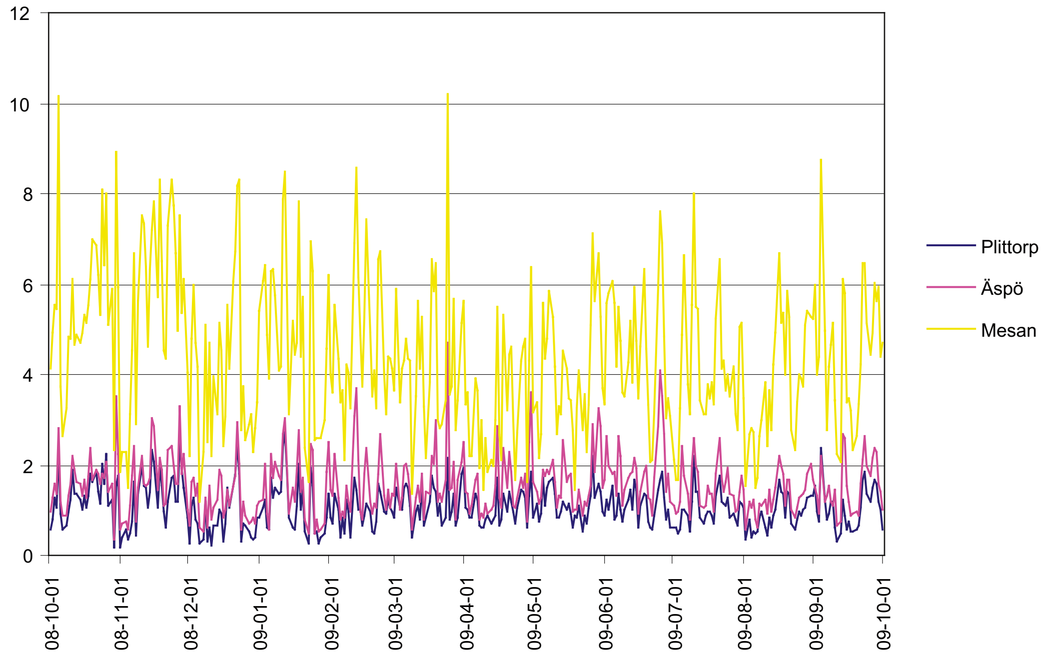
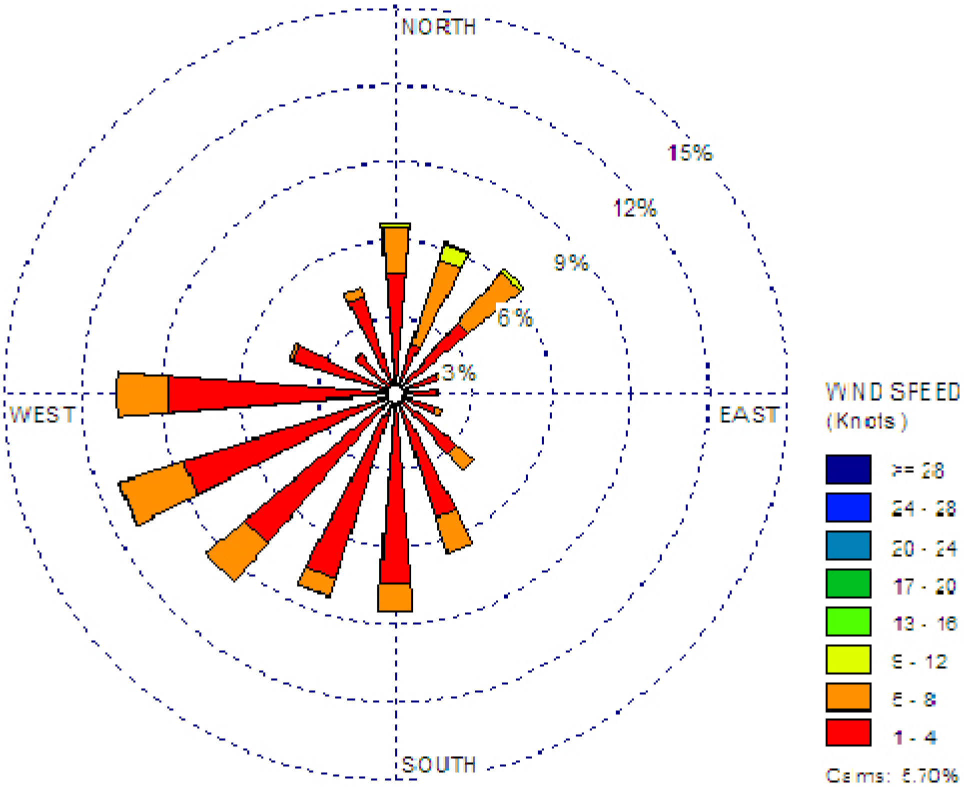


