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The Balsjö Catchment Study

– EXPERIMENTAL SET-UP AND DATA COLLECTION

Balsjö-studiens avrinningsområden – Försöksuppläggning och datainsamling

Photo E.Ring

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Sammanfattning

Balsjö-studien startades år 2004 i Västerbotten i norra Sverige, som ett demonstrationsområde för trädklädda kantzoner inom EU Life-projektet ”Forest for water” (LIFE03 ENV/S/000601). Studien kom även att inbegripa mer forskningsinriktade frågor. Vattenkemi, vattenflöden m.m. har följts i sex skogsdominerade avrinningsområden mellan 2004 och 2016. Skogen och markförhållandena är representativa för stora delar av denna region. Avrinningsområdenas storlek varierar från ca 20 till 2300 ha. År 2006 slutavverkades två avrinningsområden. Ena området avverkades hela vägen fram till vattendraget medan det andra avverkades med en ca 5–10 m bred trädklädd kantzon på vardera sidan av vattendraget. Studien har utförts i samarbete mellan främst Skogforsk och SLU. I denna rapport beskrivs studien med avseende på försöksuppläggning, datainsamling och publicerade artiklar.

Summary

The Balsjö Catchment Study was started in 2004 in the county of Västerbotten, northern Sweden, to demonstrate the functions of forest buffers as part of the EU Life project “Forest for water” (LIFE03 ENV/S/000601). The study was subsequently extended to address research-oriented issues. Variables including water chemistry and streamflow parameters have been monitored in six forest catchments between 2004 and 2016. The forest and the soil conditions are typical for large areas in this region. The catchment areas vary from approximately 20 to 2300 ha. In 2006, stands in two catchments were harvested. One catchment was harvested all the way to the stream while in the other a 5-10 m wide forest buffer was left on each side of the stream. The study has been performed as a co-operation mainly between Skogforsk and SLU. This report describes the study in detail in terms of experimental design, data collection and published papers.

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Preface

The Balsjö Catchment Study was started as a demonstration area for forest buffers as part of the broader EU Life project “Forest for water” (LIFE03 ENV/S/000601 running from 2003–2007), co-ordinated by the Swedish Forest Agency. The study was subsequently extended to address research-oriented issues. It has been performed co-operatively, mainly by staff of Skogforsk and the Swedish University of Agricultural Sciences (SLU), but scientists from other universities have also participated. The Balsjö Catchment Study has been successful and generated many valuable results. Publications presenting data from the Balsjö Catchment Study are listed in Appendix 1. Scientists representing various disciplines have been able to utilize the same experimental sites, thus increasing the amount and types of data collected. This has deepened our understanding of the responses to final felling. A paired catchment study like this requires large areas, long-term funding and good co-operation with the landowner. Given this background, we would like to thank Holmen AB for hosting the study on their land and providing various kinds of assistance on site. We would also like to thank all the organizations that have financially supported the Balsjö Catchment Study: the County Administration Board of Västerbotten, Skogforsk, EU Life, the Swedish Environmental Protection Agency, the Swedish Forest Agency, Formas, SLU, and Future Forest, a multidisciplinary research program supported by the Foundation for Strategic Environmental Research, the Swedish forestry, SLU, Umeå University, and Skogforsk.

Uppsala, October 2019

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Contents

Introduction

Several studies have shown that forestry operations can detrimentally affect surface-water quality (Ahtiainen & Huttunen 1999, Porvari et al. 2003, Gundersen et al. 2006, Kreutzweiser et al. 2008). However, knowledge of logging's effects on surface water, guidelines for logging practices, and surface-water quality protection measures in Sweden (Ring et al. 2008a, Ring et al. 2008b) are largely based on data acquired in a limited number of studies performed in south and central Sweden during the 1970s and 1980s (Grip 1982, Rosén 1984, Wiklander et al. 1991, Lundin 1994, Rosén et al. 1996, Lundin 1999). Before 2004 there had been no relevant catchment-scale field studies in northern Sweden (Löfgren 2007), and little pertinent information was available for boreal Fennoscandia generally. Furthermore, during the 1970s and 1980s forestry operations such as logging, site preparation, fertilization and peatland drainage were generally performed with less consideration for the environment than in modern forestry. Applying results of previous studies to current forestry introduced substantial uncertainty, especially in northern Sweden, where they also lacked climatic relevance. Thus, there was a clear need for more knowledge of effects of current logging practices on surface-water quality in the boreal region of Fennoscandia. Hence, the Balsjö Catchment Study was started in 2004 to investigate effects of current logging practices on stream-water quality in small catchments in northern Sweden. The study site is typical for the boreal region in terms of soils and climate

Study site and experimental design

The Balsjö Catchment Study site, also referred to as Skogforsk experiment 277 Balsjö, covers six catchments in a Natura 2000 (natural heritage preservation) area in northern Sweden, about 60 km west of Umeå (Figure 1), where the annual mean air temperature and precipitation are about 0.6 °C and 538 mm, respectively (Alexandersson & Eggertsson Karlström 2001). The growing period, defined as the period during the year when the daily mean air temperature exceeds +5°C, typically lasts 150-180 days (Raab & Vedin 1995). Four of the six catchments are drained by headwater streams (Ref-L, Ref-S, CC & BS; Figure 1, Table 1). These catchments have been used for studying effects of final felling, while the two largest catchments (BA-1 & BA-2) and Ref-L have been used for studying scale issues.

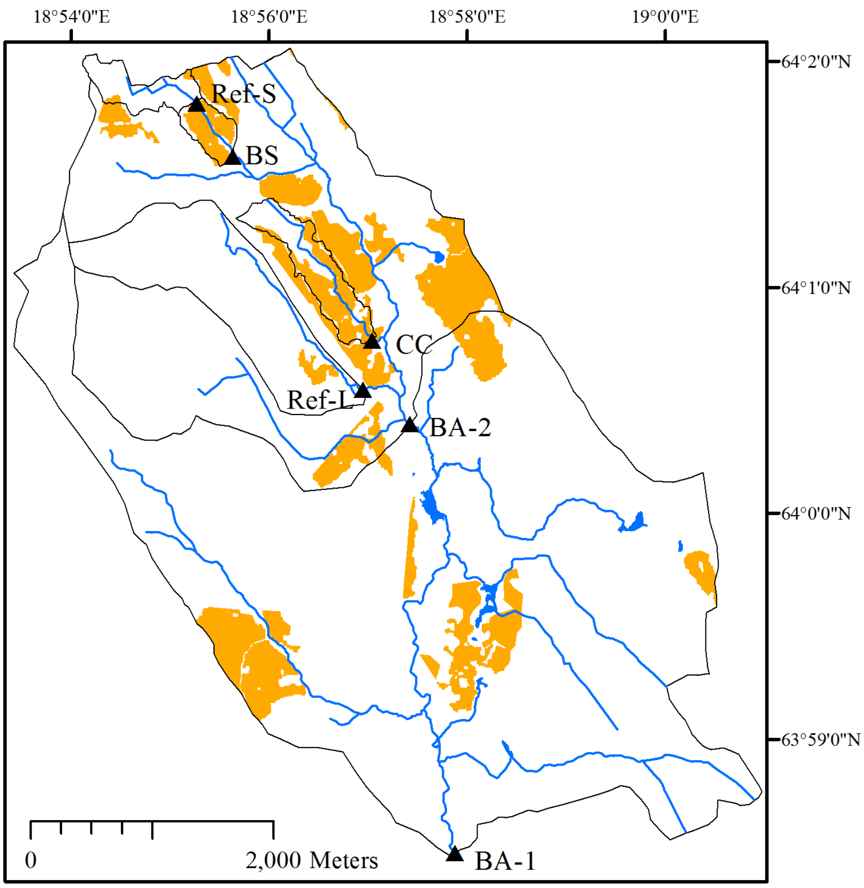

Figure. 1. Map of the six catchments monitored in the Balsjö Catchment Study. Blue areas denote open water bodies and blue lines streams. Orange areas show sites of final fellings performed between 2001 and 2011 derived from satellite data. The triangles (▲) indicate catchment outlets (see Schelker et al. (2014) for a full description).

Table 1. Description of the catchments monitored in the Balsjö Catchment Study, data from Schelker et al. (2014).

Catchment	Abbreviation	Weir	Size (ha)	Wetlands (%)	Harvested area (%) in 2004/2011	Altidtude at catchment outlet (m)	Treatment
Large reference	Ref-L	Balån 3	156	3	0/3	258	No treatment*
Small reference	Ref-S	Balån 7**	24	16***	0/16	301	No treatment until 2011, when about 3 ha was harvested
Clear-cutting	CC	Balån 4	41	7	0/64	257	64% of the catchment was clear-cut in 2006
Clear-cutting with buffer including Ref-S	BS	Balån 5	40	12	0/35	292	See Ref-S and BS_{CC}
Clear-cutting with buffer	BS_{CC}	Balån 5	16	2	0/87	292	87% was clear-cut in 2006, leaving a 5-10 m wide buffer with trees on both sides of the stream
Balån 2	BA-2	–	868	10	5/18	247	Normal land use for forest land
Balån 1	BA-1	Balån 1	2 291	15	2/11	228	Normal land use for forest land

* An area close to Balån 3 was harvested, probably during the winter in 2005/2006.

** Initially, there were two weirs at Ref-S: Balån 7, used for measuring water flow, and Balån 6 about 50 m downstream, used for streamwater sampling.Balån 6 was removed in 2010.

*** Additional harvesting was performed in November 2014.

The following site description is based on the description presented by Löfgren et al. (2009) (see Löfgren et al. (2009) for references). In the study area, the highest marine shoreline following the last glaciation is located 270 m above current mean sea level. The outlet altitudes indicate that the Ref-S and BS catchments are entirely above the highest marine shoreline, while the Ref-L and CC catchments are partly below it (Table 1). The bedrock consists of late-orogenic pegmatite with aplitic granite and aplite, except in small parts of the Ref-S and BS catchments where it is sedimentary veined gneiss (metagreywacke or meta-argillite). Above the highest marine shoreline, the soil mainly consists of unwashed till. Mires and fens are scattered across the catchments (Table 1). The dominant soil type is orthic podsol with histosols in wetter areas. Prior to harvesting, the field layer in the upland areas was dominated by *Vaccinium* species (mainly *V. myrtillus* L. and *V. viitis*-idea L.) with small patches of *Deschampsia flexuosa* (L.) Trin. Various Sphagnum species and sedges dominated in the peaty areas along the streams.

