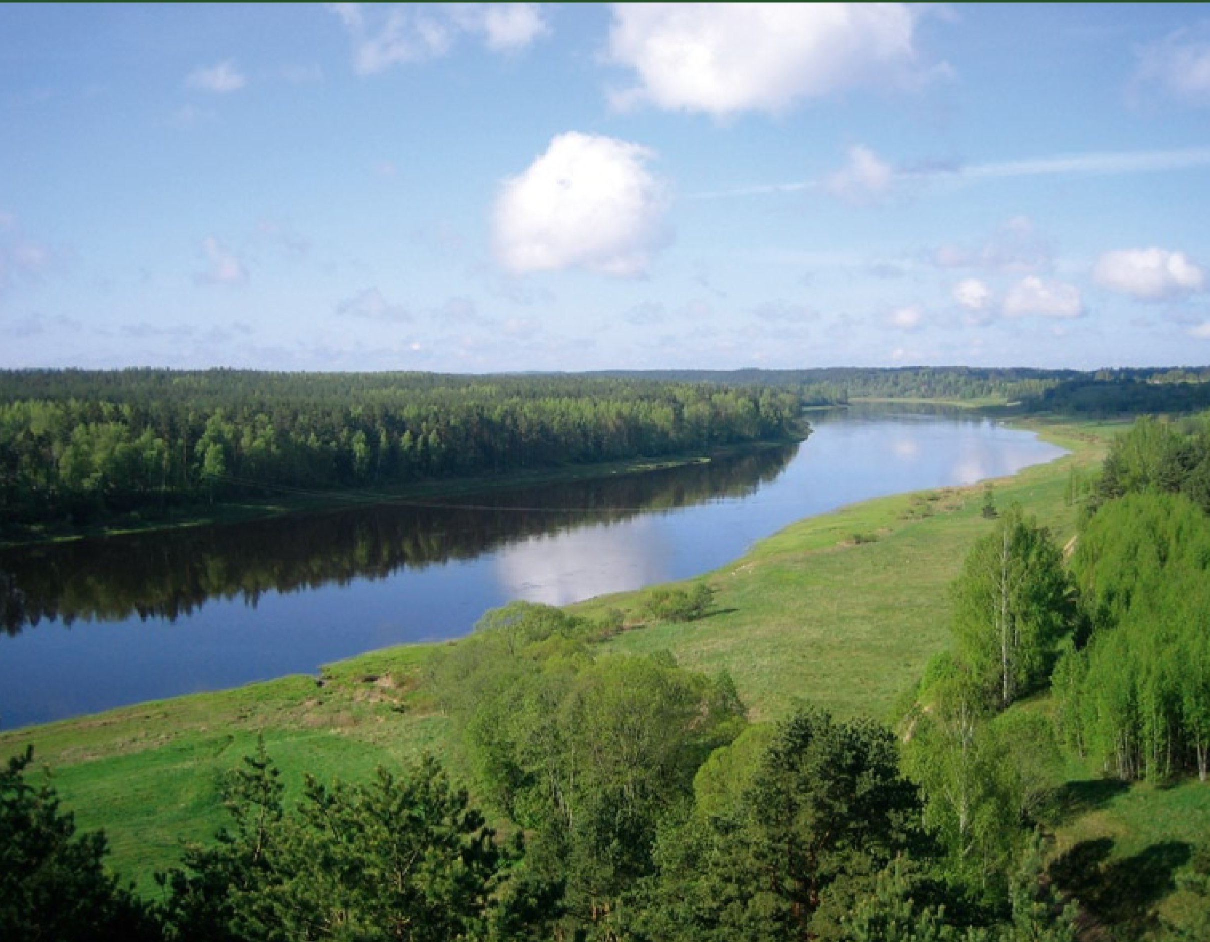
# HYDROLOGY: FROM RESEARCH TO WATER MANAGEMENT

## XXVI NORDIC HYDROLOGICAL CONFERENCE
## NORDIC ASSOCIATION FOR HYDROLOGY
## RIGA, LATVIA, AUGUST 9-11, 2010



EDITORS: **ELGA APSĪTE, AGRITA BRIEDE, MĀRIS KĻAVIŅŠ**

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# Contents

# PREFACE

This is the second time when Latvia hosts an important international conference of hydrology. Many Nordic hydrologists still remember the hydrological conferences of the Baltic Sea States in the 1920's and 1930's. The first conference held in Riga in 1926 had participants from Latvia, Estonia, Lithuania and Poland. The Nordic countries joined the conference organization in the following conferences: Sweden and Finland in 1928, Denmark in 1930 and Norway in 1936. The 7$^{th}$ hydrological conference of Baltic Sea States was to be arranged in Kaunas, Lithuania, in 1941. For well-known reasons, the conference could not be take place, and the tradition was discontinued.