Figure A5-5. *Wind speed in m/s, daily values. October 2008–September 2009.*



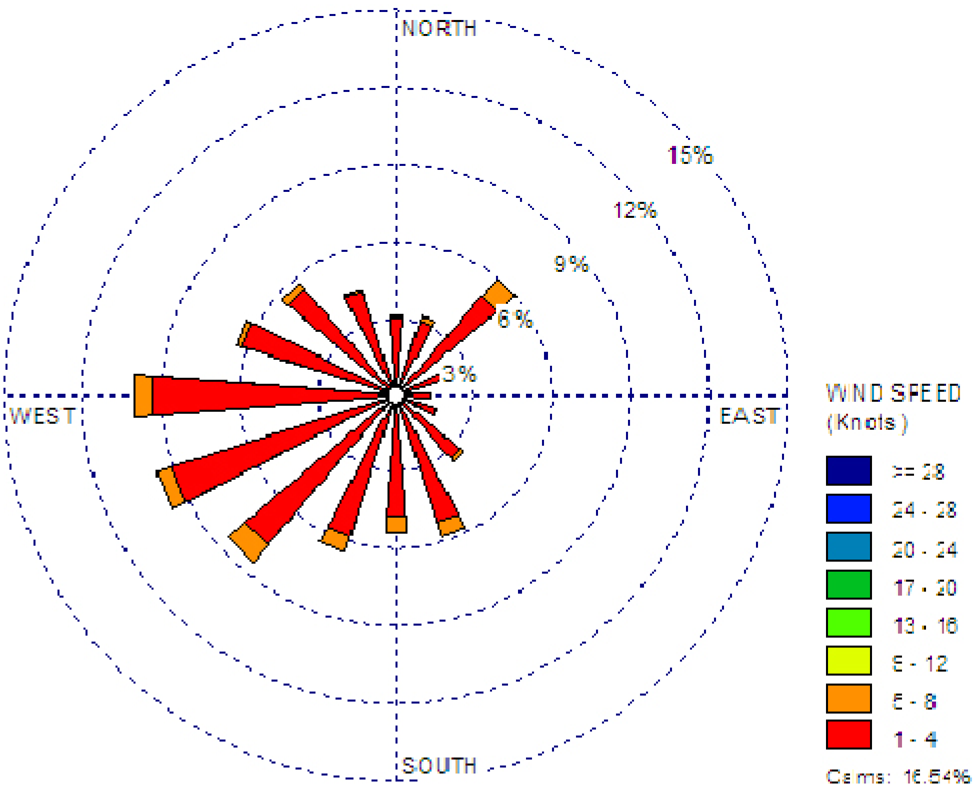


Figure A5-6. *Windroses of 30-minutes values for Äspö and Plittorp. October 2008–September 2009.*

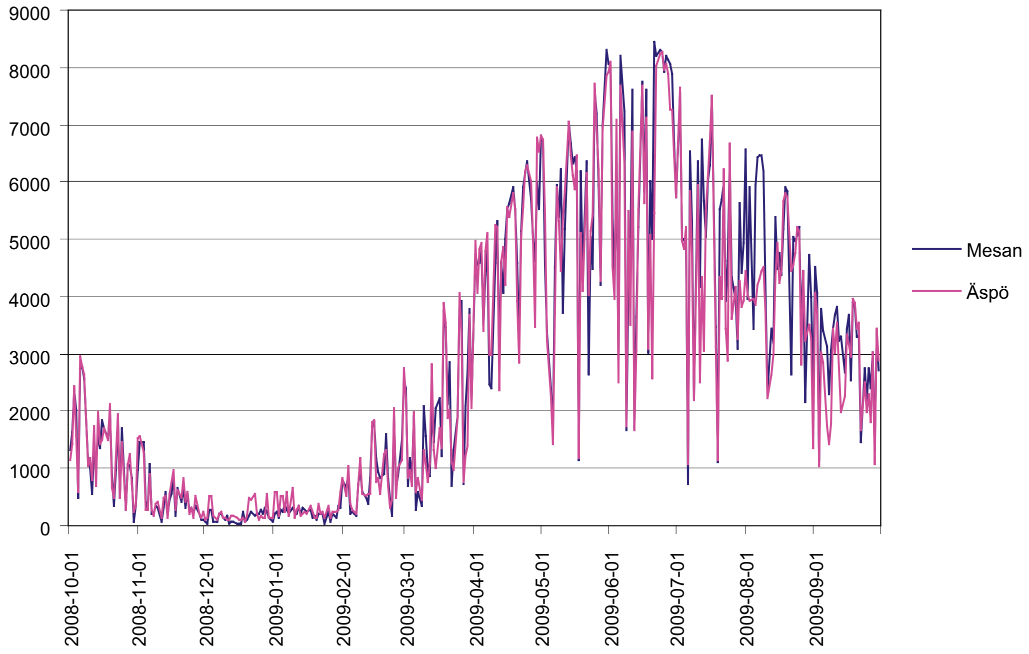


Figure A5-7. *Global radiation in Wh/m², daily sum. October 2008–September 2009.*

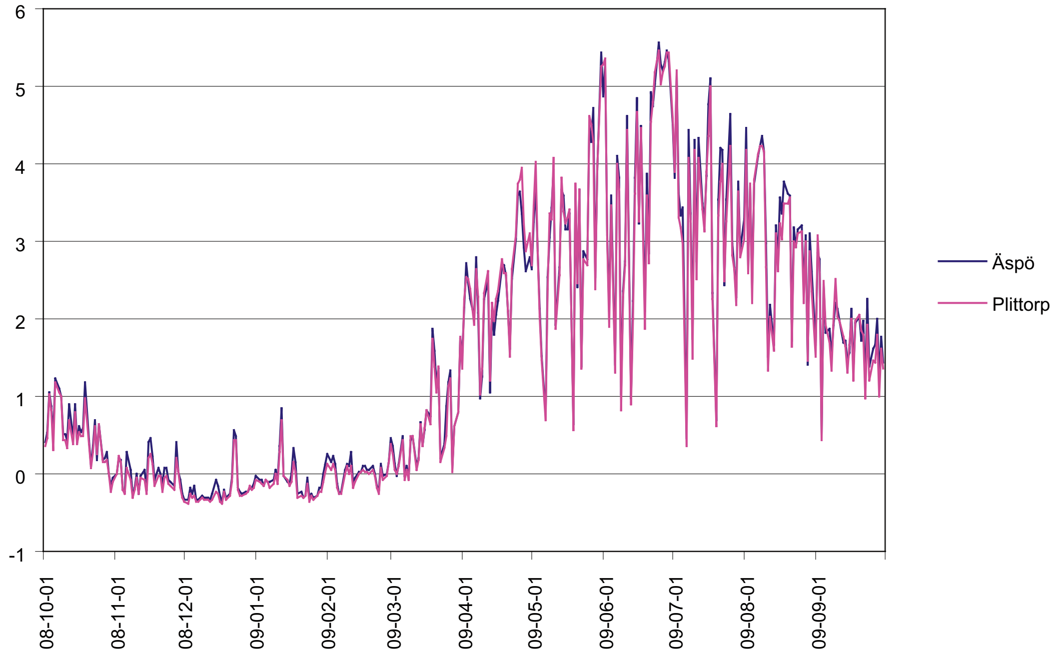


Figure A5-8. *Potential evapotranspiration in mm, daily sum. October 2008–September 2009.*