The tree-species composition before harvesting was quite similar in the Ref-S, CC and BS catchments, consisting of *Pinus sylvestris* L. and *Picea abies* (L.) H. Karst with small proportions of *Betula* spp. (Appendix 5). The conifer stands were between 85 and 120 years old. In the drier upland areas, *P. sylvestris* dominated while *P. abies* dominated closer to the streams and in wetter patches. The site-quality index varied between T22 and G18, which corresponds to an annual growth rate of 3.3 to 4.4 m^3 ha^{-1} yr^{-1}. Based on felled volume, the average standing volume was approx. 200 m^3 ha^{-1}. When the study commenced, the Ref-L catchment was covered by young *P. sylvestris*-dominated stands, less than ca. 30 years old.

FINAL FELLING

In March 2006, the tree stands in the CC and BS_{CC} catchments were harvested while the ground was frozen and covered by more than 1 m of snow (Table 2). These conditions largely prevented rutting. Only the stems were harvested, leaving tops and branches on site. The harvested areas accounted for about 35% and 64% of the BS and CC catchments, respectively (Table 1). Contractors performed the logging according to normal practices, following general instructions given by the forest owner. The environmental protection measures were planned and conducted entirely by the logging crew. High stumps, retention trees and small patches of trees on rocky and wet areas were left intact. A forest buffer was left along the BS stream and the BS catchment was harvested without crossing the stream. At the CC catchment, a woodland key habitat was left in the upper part but no forest buffer was left along the stream; trees were harvested all the way down to the stream. The machines had to cross the CC stream at two places, approximately 200 m and 500 m upstream of the gauging station. To reduce potential effects of these crossings, logs were placed in the stream as temporary bridges. The harvest operations could be regarded as representative of harvest practices routinely applied in large areas of northern Sweden at that time.

Table 2. Total timber volumes harvested at the Balsjö Catchment Study site in 2006 according to data from Holmen AB.

Assortment	Timber volume (m^3sub*)
P. sylvestris sawlogs	3 449
P. abies sawlogs	1 037
Superior quality logs (coniferous)	12.6
Pulpwood (coniferous)	1 912
Pulpwood (deciduous)	201
Pole timber	132
Firewood	4.6
Total	6 749

* Solid volume under bark

FOREST BUFFER

The forest buffer in the BS_{CC} catchment was designed in accordance with the forest owner's standard practices, leaving trees where there was a continuous cover of *Sphagnum* spp. Thus, a 5–10 m wide strip with mainly *P. abies* and *Betula* spp. was created on each side of the stream.

REGENERATION

In June 2008, the harvested areas were scarified and sown with 11 *P. sylvestris* seeds per square meter using a disc trencher (Bräcke, T26) fitted with sowing equipment (Figure 2). In September 2008, small areas (covering 1.5 ha in total) close to experimental installations such as transects with groundwater tubes and groups of soil-water samplers, were planted by hand. One-year-old seedlings were planted at 2.5 m intervals, *P. sylvestris* in upland areas and *P. abies* in wetter areas.

Figure. 2. Disc trenching and sowing at the Balsjö Catchment Study site. Photo L. Högbom.

MAJOR EVENTS

An overview of major events during the course of the study is presented in Table 3, and a more detailed list of events in Appendix 2.

Table 3. Major events at the Balsjö Catchment Study site.

Date	Event
Autumn 2003	The site was identified
Spring 2004	The first weirs were built (Balån 4, 5 and 6)
Winter 2005/2006	A small area in catchment Ref-L was harvested
March 2006	Final felling of catchments BS_{CC} and CC
28–29 May, 2008	Disc trenching and simultaneous sowing in catchment BS_{CC}
30 May–2008	Disc trenching and simultaneous sowing in catchment CC
2011	A 3 hectare area was harvested in the Ref-S catchment
2014	Final felling in parts of the Ref-S catchment

Data collection

EXPERIMENTAL INSTALLATIONS

All major installations at the Balsjö Catchment Study site are listed in Table 4 and the monitored variables in Table 5.

Table 4. Experimental installations at the Balsjö Catchment Study site during 2004 to 2013. For location, see Figure 1.

Installation	Location	Date of installation	Note
V-notch weir (90°)	Balån 7 (Ref-S)	Nov. 2004	
	Balån 6 (Ref-S)	June 2004	About 50 m downstream of Balån 7. This weir was removed in 2010.
	Balån 4 (CC)	June 2004	
	Balån 5 (BS / BS_{CC})	June 2004	
Water height logger	Balån 7 (Ref-S)	Sept. 2004	TruTrack WT-HR 1000, later complemented with a Campbell Scientific data logger and Campbell pressure transducer
	Balån 4 (CC)	July 2004	TruTrack WT-HR 1000, later complemented with a Campbell Scientific data logger and MJK pressure transducer
	Balån 5 (BS_{CC})	April 2004	TruTrack WT-HR 1000, later complemented with a Campbell Scientific data logger and MJK pressure transducer
	Balån 3 (Ref-L)	June 2012	TruTrack WT-HR 1000 installed in tubes mounted on the road culvert. Discontinuous measurements before 2012.
	Balån 1 (BA-1)	June 2006	TruTrack WT-HR 1000 installed in tubes mounted on the road culvert. In 2012, complemented with a WT-HR 2000 for high water levels.
ISCO samplers	Balån 3, 4, 5 and 6	spring 2007	In operation from spring to autumn, i.e. before snowmelt to mid-Oct in 2007, 2008 and 2009.
pCO_2 probes in streamwater	Balån 4, 5 and 7	July 2010	The probes were installed at the weirs and operated until autumn 2010.
Weather station	Balån 4, 5 and 6	≈2008	Thermistors installed for measuring air temperature at each site (10-15 m from the stream gauging station), and water temperature. In addition, there were rain gauges at Balån 4 and 6.
Groundwater wells and piezometers	4 transects in BS_{CC} (T9, T11, T12 and T13)	Sept. 2004	1 groundwater well and 2 piezometers per sampling position (A-D) with water intake at 10-20 cm or 50-60 cm soil depth

Continuous, Table 4.

Installation	**Location**	**Date of installation**	**Note**
	4 transects in BS_{CC} (T19, T21, T22 and T23)	June 2005	1 groundwater tube and 2 piezometers per sampling position (A-D) with water intake at 10-20 cm or 50-60 cm soil depth.
	Complementary installations in T9, T11, T12, T13 and T19-T23	June 2006 and June 2008	Complementary installations in two parallel lines with piezometer nests per transect and 1 groundwater tube per sampling position. Each piezometer nest comprises three piezometers with intakes at 10-20, 50-60 and 90-100 cm.
	6 transects in Ref-S (T1-T6)	May 2005	Intake at 0 to 0.5 m from the bottom of the tubes.
	3 transects in BS_{CC} (T7, T8 and T10)	May 2005	Intake at 0 to 0.5 m from the bottom of the tubes.
	4 transects in CC (T14-T17)	May 2005	Intake at 0 to 0.5 m from the bottom of the tubes.
TDR probes and thermistors	Ref-S and BS_{CC}	June 2006	In each area, TDR probes installed in one soil pit: 4 at 15 cm depth and 4 at 50 cm depth + thermistors at both depths.
Suction cups	5 cups in BS_{CC}	June 2005	Prenart Super Quartz cups at 40-50 cm soil depth. A ring of *P. sylvestris* trees was left around the area with cups at final felling in 2006, and cut in May 2007.
	5 cups in Ref-S	June 2005	Prenart Super Quartz cups at 40-50 cm soil depth.
	60 cups in soil-scarification experi-ment 282 Balsjö*	Sept. 2006	P80 at 50 cm soil depth, in total 15 cups in undisturbed soil in the harvested areas and 15 cups in the adjacent forest.
Hg deposition tubes	2 tubes on open field in BS_{CC} 3 tubes for throughfall in a 40 m transect near Balån 6	June 2007	
Hg litter collectors	12 litter collectors near Balån 6 12 litter collectors in Ref-S	Aug. 2007	
Redox rods	3 transects in Ref-S, BS_{CC} and CC	May 2005 Oct. 2005	Three sampling positions per transect each containing 2 Cu- rods and 2 Fe-rods. Pb- and Al-rods installed in the transects.
Frost tubes	Ref-S and BS_{CC}		15 tubes installed
Regeneration plots	BS_{CC} and CC	June 2009	Permanent plots in 100 m×100 m grid
Snow lysimeters	Ref-S and CC	2009, 2010 and 2011	Snow lysimeter sampling on 3-4 occasions during the melt

* 282 Balsjö refers to the site of Skogforsk Experiment 282, which is located in the Balsjö Catchment Study site (in the BS_{CC} catchment, adjacent to the CC catchment).

Table 5. Monitored variables, and the sampling locations, frequencies and periods.

Data	Sampling position/area	Sampling frequency	Sampling period
Streamwater chemistry	Ref-S (Balån 7)	1–2 times per month	2004–2005
	Ref-S (Balån 6)	1–2 times per month	May 2004 to Dec. 2016
	BS_{CC}	1–2 times per month	May 2004 to Dec. 2016
	CC	1–2 times per month	May 2004 to Dec. 2016
	Ref-L	1–2 times per month	April 2004 to Dec. 2016
	Balån 2	Once per month	April 2004 to Dec. 2016
	Balån 1	Once per month	April 2004 to Dec. 2016
Streamwater chemistry (Hg)	Ref-L	1–2 times per month	2005 to 2011
	Ref-S	1–2 times per month	2005 to 2011
	BS_{CC}	1–2 times per month	2005 to 2011
	CC	1–2 times per month	2005 to 2011
Streamwater chemistry (DOC with ISCO sampler)	Ref-L, Ref-S, BS_{CC} and CC	Daily to twice a day	Before snowmelt to mid-Oct in 2007, 2008 and 2009
Streamwater chemistry (organic chlorine)	Ref-S, BS_{CC} and CC	1–2 times per month	2005–2010
pCO$_2$ [l] in streamwater	Balån 4, 5 and 7		July until Autumn 2010
Weather (air and water temperature, precipitation)	Balån 4, 5 and 6		
Groundwater level	Transects T9, T11, T12, T13, T19, T21, T22 and T23	1–2 times per year	2006–2009
	Some transects	High-resolution data available from TruTrack loggers	
Groundwater chemistry: pH, N, Al, TOC etc.	Transects T9, T11, T12, T13, T19, T21, T22 and T23	1–2 times per year	2006–2009
Groundwater chemistry: Hg	Around 50 samples collected in total from all transects	Once per year	2006–2009

Continuous, Table 5.