Since 1996 all the three Baltic States have joined the Nordic Hydrological Association as associated members and since 2000 as full-members. In 2010 the Nordic Hydrological Conference (NHC) takes place in the Baltic States for the second time (Estonia in 2004), it is outside the traditional region of the Nordic countries. Thus, the organization of the XXVI NHC in Latvia means a return to the traditions of the first Baltic hydrological conferences.

The Conference will last three days with the aim to promote the exchange of experiences from hydrological research and practice conducted in different fields in order to compare research priorities, methods, data, knowledge and results, achieved by different scientists, who are working for a better understanding of hydrological processes and improvement of water resources management. Altogether, more than 110 participants from 16 countries have registered for the Conference.

In the book on Nordic Hydrological Programme Report No. 51 we offer 91 abstracts – both orals and posters – presented and discussed during the Conference. In this volume the abstracts are ordered by Conference sessions and alphabetically according to first authors' name, where – on purpose – no distinction is made between poster and oral presentations. The authors of the abstracts have a solelresponsibility for the content of their reports. The Conference covers the following themes:

- Climate Change Impacts and Adaptation Strategies
- Water Management within the Context of European Directives
- Hydrological Information System and Developments in Modelling
- Measurements and Monitoring
- Extremes and Uncertainties
- Groundwater and Surface Water Interactions
- Cold Climate Hydrology

The Conference is jointly organized by the Latvian Environment, Geology and Meteorology centre (LEGMC) on behalf of the Nordic Association for Hydrology (NHF) in co-operation with University of Latvia (LU) and Latvian National Commission for UNESCO (UNESCO LNC). The Organising

Committee is chaired by Iveta Dubakova (LEGMC) and composed of Vita Slanke (LEGMC) and Māris Kļaviņš (LU), and Dagnija Baltiņa (UNESCO LNC). The Scientific Advisory Committee is chaired by Elga Apsīte (University of Latvia) and composed of Agrita Briede, Andris Andrušaitis, Gunta Spriņģe, Juris Aigars, Māris Kļaviņš, Uldis Bethers, and Aija Dēliņa (University of Latvia), Līga Kurpniece and Tatjana Koļcova (Latvian Environment, Geology and Meteorology Center), Viesturs Jansons (Latvia University of Agriculture), Alvina Reihan (Tallinn University of Technology), Arvydas Povilaitis (Lithuanian University of Agriculture), Jurate Kriauciunienė (Lithuanian Energy Institute), Bjørn Kløve (University of Oulu), David Gustafsson (Royal Institute of Technology), Deborah Lawrence (Norwegian Water Resources and Energy Directorate), Jens Christian Refsgaard (Geological Survey of Denmark and Greenland), Thorsteinn Thorsteinsson (Icelandic Meteorological Office).

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the members of the Scientific Committee or Editor of this publication.

The organizers will take this opportunity to thank those who have helped to make the Conference possible. Finally, I would like to thank all participants for their contribution and making a successful Conference!

Iveta Dubakova

Chairperson of Organising Committee

# Plenary Session

# THE CLIMATE CHANGE CHALLENGE IN COASTAL ZONES AND UPSTREAM WITH SPECIAL EMPHASIS ON GROUNDWATER. COLLABORATION AND INNOVATION IN SOCIETY, SCIENCE AND INDUSTRY IS NEEDED

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## Background/Rationale

As a consequence of global warming, we in Northern Europe are facing an increase in precipitation, changes in precipitation distribution, less rainfall in summer and more in winter. The precipitation pattern is expected to have a more dynamic cycle, with longer droughts and more intense rainfalls. As a result, groundwater models predict increases in groundwater levels of up to 2 metres in some areas (Van Roosmalen et al., 2007). Sea level will also rise. The precise increase is uncertain but models show increases of up to 0.88 m (Thomé-Schmidt et al., 2006) in the next 60–90 years.