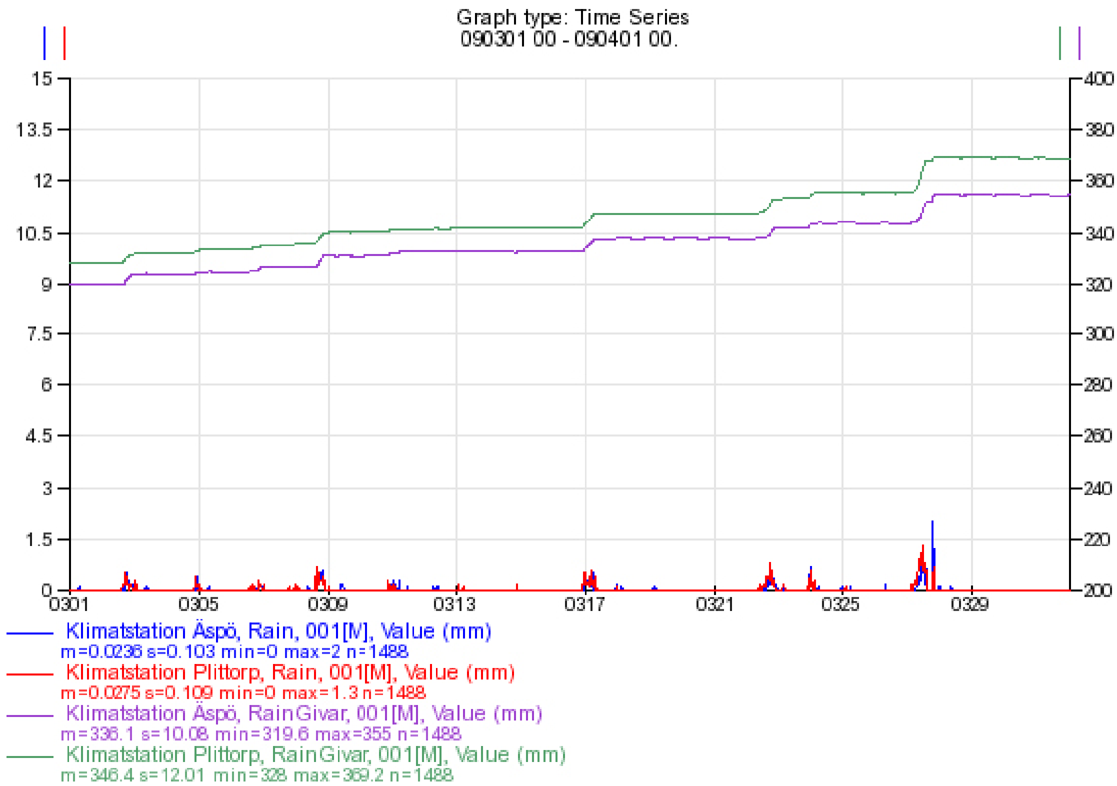


Figure A5-9. *Precipitation in mm, 30 min values. March 2009.*

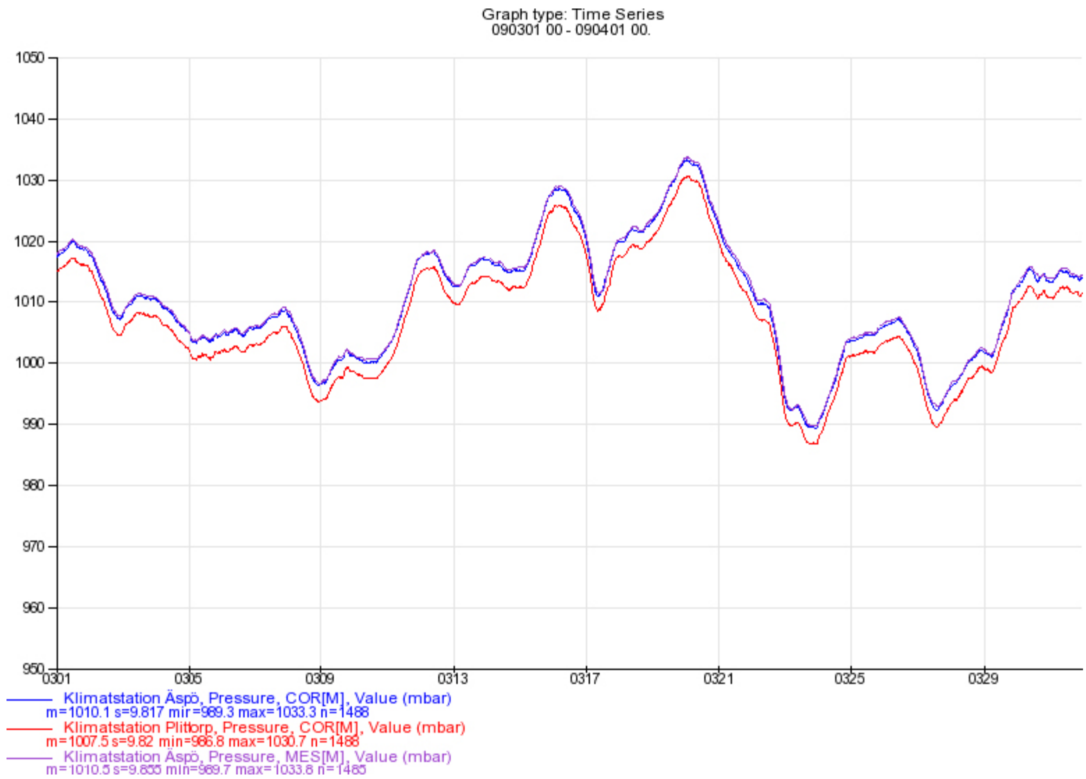


Figure A5-10. *Barometric pressure in Pa, 30 min-values. March 2009.