Data	Sampling position/area	Sampling frequency	Sampling period
Soil-water chemistry	Ref-S and BS_{CC} (5+5 cups)	1–4 times per year	2006-2009
	BS_{CC} and CC (282 Balsjö)	3 times per year	2007-2009
Soil-moisture content and soil temperature	Ref-S and BS_{CC}		Soil temperature: 2007-2011 Soil moisture: 2009-2011
Soil chemistry (Hg, TN, TC, TS)	Ref-S, BS_{CC} and CC	1 sampling	2012
Hg deposition: open field and throughfall litter	Ref-S and BS_{CC}	3 times per year	2007–2008
Diatoms, benthic fauna and fish (via electrofishing)	Ref-L, Balån 1, Balån 2	Annually in late Aug. or Sept.	2004, 2006–2013 (diatoms until 2015)
Snow water equivalents (7 transects)	BS, Ref-S and CC	Once per year (in March)	2005–2010
Snow water equivalents (around snow lysimeters)	Ref-S and CC	5-10 times per year, from January until the end of snow melt	2009, 2010 and 2011
Snow lysimeters (water equivalents, chemistry)	Ref-S and CC	3–4 times during snow melt	2009, 2010 and 2011

STREAM FLOW

V-notch weirs (90°), made of stainless steel with attached tarpaulin, were installed at the outlets of the Ref-S (Balån 6), CC (Balån 4) and BS/BS_{CC} (Balån 5) catchments in 2004 (Figure 3). In the Ref-S catchment about 50 m upstream of the Balån 6 weir, an additional weir was installed (Balån 7) dimensioned to monitor higher flows. In 2010, the Balån 6 weir was removed. All weirs were equipped with automated water height loggers (Table 4). The water level and flow were also measured manually to create weir rating curves; for procedural details see Sørensen et al. (2009b). Later, water height loggers were also installed in the Ref-L and BA-1 (Balån 1) catchments (Table 4).

There are two different hydrological time series used in the publications arising from the Balsjö catchment study. One hydrological time-series was used in Sørensen et al. (2009a,b). The time-series in Sørensen et al. (2009a,b) were extended with 4 more years in Eklöf et al. (2014, 2015). A second time series was used in Schelker et al. (2013, 2014). The differences arise from interpretation of multiple data sources during the first years of the study (2004-2009). Also, in Schelker et al. (2014), data included manual corrections based on interpolated precipitation data from SMHI. This data included estimates of evapotranspiration and stream flow for Balån 1 and 2 (Schelker et al., 2014).

Balån 7 (May 2011).

Balån 7 (October 2011).

Balån 5 (May 2011).

Balån 4 (May 2011).

Balån 3 (June 2012).

Balån 3 (Later, with wooden frame).

Balån 1 (June 2012).

Figure 3. The weirs installed at Balån 7, 5 and 4 and the water height loggers at Balån 3 and 1 at the Balsjö Catchment Study site. Photo J. Schelker and E. Ring

GROUNDWATER

A number of transects for groundwater monitoring were established (Figure 4, Appendix 3) to monitor the groundwater level and/or collect groundwater samples for chemical analysis (Table 5). Sets of three monitoring wells were installed along two transects to study effects of driving with a forwarder (Bishop et al. 2008). The wells in these transects were removed in Nov. 2005.

Transects T9/T19, T11/T21, T12/T22 and T13/T23 were established to study effects of leaving a forest buffer on groundwater chemistry (Figures 5-6). Thus, the trees in the forest buffer were harvested in transects T9/T19 and T11/T21 in May 2007 (narrow strips at first) and finally in June 2007, to obtain a ca. 44 m long stretch without trees (corresponding to about 10% of the entire buffer length) from 10 m south of T11/T21 to 10 m north of T9/T19 (Figure 5). The treatments within the buffer, *i.e.* leaving or harvesting the trees, were not randomly allocated among the transects due to large variation in tree cover within the buffer. In some transects, there were only a few trees, so the treatments were systematically assigned. Four sampling positions (designated A, B, C and D) were placed along these transects, on both sides of the stream, and about 0.5 m (A) to 20 m (D) from it. Position B was within the permanent discharge area, about 0.5 m from its upland border, ca. 4 to 5 m from the stream. The permanent discharge area was defined as the area closest to the stream where the cover of *Sphagnum* spp. was close to 100% or 100%. Position C was 4 to 5 m upland of B. Installations at each sampling position include a groundwater monitoring well (internal diameter, 33 mm), perforated at 4 cm intervals, and six piezometers, located along two parallel lines approximately 2 m apart, with intakes at 10–20, 50–60 and 90–100 cm from the ground surface (two at each depth in both cases) (Figure 6). The piezometers in T9/19 to T13/T23 were designed to collect sufficient water for groundwater chemistry analyses, and thus cannot be used for pressure head measurements. Initially the piezometers were made of white PVC, but in 2008 the original piezometers were replaced by new devices, designed to hold a greater sample volume, which were installed at 90–100 cm depth in nearly all sampling positions (Appendix 3). The groundwater samples collected in 2006 and 2007 were analysed at the Department of Aquatic Sciences and Assessment, SLU, while the samples collected in 2008 and 2009 were analysed at the Soil Science Laboratory at SLU, Umeå.

Groundwater samples for total mercury (THg) and methyl mercury (MeHg) determinations were collected. On these occasions all equipment used (vacuum chamber, tubes and bottles) as well as the groundwater tube itself was flushed with nitrogen gas before and during the sampling.

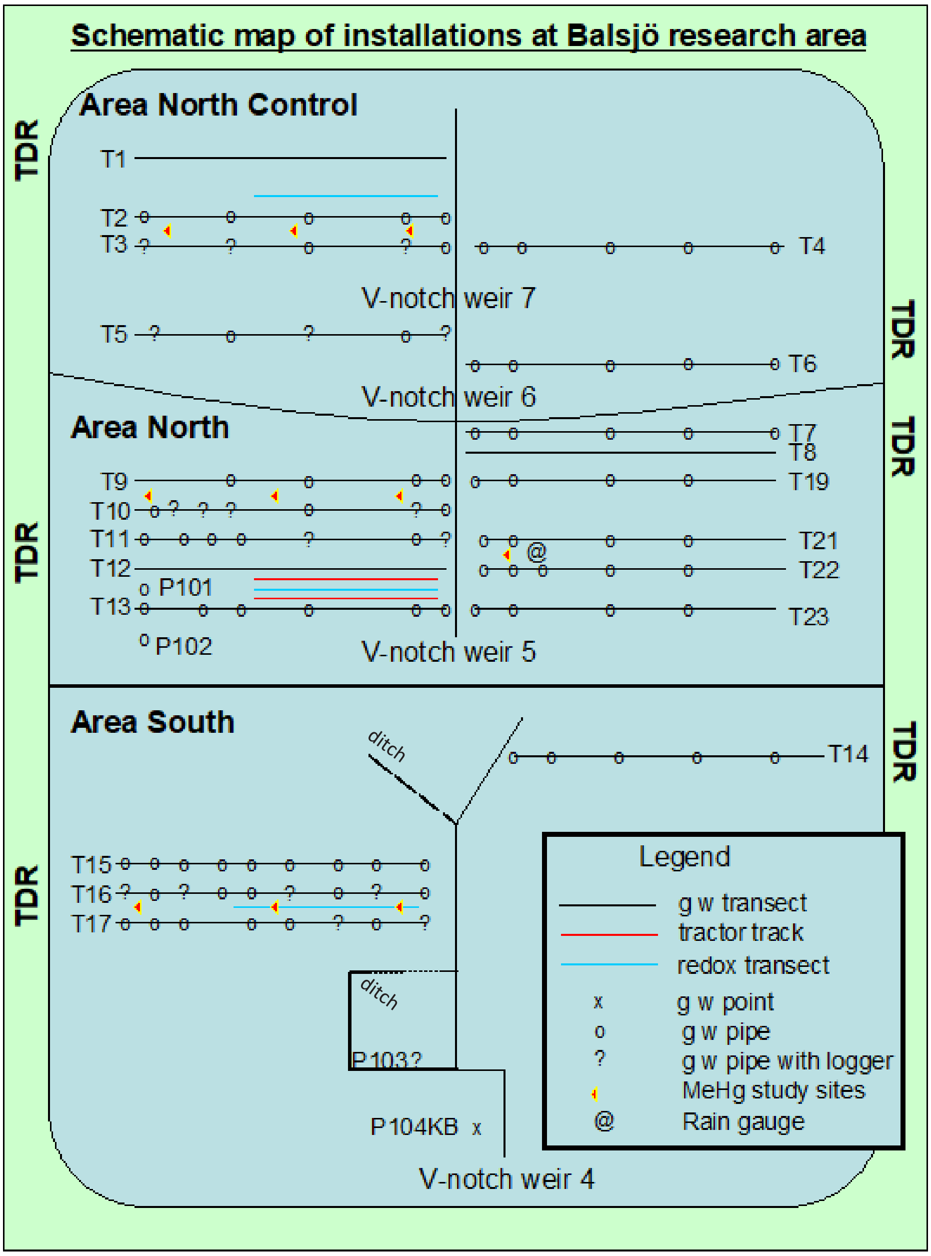

Figure 4. Schematic map of the installations at the Balsjö Catchment Study site (catchments Ref-S, BS and CC).

Figure 5. Groundwater transects with and without trees in the buffer in the BS_{CC} catchment. Photo E. Ring

Figure 6. Piezometers and blue groundwater monitoring wells have been installed at four points (A-D) along two parallel lines on each side of the boardwalk. Here sampling positions A, B and C are shown. Photo E. Ring

SOIL WATER

Suction cups were installed in BS_{CC} and Ref-S at a depth of 40–50 cm in the mineral soil (Figure 7). Soil water samples were collected after a few days of applying 75 cbar suction, and kept frozen until chemical analysis (Table 5). The soil-water samples collected in 2006 and 2007 were analysed at the Department of Aquatic Sciences and Assessment, SLU, while the samples collected in 2008 and 2009 were analysed at the Soil Science Laboratory at SLU, Umeå.

In addition, 60 suction cups were installed in the Balsjö catchments to study effects of site preparation on soil-water chemistry. These cups have been placed in plots subjected to two site-preparation practices (formation of inverted mounds and simulated disc trenching) and control plots in both areas of intact forest and areas that have been harvested but not subjected to any site preparation.

Figure 7. An area with five suction cups in the northwestern part of the BS_{CC} catchment. Photo E. Ring

SNOW SAMPLING

Snow was sampled using a 4.2 cm snow corer, following both large- and small-scale sampling strategies (Table 5). In the former, snow cores were taken in March each year from 2005 to 2010 (78–110 annually) at 15–20 m intervals along seven transects crossing the CC, BS and Ref-S catchments in an east–west direction (Schelker et al. 2013). In the latter, 5–10 samples were collected, within an approximate radius of 30 m, more frequently (at time intervals ranging from ca. 2 days during snow melt to 4 weeks in mid-winter). This sampling was performed during the winters of 2009, 2010 and 2011. Snow water equivalents for all snow samples were determined by weighing the samples in the field. Some of the samples were also collected for chemical and isotopic analysis.

In addition, 0.78 m × 0.78 m snow lysimeters were used to collect melt water from the snowpack at sites in Ref-S and the western boundary of the CC catchment in 2009, 2010 and 2011. The melt water was collected in bags, which were weighed in the field and samples were drawn for chemical and isotopic analysis. The results from the snow sampling are presented in Schelker et al. (2013).

SOIL SAMPLING

Soil samples were collected in September 2012 for analyses of the contents of THg, total carbon (TC), total nitrogen (TN) and total sulphur (TS) (Table 5). The samples were collected using a soil coring tube (Ø=23 mm) or by manual digging if abundant stones and roots prevented coring. In total, 75 soil samples were collected from the CC, BS_{CC} and Ref-S catchments. In each catchment, 12 samples were collected at fixed distances along three 30 m-long transects (n=4 per transect) established along the topographic fall line starting from the stream. The samples from the transects were from the upper 6 cm of the O horizon or the whole O horizon if the depth of the O horizon was less than 6 cm.

In addition, 13 samples per catchment were collected from potential hotspots for Hg methylation, like wet patches or wheel ruts. THg analyses were carried out at the Department of Aquatic Sciences and Assessment using a Perkin Elmer SMS100 following US EPA method 7473 (2007). TC, TN and TS were determined at the Department of Limnology at Uppsala University on freeze-dried and homogenized soil samples. The results from the soil sampling are presented in Eklöf et al. (2018).

REGENERATION

To follow the regeneration following harvests a number of permanent plots (in a 100 m × 100 m grid) were established in BS_{CC} and CC. The centre of each plot was marked with an aluminium profile (aluminium rod) inserted in the ground and coordinates for each plot can be found in Appendix 4.

STREAMWATER SAMPLING

Water samples were collected in high-density polyethylene bottles at the inlet of the dams upstream of the weirs every second week during the snow-free period and once a month during winter (Table 5, Appendix 6). During high-flow events, such as snowmelt, samples were collected weekly, and kept frozen until chemical analysis. The chemical analyses were performed at the Department of Aquatic Sciences and Assessment, SLU. The analytical methods are presented at: https://www.slu.se/en/departments/aquatic-sciences-assessment/laboratories/vattenlabb2/. They are accredited by the Swedish Board for Accreditation and Conformity Assessment (https://www.swedac.se/) and follow Swedish standard methods. The DOC concentrations presented in Schelker et al. (2012) were analysed at SLU, Umeå. Results from the streamwater studies are presented in Laudon et al. (2009), Löfgren et al. (2009), Sørensen et al. (2009a), Eklöf et al. (2014 & 2015), Schelker et al. (2012 & 2016).

Contact

The Balsjö Catchment Study has been carried out mainly by scientists at Skogforsk and SLU, Department of Forest Ecology and Management and Department of Aquatic Sciences and Assessment. More detailed information about specific research activities can be obtained from the contact persons listed in Table 6.

Table 6. Contact persons for the Balsjö Catchment Study.

Information about	Contact person	Affiliation
Study site	Lars Högbom	Skogforsk
	Eva Ring	Skogforsk
Hydrology		
	Kevin Bishop	SLU
	Karin Eklöf	SLU
	Hjalmar Laudon	SLU
	Jakob Schelker	University of Vienna
	Rasmus Sørensen	Skogforsk
Streamwater chemistry	Stefan Löfgren	SLU
	Hjalmar Laudon	SLU
	Lars Högbom	Skogforsk
	Eva Ring	Skogforsk
Mercury	Kevin Bishop	SLU
	Karin Eklöf	SLU
	Rasmus Sørensen	Skogforsk
Soil water chemistry	Lars Högbom	Skogforsk
	Eva Ring	Skogforsk

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Appendix 2. Important events

<table>
<tr><th>Date</th><th>Event</th></tr>
<tr><td>Nov. 2004</td><td>The Balån 6 weir was raised on 19 Nov., so that a 33 cm fall was achieved.</td></tr>
<tr><td>May 2005</td><td>A pressure transducer and a water thermometer connected to a logger were installed east of Balån 6, within Ref-S. Soil moisture was measured with a portable TDR-instrument in six places in recharge areas of Ref-S, BS_{CC} and CC.</td></tr>
<tr><td>Aug. 2005</td><td>Water sampling and chemical analysis at Balån 7 was terminated, since the chemistry data from Balån 6 and Balån 7 corresponded well.</td></tr>
<tr><td>Oct. 2005</td><td>Maps of Ref-S, BS_{CC} and CC were created after field surveying.</td></tr>
<tr><td>Oct. 2005</td><td>The depth of the peat layer was measured in the transects T9/T19, T11/T21, T12/T22 and T13/T23.</td></tr>
<tr><td>Nov. 2005</td><td>The groundwater tubes in the tractor transects were removed. A board was mounted in the dam of the Balån 4 weir to reduce the water flow rate in the dam.</td></tr>
<tr><td>March 2006</td><td>


Left: Harvester in action. Right: Logging along the brook in the northern catchment. Photo L. Högbom

The felling of field-experiment 277 Balsjö started on Monday March 6, 2006. On the second day, the logging continued along the east side of the brook. Meter by meter the harvester moved up-stream parallel to the brook. In general, the harvester was never closer than 10 m from the trees left along the brook. Thus, the logging machines were never closer than 15 m from the brook on either side of the brook in the northern watershed. The previously installed groundwater tubes and piezometers were skillfully avoided, although there might be some damages caused by the severe cold (down to -29°C occasionally), and some twig or top sweeping by. By the end of the first week most of the Northern watershed was cleared and all the timber was removed. For the naked eye, and because of all the logging residues no visible damages to the soil could be found. However, this does not exclude that damages could be detected in the future. Because of the generous protection zones there are no logging tracks connecting the surrounding soil with the brook.”


Left: Forwarder in action. Right: View to the south taken from the highest point in the northern catchment. Photo L. Högbom

</td></tr>
</table>

Date	Event
Continuous, March 2006	During the next week the time came to the south watershed. This was slightly trickier since it had a very different shape – long and narrow. Further, the only road was on one side of the catchment. Since this was the case the brook at that site had to be crossed at several places. The brook crossing was made by putting birch logs in the brook, logs that later were removed. This practise calls for mapping of the crossings. Further, since the logging at this site was supposed to include also the protection zone there might be places that could be rather damaged by the logging, these are also to be mapped. The southern watershed was not completely felled this since in the northern part of that watershed there is a key habitat. The general instruction to the drivers was to apply normal environmental protection during the logging, this meant that eternity trees, high stumps should be left as well as groups of trees on rocky parts.
Sept. 2006	Experiment 282 Balsjö, with three blocks, was established within 277 Balsjö. One block was located in CC and two blocks in BS_{CC}. Each block holds 20 suction cups; 15 cups in clearcut areas and 5 cups in adjacent forest. The cups in the clearcut areas represent different forms of site preparation (no preparation, simulated disc trenching and inverted mounding by spade).
Jan. 2007	The water-sampling point at the outlet of Ref-L. was moved a few meters (<5 m) upstream to avoid risking to sample water from a road ditch which enters the stream upstream the current sampling point. The road ditch has mostly been dry.
May 2007	A WTHR logger was installed in the road culvert at Balån 3.
May 2008	At site preparation, the cables going out from the logger located at Balån 6 were damaged. Several TDR and temperature cables were cut. These cables were mended in June 2008.
June 2008	Multi-plate radiation shields were connected to the newly installed air temperature probes at Balån 4 and 5. To improve the manual measurements of the streamwater level at the weirs, additional measurement points were added. Thus, on each weir, 3–4 markings were made (|, ||, ||| and ||||) on the upper edge of the metal sheet. Measurements are also to be done in the "V". Two Campbell logger systems were installed, one at Balån 4 and one at Balån 5.
Aug. 2008	The rain gauge (tipping bucket) at Balån 6 did not work because it was filled with litter. After cleaning, it was running again from 11.30 a.m. 18 Aug. 2008.
2008	The chemical analysis of total N was changed. It was concluded that both methods yield similar results for concentrations ranging from 300 to 800 µg l^{-1} (http://publikationer.slu.se/Filer/TotN.pdf). Thus, the effects on the time series from 277 Balsjö should be negligible. Present method (combustion) (2007-01 –): SS-EN 12260:2004. Instrument: Shimadzu TOC-VCPH with TNM-1 module and automatic sample exchanger ASI-V. The samples are treated with HCl. The N concentration is measured by chemiluminescence following catalytic oxidation to N oxides. Previous method (persulphatenitrogen) 2002-01–2006-12: SS-EN ISO 11905 mod. for Traacs. Bran*Luebbe Method No. J-002-88 B. Instrument: Technicon Traacs 800. Note: The water samples were preserved with H_2SO_4.
Nov. 2008	All ISCOs were returned to the lab to avoid frost damage. Streamwater sampling interval was reduced to 4 weeks as during the winters before. Snow-lysimeters were also set up for the winter. Some of the tubes were slightly damaged, but due to a lack of time they were simply cut to a shorter length and sealed by vulcanizing tape. The plastic tubes should be replaced before winter 2009/10.
Jan. 2009	The entire TDR logger case was dismounted in the lab to check its function. It was rewired so that for each TDR probe, a separate set of connectors is available and additional fuses were installed for each set of 4 TDRs together. Both, the data logger (CR10) and the multiplexer were found to be undamaged.
Feb. 2009	The TDR logger and Multiplexer were reinstalled at their original place near Balån 6 on 11 Feb. 2009 and reconnected to the GSM modem. During this process two defective TDRs were identified; both at 15cm depth, open area (Number TDR15 and TDR16). The other TDRs and all soil temperature probes were working fine. Due to the fact that the defective TDRs probes generated a short-cut the loggers were not working properly and, thus, there is a **lack of data from 2008-05-29 to 2009-02-11** for soil moisture derived from the TDR probes and for soil temperature there is a **lack of data from 2008-07-09 to 2009-02-11**. Some soil temperature probes were also malfunctioning during the period between 2008-05-29 to 2008-07-09.