*

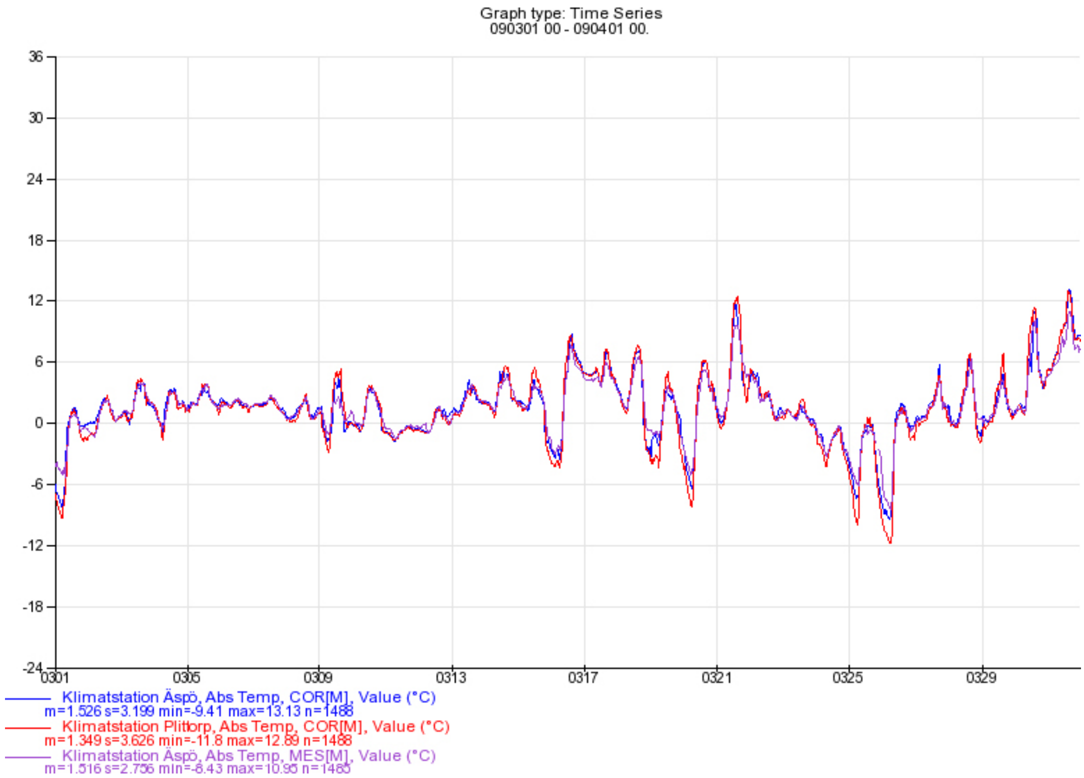


Figure A5-11. *Temperature in °C, 30 min-values. March 2009.*

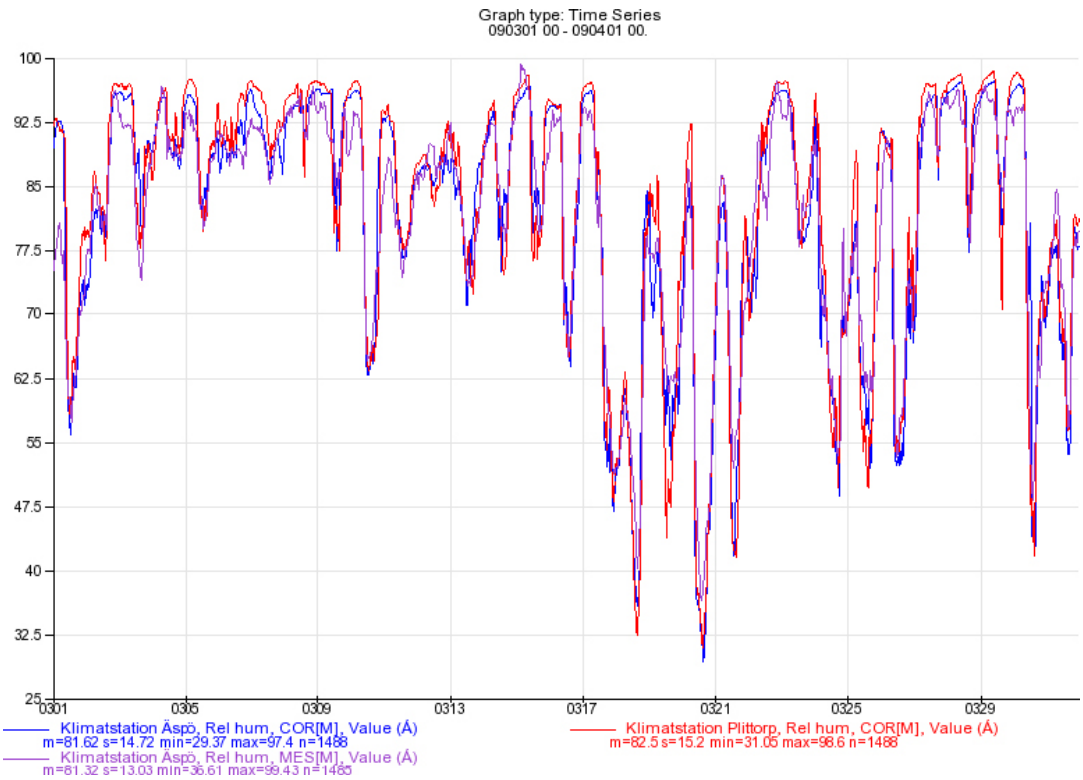