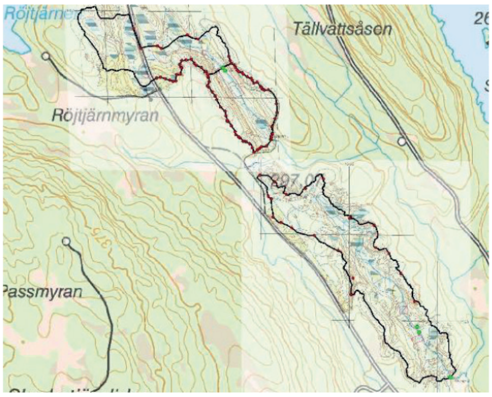
Date	Event
March 2009	Preparations for the snow melt: 1. Snow cores were taken (2009-03-24 and 25). 2. The rain gauge (tipping bucket) at Balån 6 (within the buffer) was set up and cleaned so that it should work for possible Rain-on-Snow events. 3. Snow lysimeters were set up for the spring flood. 4. ISCO-samplers are in position for the spring flood at Balån 4 and 6. Planned activities for the next weeks: 1. Install SMHI rain gauge with tipping bucket in open area near Balån 4. 2. Install tripods for weighing collector bags of snow lysimeters. 3. Install ISCOs at Balån 3 and 5. 4. Install pressure transducer (Campbell) at Balån 4. 5. Compare discharge measurements (bucket, bag, salt-dilution) during pre-melt low flow. 6. Possibly start ISCOs.
May 2009	The spring flood is almost over now (5 May). The flow this year demonstrated the difference in microclimate between the reference and harvested catchments, resulting in different timing of the snow melt. The peak for the open area was last weekend, the controls peaked this weekend (Saturday/Sunday), both are mainly forced by high temperature and radiation and only very little influence of rain. Hydrological measurements 1. The weir at Balån 4 is creating a backlog if the flow reaches levels greater than approx. 30 l/s. The highest flow measured this year was 42 l/s. The weir also tilted, shifting the V notch to the side. The eastern side is now about 10 cm lower than the western side. 2. The weir at Balån 7 is creating a backlog if the flow exceeds approx. 10 l/s. The highest measured flow here was 22 l/s this year. Here some digging in the channel downstream might help because there is a drop in elevation just about 1.5 m downstream. 3. The tests at lower flows show that the salt dilution method works great for almost all sites, even if the weirs are raised. In general, good discharge measurements were obtained at all 3 weirs and to some extent at Balån 3. Streamwater sampling 1. For Hg, TOC, O-18…, the ISCO samplers collected 2 samples per day during the main melting period. Sampling was set to 10 a.m. and 10 p.m.to capture the highest and lowest daily flow. 2. The manual sampling of streamwater was done every 2nd or 3rd day. Snow lysimeters There were some problems with ice in the bags or the tubes at the beginning of the melt – later they worked fine but filled up quite fast.

<table>
<tr><th>Date</th><th>Event</th></tr>
<tr><td>20 May 2009</td><td>1. The channel downstream of Balån 7 was trenched by digging (10 to 20 cm deep) at a length of about 1.5 m. This enhanced the weir fall by 5 to 8 cm. The digging might affect the GW measurement of the nearby GW logger and the rating curve.


Location of the digging downstream of Balån 7. Photo J. Schelker
2. The dam at Balån 4 was emptied of plant material and mud which had accumulated during the spring flood. Further downstream, some gravel had to be removed to make sure the bucket measurements can be performed properly in the future.</td></tr>
<tr><td>21 May 2009</td><td>A new rain gauge was installed about 20 m from Balån 4. A SMHI standard rain gauge was combined with a Campbell tipping bucket. The SMHI gauge with an SMHI wind shield was installed at a height of 1.5 m. Precipitation collected in the funnel drains through a tube into the tipping bucket below, which was covered by plastics to avoid additional rain entering the system. The tipping bucket was connected to the Campbell logger at Balån 4.

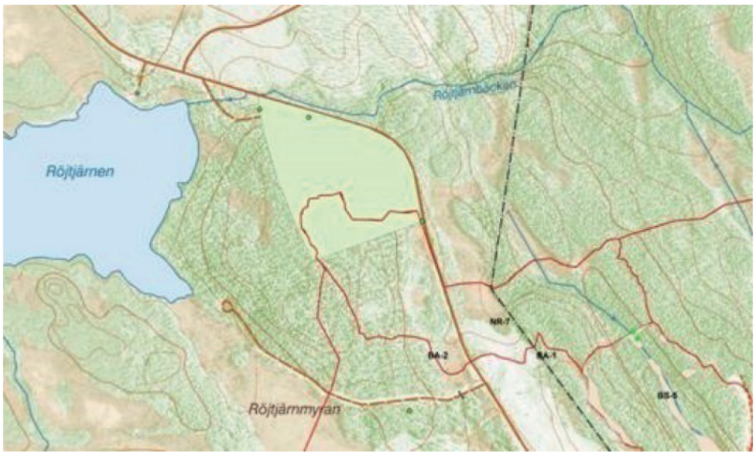
Rain gauge at Balån 4. Photo J. Schelker</td></tr>
</table>

Date	Event
June 2009	A 30 m×30 m study plot was established in 277 Balsjö, within the EU Life+ project FutMon. Coordinates for the SW corner of the plot is 1652166, 7106779.
6-9 June 2009	Balån 4 The weir was reinforced and balanced by pushing a 2–3 m long steel bar into the ground on each side of the weir. The bars were inserted as deep as possible and then the weir was screwed unto them. The weir was lifted approx. 3 cm on the right side and about 8 cm on the left. About 10 to 12 m of the channel downstream the weir was dug out to prevent lifting at high flow. Site 5 At the inlet of the dam, the tarpaulin was fixed to the bottom of the stream with U-shaped steel clamps, which reached about 40 cm into the ground. Site 6 The weir and all other installations (TruTracks) were removed. A solar panel was mounted on a tree on the western side of the stream. The charging unit and the battery were installed near the case used for the CR10 logger at Balån 7. From 2009-07-29 both loggers (the logger for water height at site 7 and the logger for TDR, multiplexer from TDR and both GSM modems) are fully powered by the solar charged battery. Within the next weeks we will also connect the ISCO sampler to this system. Site 7 The weir was stabilized in a similar way as at Balån 4, i.e. by putting long steel bars 3–4 m into the ground on each side (below the peat) and attaching the weir to these bars. The weir was better levelled than Balån 4, but it had lifted some centimetres as well. The tarpaulin was fixed to the bottom with U-shaped steel clamps and the channel downstream was widened again. The old tree was removed, to which the pressure transducer and the Trutrack loggers had been mounted, and replaced with a construction made of impregnated wood, not in direct contact with streamwater (including a tube for the pressure transducer) similar to the one at Balån 5. The pressure transducer and the TruTracks were reinstalled at the same water level as they were before (ca ±1 mm). Impregnated wood has been used at Balån 4, in direct contact with streamwater, but the water sampling is upstream of this wood.
July 2009	To follow up regeneration, a number of permanent plots (in a 100 m×100 m grid) were established in BS$_{CC}$ and CC.
17 Sept. 2009	Balån 4 Calibration of the tipping bucket: 1. The saved data every hour was changed from average to totalize for the tipping bucket. The logger takes an average of the data that was collected with 3 min. intervals which means to get the total amount of rain the old values need to be multiplied by 20. 2. Calibration shows that one tip of the bucket represents 0,600077. The old calibration factor was 0,2 mm per tip of the bucket. 3. To correct the old data, multiply **“old data”×20 × 0,600077/0,2**. 4. From 2009-09-17 13:30 the logger gives correct data without need for further correction. The range of the temperature probe for air was expanded to be able to measure larger intervals (changes were made from 250 mV to 2 500 mV range). Balån 5 1. The range of the temperature probe was expanded to be able to measure bigger intervals (changes was made from 250 mV to 2 500 mV range). Balån 7 Logger and logger cabinet changed, from old leaking box and CR10, to new box and CR10X. Calibration of the tipping bucket: 1. Calibration shows that one tip of the bucket represents 0,279151. The old calibration factor was 0,254 mm per tip of the bucket. 2. To correct the old data, multiply **“old data” × 0,279151/0,254**. 3. From 2009-09-17 20:00 the logger gives correct data without need for further correction. The temperature probe for water was changed from a 107 to a T3OR. The range of the temperature probe for air was expanded to be able to measure larger intervals (changes were made from 250 mV to 2 500 m V range).

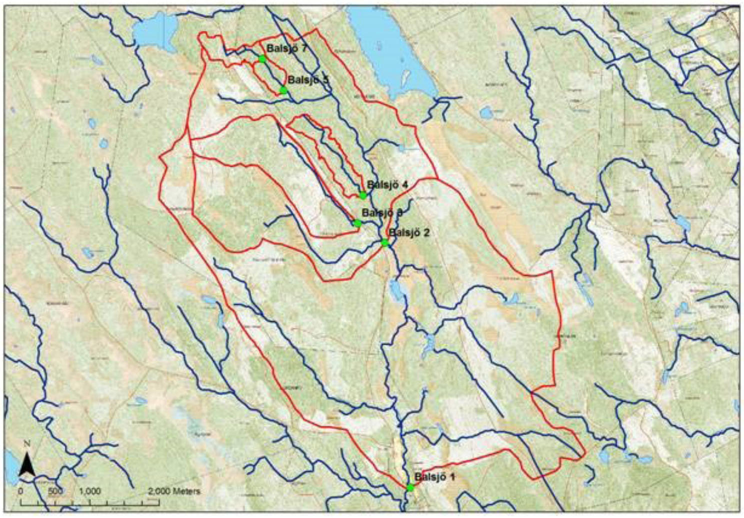
<table>
<tr><th>Date</th><th>Event</th></tr>
<tr><td>3 Nov. 2009</td><td>The catchment areas were updated in June and Oct. 2009.