Figure A5-12. *Relative humidity in %, 30 min-values. March 2009.*

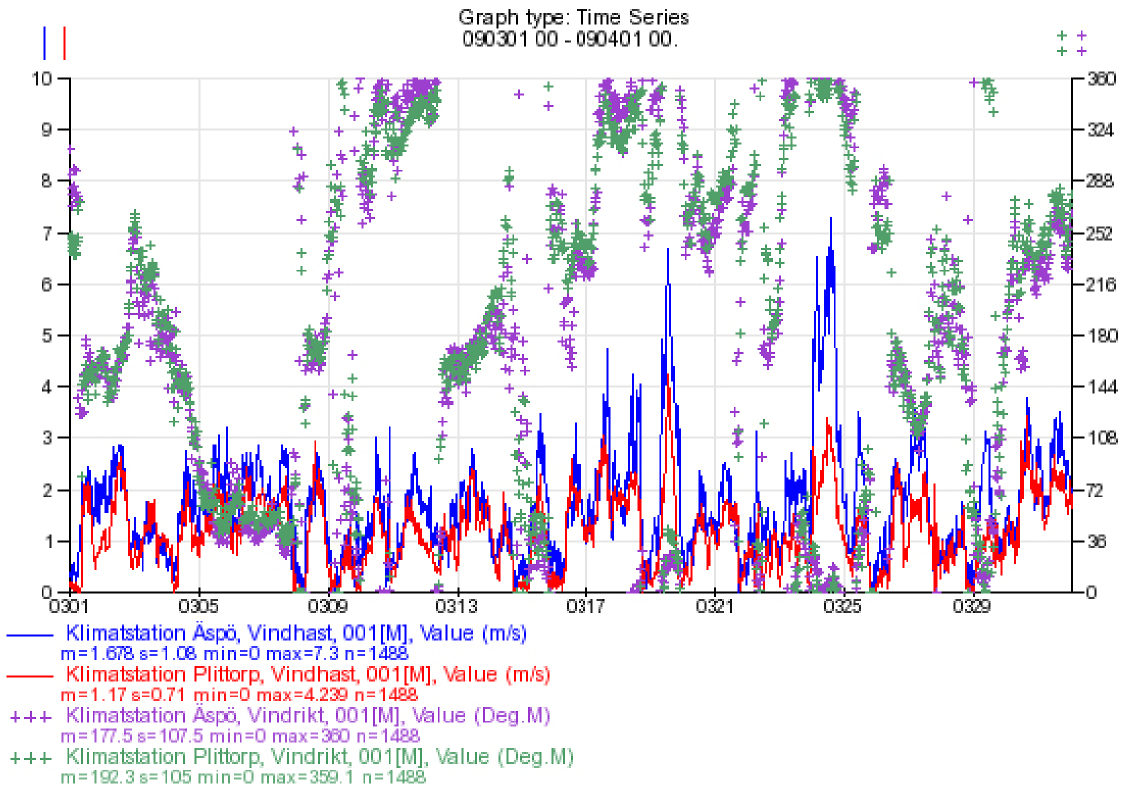


Figure A5-13. *Wind speed in m/s and wind directions in ° , 30 min values. March 2009.*