Catchment area (ha) obtained at different times.
<table>
<tr><td>Name</td><td>Area from Löfgren et al. (2009)</td><td>Area in June 2009</td><td>Area in Oct. 2009</td></tr>
<tr><td>Bs</td><td>31</td><td>41.23</td><td>37.00</td></tr>
<tr><td>Ref-S</td><td>20</td><td>25.09</td><td>22.82</td></tr>
<tr><td>BS_{CC}</td><td>11</td><td>16.14</td><td>14.18</td></tr>
<tr><td>CC</td><td>37</td><td>45.55</td><td>44.97</td></tr>
<tr><td>Ref-L</td><td>320</td><td>–</td><td>156.20 (preliminary)</td></tr>
</table></td></tr>
<tr><td>March 2010</td><td>Holmen AB harvested stands adjoining the CC catchment.</td></tr>
<tr><td>June 2010</td><td>Holmen AB harvested stands adjoining the BS catchment.

</td></tr>
</table>

Date	Event
June 2010	BS_{CC} catchment size updated The size of the area on the plateau on the western side of the BS_{CC} catchment is still uncertain. We have been quite convinced that this area cannot drain into the BS_{CC} catchment, if the flow follows the surface gradient. In this case, the catchment size would be 14 ha. However, in the flow calculation of the digital elevation model (DEM) this area drains into BS_{CC}, but only because the algorithm “removes” sinks which have no outflow from the raw DEM data. In addition, our calculations of the water balance showed that the annual discharge from the BS_{CC} catchment was higher than the annual precipitation. Therefore, I compared the daily specific discharge of Balån 5 to that of Balån 4 and calculated a “hypothetical” catchment size, assuming that these two catchments would react similar according to their daily specific runoff. The fitting of a 1:1 line for the two catchments ($r2= 0.84$) gave a catchment area of 17.2 ha, which is almost the same as the17.0 ha according to the GIS approach. Comparison with Krycklan runoff Daily specific discharge (now using 17 ha for BS_{CC}) was calculated and compared with the data from Dammhuset in Krycklan (site7; 50 ha; 15% peatland, 85% forest land). Although the sites are quite close to each other, they are not very well correlated. The r^2 values were between 0.43 and 0.5 and the slopes for all sites were between 0.74 and 0.88, indicating that the specific runoff in Krycklan is generally higher than in Balsjö. Furthermore, the extreme events during the summer 2009 were higher in Balsjö than in Krycklan. Therefore, it may not be wise to use data from Krycklan to fill in gaps in the Balsjö Q-time series.
Oct. 2010	1. The CO_2 measurements were terminated on 22 Oct. 2010. 2. Due to strong wind, several trees had fallen, mainly at the edges of cuttings and in the buffer. Two trees in the buffer near Balån 5 fell over the stream with minor damage on installed equipment. 3. All main sites (Balån 3, 4, 5 and 6) had ISCO samplers running this summer with a 1-sample per day frequency during events and a 1-sample every 2 days.
Nov. 2010	The Hg sampling in streamwater is terminated.
Aug. 2011	About 3 ha had been harvested in Ref-S during this year: 
Dec. 2011	Balsjö hydrology update 2011 The weirs at Balån 4, 5 and 7 are working very stable (the loggers too). Nevertheless, the weirs need an update of the calibration typically once a year. I use the period from the beginning of June to the beginning of June in the next year, because the frost lifts the weirs a bit from year to year. The number of manual discharge measurements (salt and bucket) was high in 2010 and lower in 2011, but with these stable conditions the results are very reliable. Further, bucket and salt measurements during the springflood and other high flow events during 2010 and 2011 helped to confirm the upper parts of the rating curves for all sites. The equations have almost not changed since 2009. Note: From 2010 I have changed to only apply the updated rating curve to every new year, and not recalculate the earlier flows using the new curve (as we did earlier). However, all older data points are kept in the curves. This keeps the curves very stable and it is easy to see if a shift occurs. Further this allows to just update the hydrology for the recent years and to keep the data obtained in earlier years. This is a big advantage, because all analysis done on the flow data will not have to be redone every time we update the hydrology data.

<table>
<tr><th>Date</th><th>Event</th></tr>
<tr><td>1 June 2012</td><td>Consistent discharge data from Balån 1 is now available (with 1 h resolution) from 1st of June 2006 throughout 2011, i.e. 5.5 years of data with only one small 14-day gap in August 2009.

Spring snowmelt in 2012 at a water level of 126 cm (measured May 1st 2012, 11:40h). The tops of the loggers are visible on the left. Photo J. Schelker</td></tr>
<tr><td>June 2012</td><td>1. The map shows all the sampling sites for the regular streamwater sampling. These sites have been used since autumn of 2008.


2. A new, extra long Trutrack logger has been installed at Balån 1 on 31 May 2012, to cover very high water levels.
3. Two new Trutrack loggers have been installed in the road culvert at Balån 3 on 7 June 2012. Some protection for the exposed parts of these loggers should be constructed.
4. The cable from the solar panel at Balån 5 was protected.
</td></tr>
</table>

Appendix 3. Groundwater transects

Transects for groundwater monitoring were established by Skogforsk (Table A3-1) and SLU (Table A3-2). The Skogforsk transects were located in BS_{CC}: transects T9, T11, T12, T13 on the western side of the stream and T19, T21, T22 and T23 on the eastern side. The T9, T11, T12 and T13 transects were located 48.2 m, 71.8 m, 103.6 m and 180.8 m, respectively, from the Balån 6 weir. A depth profile of the peat layer surrounding the stream in the upper part of BS_{CC} is shown in Figure A3-1.

Table A3-1. Details of the piezometers installed in the Skogforsk transects T9, T11, T12, T13, T19, T21, T22 and T23, i.e. the final set-up completed in June 2008.

Transect – sampling position	Piezometer total tube length (cm) Intake depth 10-20N	10-20S	50-60N	50-60S	90-100N	90-100S
T9-A	100	100	115	115	125	125
T9-B	100	100	115	115	125	125
T9-C	100	100	115	115	125	125
T9-D	100	100	115	115	125	125
T11-A	92.4	60.1	104.3	76.8	125	125
T11-B	100	99.3	115	108.1	125	125
T11-C	100	100	115	115	125	125
T11-D	100	100	115	115	125	125
T12-A	50.7	67.8	86.2	92.5		125
T12-B	100	85	108.5	113	125	125
T12-C	100	100	115	115	125	125
T12-D	100	100	115	115	125	125
T13-A	100	100	115	115		125
T13-B	100	100	115	115	125	125
T13-C	100	100	115	115	125	125
T13-D	100	100	115	115	125	125
T19-A	27.5	28	119	33	125	125
T19-B	41	52	115	115	125	125
T19-C	67	89	115	34		
T19-D	71	73	78	91		
T21-A	28	46	115	115	125	125
T21-B	100	48	115	105	125	125
T21-C	51	28	115	88	125	125
T21-D	51.9	67.3	75.6	90.5		
T22-A	81	54	89.5	77	125	125
T22-B	98.4	95.8	96.3	114.8	125	125
T22-C	89.4	100	115	102.1		
T22-D	46.7	52.2	76.7	115		
T23-A	69	55.2	91.6	96.1		
T23-B	48	27.6	80.3			
T23-C	90.4	39.8		75		
T23-D	77.2	80.6		97.2		

"S" is the southernmost line.
"N" is the northernmost line.
Red and orange: piezometer exchanged but without length information.
Yellow: piezometer exchanged but not cut to correct length.
Green: new piezometer but not cut to correct length.
Grey: piezometer missing.

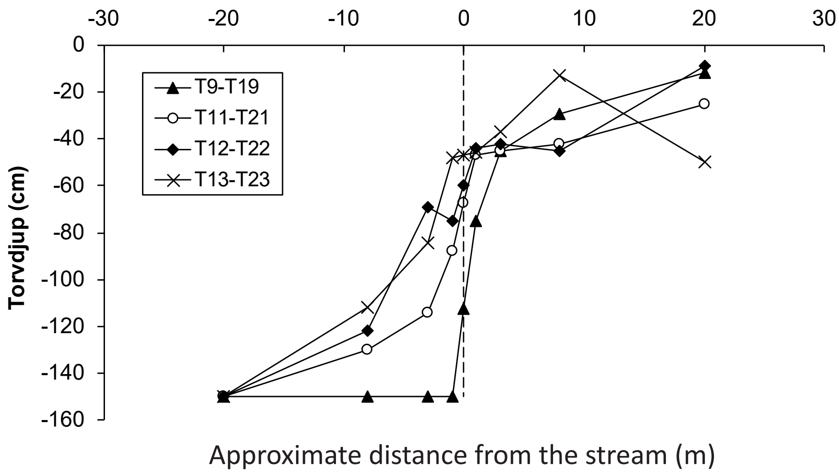


Figure A3-1. Depth profiles of the peat layer in the T9-T23 transects. "0 m" represents the stream; positive and negative distances from the stream represent the eastern and western sides, respectively.

Table A3-2. Groundwater transects at the Balsjö Catchment Study site established by SLU. The x- and y-coordinates are according to the RT90 system.

Transect and posistion		Direction (°)	X	Y	Distance from A	Tube dimension (mm)	Tube length (cm)	Tube height above soil surface (cm)	TruTrack logger
T1	A	220	7106725	1652066	0		75	11	
	B				2.6		75	14.5	
	C				6.2		150	69.5	
	D				15.4	10	100	12	
	E				20.6	10	100	22.5	
T2	A	220	7106636	1652189	0		75	18	
	B				2.6		75	15	
	C				6.2		150	54.5	
	D				20.6		150	47	
	E				25.8		150	64	
T3	A	220	7106642	1652190	0		75	21	
	B				2.6		75	16	yes
	C				6.2		150	27	
	D				20.6		150	50.5	yes
	E				25.8		150	68	yes
T4	A	220	7106633	1652201	0		75	17	
	B				2.6		75	21	
	C				6.2		150	32	
	D				20.6		150	16	
	E				33.8		150	11.5	
T5	A	50	7106630	1652207	0		75	23.5	yes
	B				2.6		75	23	
	C				6.2		150	49	yes
	D				20.6		?	52.5	
	E				28		?	66	yes

Continuous, Table A3-2.

Transect and posistion		Direction (°)	X	Y	Distance from A	Tube dimension (mm)	Tube length (cm)	Tube height above soil surface (cm)	TruTrack logger
T6	A	50	7106619	1652216	0		75	18	
	B				2.6		75	20.5	
	C				6.2		1.5	51	
	D				20.6		?	13.5	
	E				25.5		?	24	
T7	A	50	7106594	1652231	0		75	18.5	
	B				2.6		75	16.5	
	C				6.2		?	61	
	D				20.6		?	13.5	
	E				25		?	7	
T8	A		7106587	1652244	0			14.5	
	B				2,6			14	
	C				6,2			55.5	
	D				17,5			13	
	E				25			19.5	
T9	A	220	7106559	1652249				50	
	Apg								
	Apd								
	B								
	Bpg								
	Bpd								
	C							43.5	
	Cpg								
	Cpd								
	D							49	
	Dpg								
	Dpd								
T10	A	220	7106557	1652255				23.5	
	B							11.5	yes
	C							46	
	D							53	yes
	E		7106537	1652228		33	125	21	yes
	F		7106527	1652220		10	100	11.5	
	G		7106527	1652224		33	125	25	yes
	H		7106521	1652208		10	100	16	

Continuous, Table A3-2.

Transect and posistion		Direction (°)	X	Y	Distance from A	Tube dimension (mm)	Tube length (cm)	Tube height above soil surface (cm)	TruTrack logger
T11	A	220	7106556	1652269				45.5	yes
	Apg								
	Apd								
	B							47.5	
	Bpg								
	Bpd								
	C							40.5	yes
	Cpg								
	Cpd								
	D							66.5	
	Dpg								
	Dpd								
	E		7106504	1652236		33	125	46.5	
	F		7106513	1652231		33	125	64	
	G		7106506	1652218		33	125	56	
T12	A	230	7106523	1652276				48.5	
	Apg								
	Apd								
	B							40	
	Bpg								
	Bpd								
	C							39.5	
	Cpg								
	Cpd								
	D							38	
	Dpg								
	Dpd								
	E		7106491	1652257		33	1.25	47	
	F		7106472	16522554		10	100	16	
T13	A	225	7106453	1652313				36	
	Apg								
	Apd								
	B							33	
	Bpg								
	Bpd								
	C							39	
	Cpg								
	Cpd								
	D							47.5	
	Dpg								
	Dpd								
	E		7106424	1652293		10	100	35	
	F		7106438	1652273		10	100	19.5	

Continuous, Table A3-2.

Transect and posistion		Direction (°)	X	Y	Distance from A	Tube dimension (mm)	Tube length (cm)	Tube height above soil surface (cm)	TruTrack logger
T13	A	225	7106453	1652313				36	
	Apg								
	Apd								
	B							33	
	Bpg								
	Ppd								
	C							39	
	Cpg								
	Cpd								
	D							47.5	
	Dpg								
	Dpd								
	E		7106424	1652293		10	100	35	
	F		7106438	1652273		10	100	19.5	
T14	A	45	7105046	1653369	0	33	100	16	
	B				2.6	33	100	20.5	
	C				6.2	33	100	21.5	
	D				13	10	100	12	
	E				20.6	10	100	38	
T15	A	240	7104927	1653463	0	40	75	8	
	B				2.6	33	75	9.5	
	C				6.2	33	150	65	
	D				13	33	140	48.5	
	E				20.6	33	150	62	
	F				32	33	75	17	
	G				47	33	150	64.5	
	H				60	10	100	8.5	
	I				72	33	150	63	
T16	A	240	7104919	1653458	0	40	100	27	
	B				2.6	40	100	11.5	yes
	C				6.2	40	100	17	
	D				13	40	100	9	yes
	E				20.6	33	150	48.5	
	F				32	33	150	75.5	
	G				47	33	150	58.5	yes
	H				52	33	125	38	
	I				60	33	150	32	yes

Continuous, Table A3-2.

Transect and posistion		Direction (°)	X	Y	Distance from A	Tube dimension (mm)	Tube length (cm)	Tube height above soil surface (cm)	TruTrack logger
T17	A	240	7104894	1653469	0	40	100	23	yes
	B				2.6	40	100	16.5	
	C				6.2	40	150	14.5	yes
	D				13	33	150	37.5	
	E				20.6	33	150	51.5	
	F				32	33	125	17.5	
	G				47	33	125	34.5	
	H				60	33	125	24.5	
	I				70	10	100	14	
P	101		7106514	1652223		10	100	34.5	
P	102		7106482	1652253		10	100	13.5	
P	103		7104770	1653515		33	125	46.5	yes
P	104		7104690	1653576		10	100	11	
Tractor	A								
	B								
	C								
	D								
Tractor	A								
	B								
	C								
	D								

Appendix 4.
Permanent plots for monitoring regeneration

Table A4-1. Coordinates of permanent plots for monitoring regeneration. The x- and y-coordinates are according to the RT90 system.

Balsjö BS catchment June 2009			**Balsjö CC catchment June 2009**		
Plot	**x-coordinate**	**y-coordinate**	**Plot**	**x-coordinate**	**y-coordinate**
1	7106200	1652400	1	7104500	1653400
2	7106300	1652500	2	7104500	1653500
3	7106300	1652400	3	7104600	1653600
4	7106300	1652300	4	7104500	1653600
5	7106400	1652300	5	7104700	1653600
6	7106400	1652200	6	7104800	1653600
7	7106500	1652200	7	7104800	1653500
8	7106500	1652300	8	7104700	1653500
9	7106500	1652400	9	7104600	1653500
10	7106400	1652400	10	7104600	1653400
11	7106400	1652500	11	7104700	1653400
12	7106600	165700	12	7104800	1653400
13	7106500	165700	13	7104800	1653300
14	7106500	1651600	14	7104900	1653400
15	7106600	1651600	15	7104900	1653300
16	7106600	1651500	16	7104900	1653200
17	7106700	1651500	17	7105000	1653100
18	7106800	1651500	18	7105000	1653200
19	7106700	1651600	19	7105000	1653300
20	7106600	1651800	20	7105000	1653400
21	7106500	1651825	21	7105000	1653400
22	7106500	1651900	22	7105100	1653400
23	7106600	1651900	23	7105100	1653300
24	7106700	1652000	24	7105100	1653200
25	7106700	1652100	25	7105100	1653100
26	7106700	1652200	26	7105200	1653100
27	7106600	1652200	27	7105200	1653200
28	7106600	1652100	28	7105200	1653300
			29	7105200	1653400
			30	7105300	1653300
			31	7105300	1653200
			32	7105300	1653100
			33	7105300	1653000
			34	7105400	1653900
			35	7105400	1653000

Continuous, Table A4-1.

Balsjö BS catchment June 2009			Balsjö CC catchment June 2009		
Plot	**x-coordinate**	**y-coordinate**	**Plot**	**x-coordinate**	**y-coordinate**
			36	7105400	1353100
			37	7105400	1653200
			38	7105500	1653100
			39	7105500	1653000
			40	7105500	1652900
			41	7105500	1653800
			42	7105600	1652600
			43	7105600	1652700
			44	7105600	1652800
			45	7105600	1652900
			46	7105600	1653000
			47	7105600	1653100
			48	7105700	1652900
			49	7105700	1652800
			50	7105700	1652700
			51	7105700	1652600

Appendix 5.
Basal area of the harvested stand

Table A5-1. Estimates of basal area, BA, (m^2 ha^{-1}). The reference points for the coordinates are the centres of corresponding plots. The estimates are based on calipering stumps on 78.54 m^2 plots (5 m radius) and species-wise linear regressions between stump diameter and diameter at breast height. The x- and y-coordinates are according to the RT90 system.

				BA on the plot scale (m^2)			BA per ha (m^2 ha^{-1})			
Site	X-coordinate	Y-coordinate	Plot #	Pine	Spruce	Broadleaf	Pine	Spruce	Broadleaf	SUM
Balån 4	7104500	1653400	1	0.01	0.01	0.01	0.69	0.79	1.03	2.51
Balån 4	7104500	1653500	2	0.12	0.06	0.07	15.24	7.15	8.99	31.37
Balån 4	7104600	1653600	3	0.17	0.07	0.05	22.16	8.54	6.14	36.84
Balån 4	7104500	1653600	4	0.02	0.01	0.06	2.31	0.70	7.31	10.32
Balån 4	7104700	1653600	5	0.04	0.16	0.01	5.04	20.83	1.11	26.98
Balån 4	7104800	1653600	6	0.13	0.02	0.00	17.09	2.43	0.42	19.94
Balån 4	7107800	1653500	7	0.22	0.01	–	28.20	1.62	–	29.82
Balån 4	7104700	1653500	8	0.00	0.08	0.03	0.00	9.84	3.26	13.10
Balån 4	7104600	1653500	9	0.16	0.07	0.05	20.86	8.75	6.41	36.02
Balån 4	7104600	1653400	10	0.36	–	–	45.33	–	–	45.33
Balån 4	7104700	1653400	11	0.15	–	–	19.67	–	–	19.67
Balån 4	7104800	1653400	12	0.11	–	–	13.98	–	–	13.98
Balån 4	7104800	1653300	13	0.46	0.02	0.05	59.07	2.13	6.38	67.58
Balån 4	7104900	1653400	14	0.00	0.28	0.12	0.00	35.42	14.86	50.28
Balån 4	7104900	1653300	15	0.20	–	0.07	24.96	–	9.43	34.39
Balån 4	7104900	1653200	16	0.14	–	0.05	17.95	–	6.14	24.09
Balån 4	7105000	1653100	17	0.03	0.01	0.01	4.13	1.20	0.81	6.14
Balån 4	7105000	1653200	18	0.15	–	–	19.30	–	–	19.30
Balån 4	7105000	1653300	19	0.08	0.09	–	10.33	10.99	–	21.33
Balån 4	7105000	1653400	20	0.07	0.05	–	9.10	6.07	–	15.17
Balån 4	7105000	1653500	21	0.13	0.06	0.02	16.65	7.68	2.57	26.90
Balån 4	7105100	1653400	22	0.32	–	0.05	40.60	–	6.97	47.57
Balån 4	7105100	1653300	23	0.00	0.07	0.04	0.00	8.75	4.58	13.32
Balån 4	7105100	1653200	24	0.08	0.03	0.01	9.74	3.21	1.11	14.06
Balån 4	7105100	1653100	25	0.19	0.03	0.01	23.62	4.09	1.03	28.74
Balån 4	7105200	1653100	26	0.13	0.06	0.16	16.33	7.69	19.93	43.95
Balån 4	7105200	1653200	27	0.00	0.05	0.12	0.00	5.94	14.83	20.77
Balån 4	7105200	1653300	28	0.16	0.03	0.07	20.52	4.00	9.28	33.80
Balån 4	7105200	1653400	29	0.24	–	–	30.37	–	–	30.37
Balån 4	7105300	1653300	30	0.11	0.07	0.00	13.97	8.62	0.00	22.59
Balån 4	7105300	1653200	31	–	0.09	0.05	–	11.82	6.13	17.95
Balån 4	7153300	1653100	32	0.16	–	0.05	20.63	–	6.55	27.17
Balån 4	7105300	1653000	33	0.23	–	–	29.39	–	–	29.39
Balån 4	7105400	1652900	34	0.31	0.03	–	39.82	3.20	–	43.02
Balån 4	7105400	1653000	35	0.18	0.01	–	22.68	1.04	–	23.72
Balån 4	7105400	1653100	36	–	0.03	0.03	–	3.25	3.91	7.16
Balån 4	7105400	1653200	37	0.14	0.01	–	17.46	1.80	–	19.26
Balån 4	7105500	1653011	38	0.20	–	–	25.71	–	-	25.71
Balån 4	7105500	1653000	39	-	0.05	0.03	–	6.81	3.37	10.18
Balån 4	7105500	1652900	40	0.24	0.01	0.04	31.06	0.76	4.63	36.45
Balån 4	7105500	1652800	41	0.18	0.02	0.00	23.50	2.91	–	26.41
									Average	26.16
									s.e.	2.09

Continuous, Table A4-1.