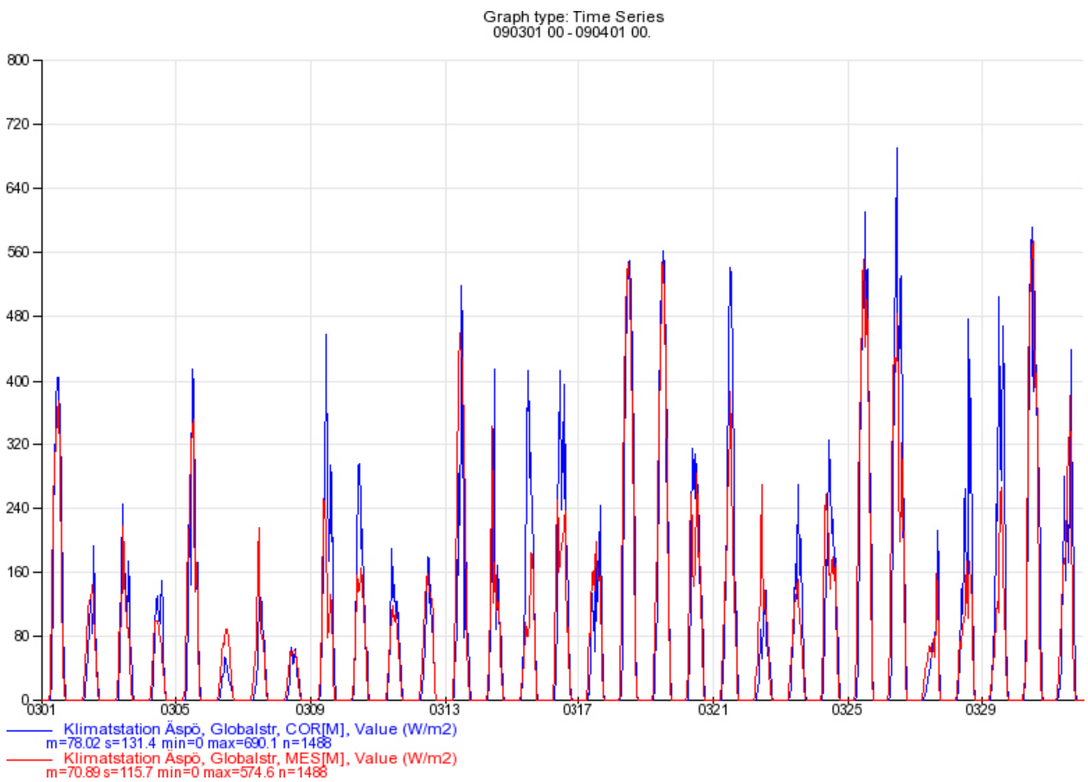


Figure A5-14. *Global radiation in W/m², 30 min values. March 2009.*

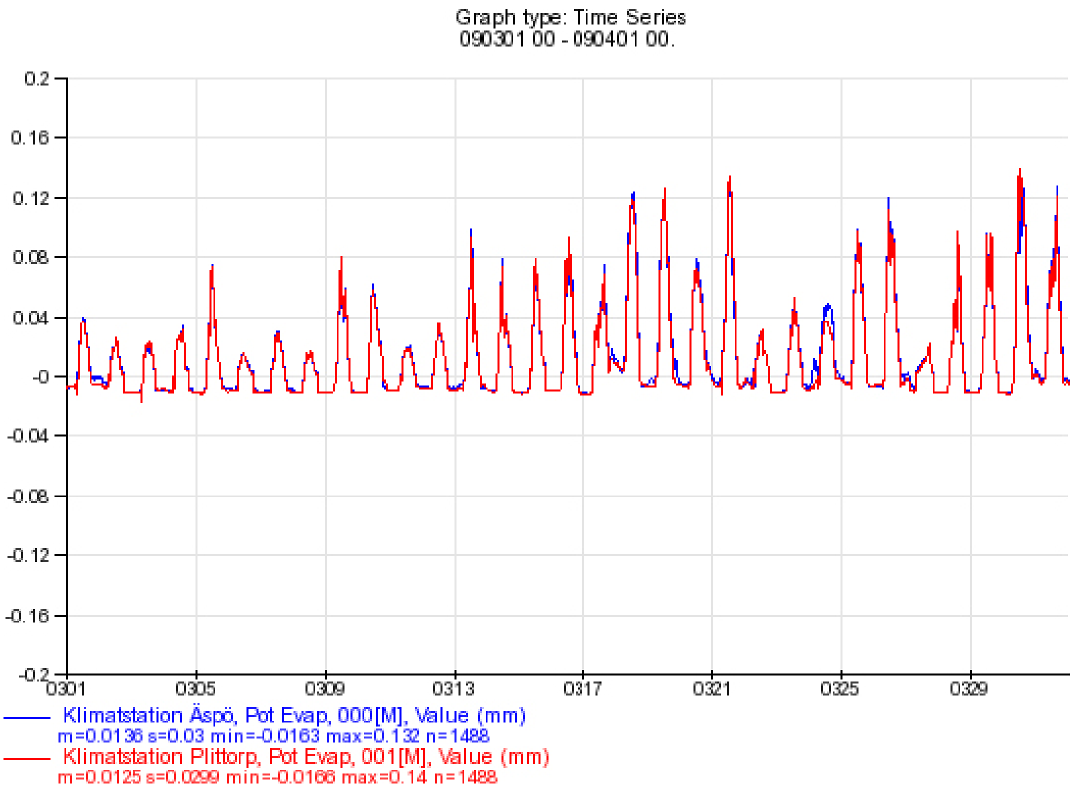


Figure A5-15. *Evapotranspiration in mm, 30 min values. March 2009.*

Appendix 6

Water level fluctuations

SKB – "Water level fluctuations" Oskarshamn

Issue

According to measurements, there are daily fluctuations in water level at some stations, see Figures A6-1 and A6-2. The question to be asked is whether this affects the daily mean discharge or not.

Investigation

We have studied the registered water levels at PSM000347, PSM000341, PSM000343 and PSM000345, and records of precipitation and temperature at Äspö.

Conclusions

- Apart from PSM000341 the daily fluctuations are negligible compared to the total fluctuations during the year (Figure A6-1). (There are greater uncertainties in data – see for example station PSM000345 in December 2008.)
- The fluctuations mainly occur during the summer season and are directly connected to the daily fluctuations in temperature; small fluctuations in temperature => small fluctuations in water level (Figure A6-2).
- Possible reasons to the fluctuations:
  - The water inflow to the station varies due to variation in evaporation in the catchment area.
  - The water level in the dam varies due to the fact that evaporation is greater during the warm part of the day.
  - The water level in the dam varies due to the fact that density of water varies with temperature.
  - The water level instrument is sensitive to temperature.
- There is no obvious explanation to the difference in size of the fluctuations between different areas.

Notes

For PSM000341 there are measurements from two instruments. At least for July 2009 the differences between these two instruments cannot be neglected if one is interested in precise data when recording low water levels (Figure A6-3).

A SMHI station that may be relevant to compare with is Ryttarbacken in Söderköpingsån (7.3 km^2). Even here there are daily fluctuations but it is hard to find a certain pattern (Figure A6-4).