				BA on the plot scale (m^2)			BA per ha (m^2 ha^{-1})			
Site	X-coordinate	Y-coordinate	Plot #	Pine	Spruce	Broadleaf	Pine	Spruce	Broadleaf	SUM
Balån 5	7106200	1652400	1	0.07	0.15	0.05	8.46	18.83	6.35	33.64
Balån 5	7106300	1652500	2	0.22	0.01	0.02	28.23	1.32	3.10	32.65
Balån 5	7106300	1652400	3	0.02	0.13	–	2.63	17.01	–	19.63
Balån 5	7106300	1652300	4	0.28	0.06	–	35.39	7.96	–	43.35
Balån 5	7106400	1652300	5	–	0.24	0.12	–	29.99	15.22	45.20
Balån 5	7106400	1652200	6	0.08	0.09	0.15	10.30	11.77	19.51	41.57
Balån 5	7106500	1652200	7	0.24	0.14	–	30.41	17.23	–	47.65
Balån 5	7106500	1652300	8	–	0.18	0.17	–	22.37	21.11	43.48
Balån 5	7106500	1652400	9	0.25	0.01	–	31.90	0.99	–	32.89
Balån 5	7106400	1652400	10	–	0.19	0.02	–	23.75	2.57	26.32
Balån 5	7106400	1652500	11	0.37	0.03	0.05	46.52	3.35	6.40	56.27
Balån 5	7106600	1651700	12	0.07	–	–	9.52	–	–	9.52
Balån 5	7106500	1651700	13	0.07	0.01	–	8.72	1.16	–	9.88
Balån 5	7106500	1651600	14	0.08	0.00	–	9.89	0.61	–	10.50
Balån 5	7106600	1651600	15	–	0.18	0.22	–	22.32	27.41	49.72
Balån 5	7106600	1651500	16	0.05	0.23	0.25	6.38	29.41	32.42	68.21
Balån 5	7106700	1651500	17	0.00	0.01	0.01	0.40	0.85	0.89	2.14
Balån 5	7106800	1651500	18	–	0.11	0.10	–	13.78	12.50	26.28
Balån 5	7106700	1651600	19	0.02	0.00	–	2.92	0.40	–	3.32
Balån 5	7106600	1651800	20	–	–	–	–	–	–	0.00
Balån 5	7106500	1651825	21	–	0.01	–	–	1.82	–	1.82
Balån 5	7106500	1651900	22	0.02	0.01	0.03	3.16	0.69	4.09	7.94
Balån 5	7106600	1651900	23	0.02	0.01	0.02	2.70	1.12	2.66	6.47
Balån 5	7106700	1652000	24	0.23	–	–	29.54	–	–	29.54
Balån 5	7106700	1652100	25		0.12			15.04		15.04
Balån 5	7106700	1652200	26	0.01	0.08	0.015	1.89	9.67	1.90	13.47
Balån 5	7106600	1652200	27	0.35	0.11	–	44.85	14.12	–	58.96
Balån 5	7106600	1652100	28	0.29	0.01	–	37.55	1.79	–	39.34
									Average	**27.67**
									s.e.	**3.72**

Appendix 6.
Sampling protocol for streamwater (in Swedish)

Contact information has been removed.

Provtagning i 277 Balsjö: Balån 1–6 (bäckar)

07-01-12 Uppsala Eva Ring, Peder Blomkvist och Balsjö-gruppen inklusive korrigeringar gjorda av Rasmus Sørensen 2007-01-15.

Förberedelser

- Meddela en närstående eller en kollega när du far ut i fält (plats och beräknad hemkomst)!
- Ta med mobiltelefonen men kom ihåg att täckningen är dålig i försöksområdet.
- Ta med provtagningshandskar, provflaskor, blankprov, stövlar, fält-instruktionen, fältprotokoll, Palm-datorer eller fältdator, termometer/termistor, tumstock, hink för flödesmätning och tidtagarur samt anteckningsmaterial. På vintern kan skidor och isborr eller yxa behövas.
- Märk varje provflaska i förväg inomhus med **provtagningspunkt, serienummer och datum**.

Provtagningspunkter

I försöksområdet finns sex provtagningspunkter. I Balån 1L och 2M tas endast prover för allmän kemi. I övriga punkter tas alla prover (se specifikation på fältprotokollet). Provtagningspunkterna med korrekt beteckning är utmärkta i fält.

Balån 1L: Fyll flaskorna med vatten uppströms bron.

Balån 2M: Sträck dig ut från stranden så långt du kan och ta proverna uppströms från där du står. På detta sätt minskar risken för att du skall få grumliga prover orsakade av dig.

Balån 3R2: Fyll flaskorna med vatten uppströms vägtrumman.

Balån 4CC, Balån 5BU och Balån 6R1: Ta proverna i inloppet av mätdammen.

Bäckvattenprovtagning

1. Allmän kemi, org Cl och O18

- Använd provtagningshandskar
- Se till att vattnet inte kommer i kontakt med provtagningshandskarna innan vattnet samlas upp i provflaskan och undvik att ta med händerna vid flaskhalsen.
- Skölj flaskor och lock tre gånger med bäckvatten:
  - häll ut eventuellt sköljvatten i flaskorna och skölj sedan flaskorna tre gånger med bäckvatten. Flaskorna fylls upp helt vid sköljningen. Locken doppas tre gånger i bäckvattnet. Ta sedan proverna. **Flaskorna för allmän kemi och org Cl fylls till ca 9/10 eftersom dessa prover ska frysas**. O18 fylls helt. Sätt på locken.
- Notera tidpunkten för provtagningen i protokollet.
- Mät vattentemperaturen i varje provtagningspunkt och notera i protokollet.
- Skriv ner eventuella problem eller iakttagelser exv. islagd bäck, låg/hög vattenföring (torrt?!), grumligt vatten av naturliga skäl.
- Mät vattenståndet i överfallet i de 3 mätpunkter som anges i fältprotokollet och notera.
- Om vattenflödet är lågt, gör tre flödesmätningar med hinken.
- Töm loggrarna med Palmen eller fältdatorn.
- Vid hemkomsten: Distribuera proverna enligt listan nedan och skicka ut fältprotokollet via e-post till Balsjö-gruppen. Prover som ska förvaras i frysen ska ligga i –20 grader eller kallare. Loggerfilerna sparas på egen dator och skickas till Eva Ring och Rasmus Sörensen.

2. Bäck-projekt 2007-: 2. Provtagnings-procedur för total-kvicksilver (HgTot) @ ITM.su.se

Flaskor: **Syradiskade plastflaskor från ITM** material HDPE, volym 125 ml, packade i individuella plastpåsar (zip-lock).

Blankprov: Två Blankprov ska tas med vid varje provtagningstillfälle (öppnas vid Balån 6). Blank = flaska som är fylld med destvatten, färdiga Blankar levereras av ITM.

Vid varje provtagning tas två Blankprover vid Balån 6.

- Ta ut Blankarna från plastpåsarna vid provtagningspunkten Balån 6.
- Öppna Blank-flaskorna och låt dem stå öppna under den tid då bäckvattenproverna för HgTot tas. Undvik att andas på flaskorna.
- Stäng flaskorna och stoppa tillbaka i plastpåsarna.
- Behandla sedan ena blanken på precis samma sätt som bäckvatten-proverna, DEN ANDRA SKA INTE KONSERVERAS.

Provtagning:

- Undvik kontaminering: Använd engångs-labbhandskar, doppa flaskan för hand (utan redskap) med öppningen "uppströms".
- Skölj 3 gånger med provvatten: skaka med locket på (på glänt), ta den fjärde fyllningen som prov, fyll ända upp (men lämna några mm till syratillsats).

Transport till Umeå:

- Efter provtagning sänds proverna omgående (om möjligt samma dag) till Peder Blomkvist, Umeå.

Provbehandling:

Inkomna HgTot-prover konserveras snarast med **0.5% HNO_3 Suprapur®** (65%, ospätt):

- 0.7 ml per 140 ml, använd mikropipett med syrasköljd engångsspets, som båda har lagrats rent.
- Endast en av de två blankarna ska konserveras.

Förvaring:

- Prover som inte skickas omgående ska förvaras mörkt i kylskåp.

Transport från UmU till ITM:

- Efter uppsamling skickas lagrade prover inkl "Blankar" för analys, med intervall som känns praktiska (pga kylutrymme, förpackningar, etc).

Adress: (företagspaket) Inst. för tillämpad miljövetenskap (ITM), Stockholms universitet.

3. Provtagningsprocedur för metyl-kvicksilver (MeHg)

Som för Hg-tot, men inga blankprover tas. MeHg konserveras inte utan levereras till laboratoriet så fort som möjligt.

Provhantering efter insamling i fält

Prover för analys av	Förvaring efter hemkomst	Skickas som
Allmän kemi*.	Fryses.	Företagspaket i specialträlådor.
Org Cl*.	Fryses.	
HgTot.	Konserveras och förvaras sen i kylskåp.	Företagspaket.
MeHg.	Omgående leverans till Inst. Analytisk Kemi, Umeå Universitet. (Förvaras annars mörkt i kylskåp).	Personlig leverans omgående.
O18	Förvaras i kylskåp tills beslut om att analysera.	–
Fältprotokoll.		Brev + e-post
Loggerfiler.	Lagras hos SLU, Umeå.	

* Flera provomgångar samlas ihop för Allmän kemi-prov och org Cl-prov och skickas iväg efter överenskommelse med ansvarig forskare. Skicka med pappersprotokollen som hör till proverna (fliken "Labbprotokoll Miljöanalys" som finns i 277stream protocol_yyyymmdd.xls.).