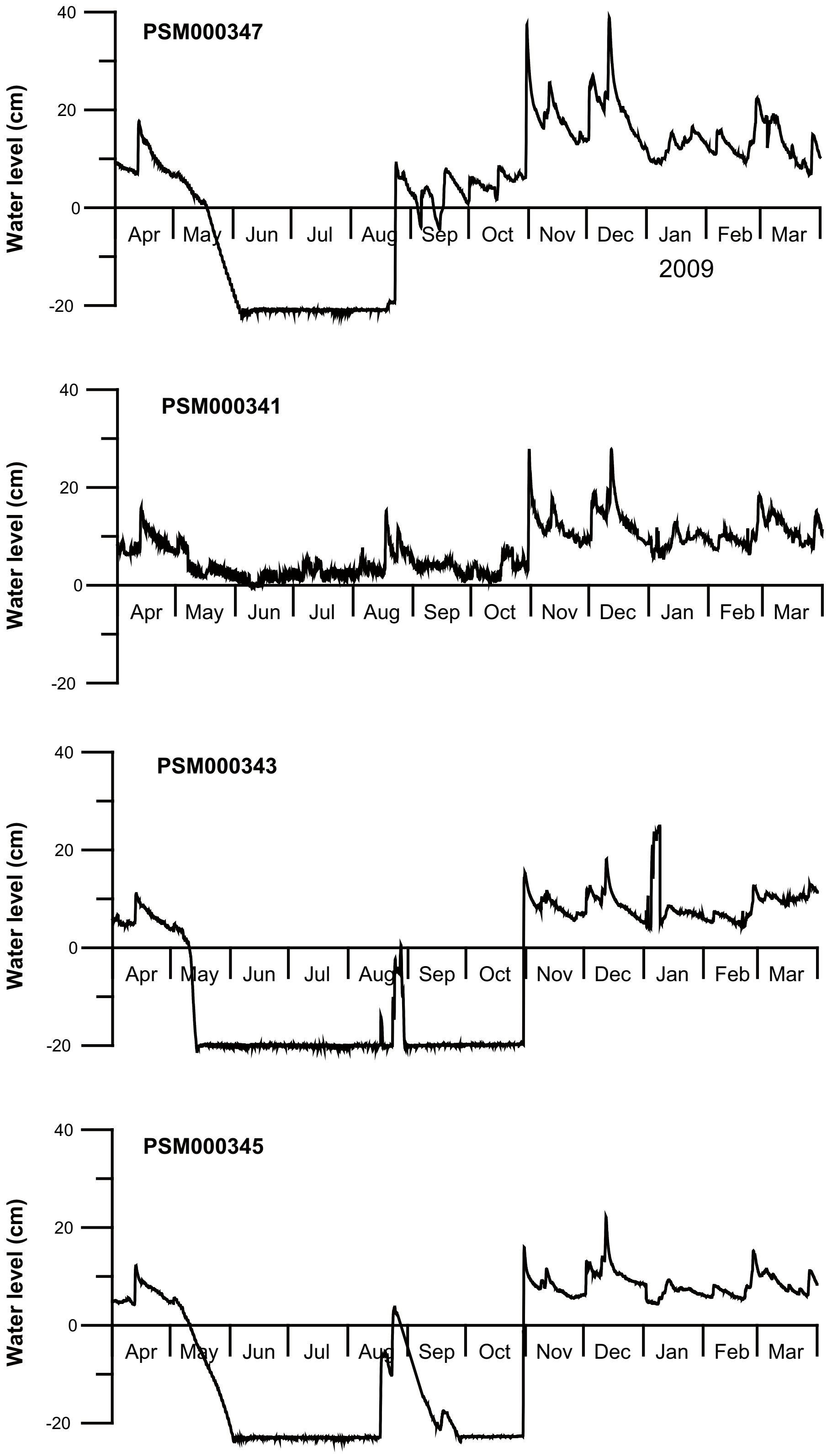


***Figure A6-1.** Water level fluctuations 20080401 to 20090401.*

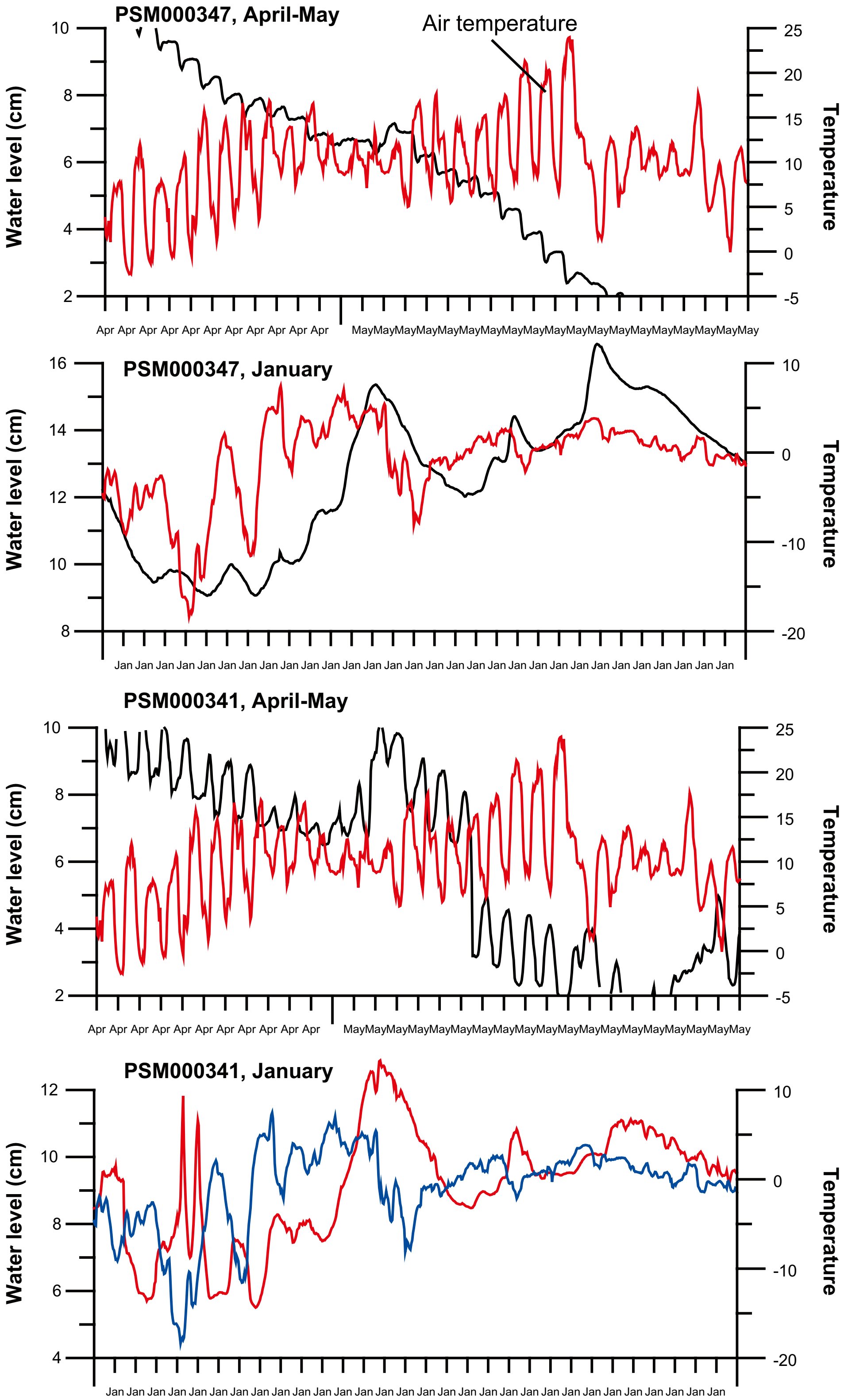


Figure A6-2. *Detailed comparison between fluctuations water level/temperature. Summer and winter respectively.*

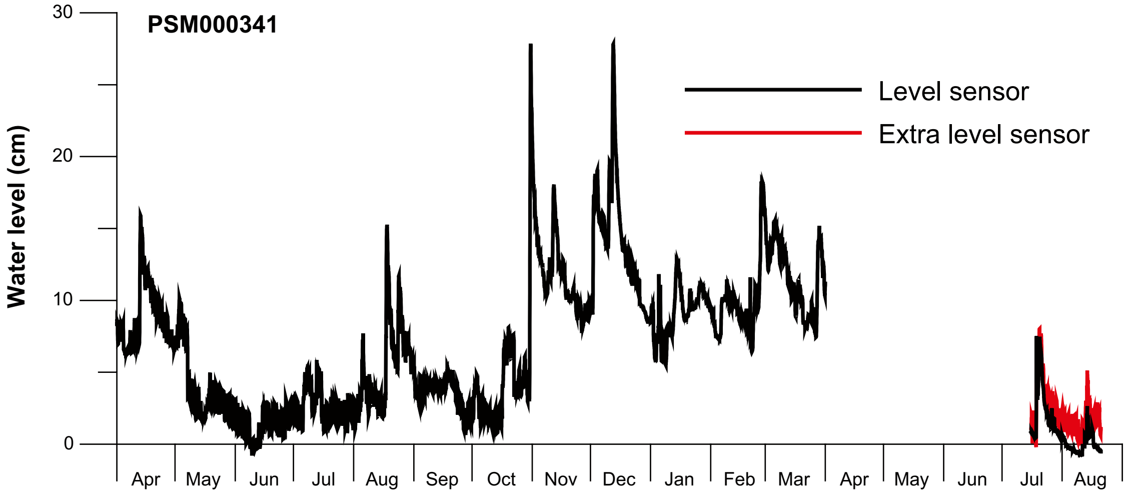


Figure A6-3. *Measurements from two different instruments at Ävrö 1.*

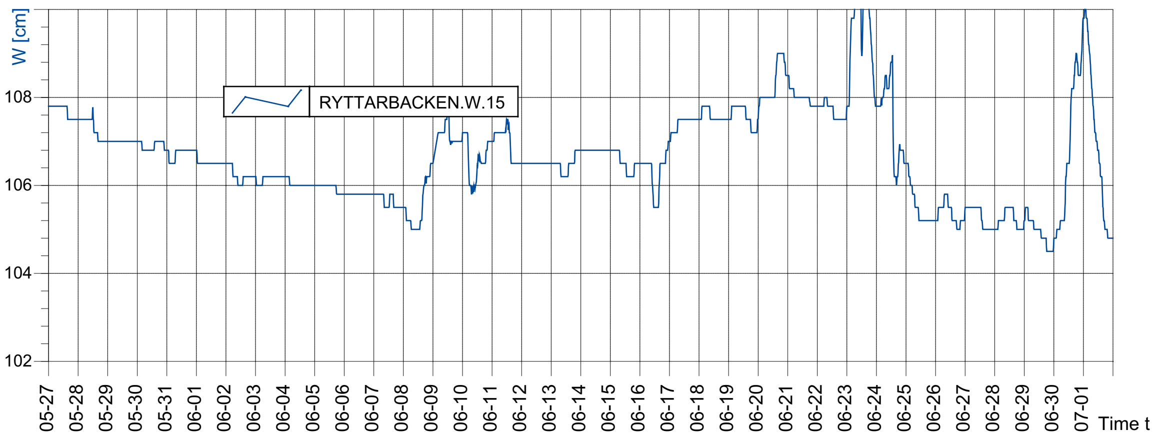


Figure A6-4. *Exemple of measurements with high resolution from Ryttarbacken (May–June 2008).*