Economic growth, population growth and intensified agricultural land use will increase demands on fresh groundwater resources in the future. The uppermost surface groundwater is and will be increasingly contaminated due to the land use. Changes in evaporation and recharge patterns will lead to increased demand for water for agricultural use. Additionally, the fresh water in coastal zones will be affected by the anticipated sea level rise.

One of the consequences of climate changes will be flooding which will affect the assessment and delineation of suitable industrial and agricultural development areas. Groundwater level and sea level rises will challenge the construction sector and it will be necessary to come up with new standards. It will also change the available groundwater resource and stream flow patterns between summer and winter. Rising sea levels will also affect the development of recreational areas and water abstraction in coastal zones because of flooding and seawater intrusion into fresh aquifers. Climate change scenarios pose great challenges to adaptive local and transboundary spatial planning in the North Sea Region and in other regions.

The changes will have consequences on the hydrological cycle and calls for greater awareness among society as a whole. Climate change will affect us all and water is a common challenge. Are we prepared?

## CLIWAT project

CLIWAT (CLImate change and groundWATer) is a transnational project in the North Sea Region, mapping groundwater and dealing with sustainable planning and solutions to meet the approaching challenges caused by climate change. A wide range of sectors will be affected by the changes and they are therefore a part of the project. This has lead to adaptation strategies focussed on the needs of the sectors.

The CLIWAT project has set up groundwater models. These models vary from local models focussing on local issues, to large-scale models focusing on future demand and water balance. The models provide a strong tool to make forecasts about groundwater systems and the water cycle in a future climate regime. It is also a tool for water managers, enabling them to better prioritise challenges. Priority in this context could be: Are the low lying parts of a specific town threatened by flooding due to groundwater flow, a rise in sea level or both? Is the local water supply threatened by flooding? Can we expect more dynamic catchment areas from the abstraction wells? Will the demand for abstraction and irrigation increase and can the hydrological system meet demand?

CLIWAT focuses on "flooding" underneath the surface, where groundwater levels may rise above or close to the surface. At present this aspect is not greatly elaborated on in the EU or at the national level. The results from this project will be used to predict how future climate changes will affect groundwater quantity and quality and hence communities, for example in the lowlands around the North Sea Region and groundwater-dependent ecosystems. There will be a need for new legislation and/or new engineering standards for drainage, roads and buildings, and status assessments of the aquatic environment at regional, national and EU levels, when climate and water and pollution fluxes change.

In order to prepare society for these expected changes and to determine useful and necessary protection measures, it is essential to base the adaptation process on sound knowledge derived from scientific research. The water challenges must be solved by broad professional cooperation, at regional, national and transnational levels.

An early adaptation strategy should include all of the affected sectors and authorities and their planned activities, such as buildings, roads, etc. This will give communities a strong base for meeting the climate change challenges they face.

For further information on CLIWAT please visit www.cliwat.eu

## Case Study

## Horsens City – an example of an integrated approach

*Introduction*

Horsens is situated in Mid East Jutland. A local creek with a river basin of about 180 km$^2$ flows into the eastern part of the city via a dammed lake.

The estuary flows into Horsens Fjord. The water from the dammed lake is controlled by a mechanical water sluice.

An increase in sea level will cause more frequent flooding in the town due to its low lying position by the fjord. In 2006, the local town hall was flooded when sea level rose 1.76 m above normal. Simultaneously, increased net precipitation and increased rainfall intensity will increase pressure on the sewage system and the lake dam. Flooding of the town is expected to occur more frequently.

The challenges have been divided into two main themes: sea level change and rainfall.

Rising sea level:

- Flooding and water quality – increased challenges for the sewage system and sewage plant's capacity
- Flooding and challenges for local land owners.

Increased rainfall intensity, more water from the hinterland and groundwater

- Flooding of a local park
- Increased pressure on the sewage system
- Increased pressure on the local dam.

During a three hour brainstorming meeting, a group of technicians representing expert knowledge at many levels and public authority sectors (Horsens municipality, other municipalities, advisory consultants from different companies, The Geological Survey of Denmark and Greenland, Danish Coastal Authority, Danish EA and Central Denmark Region, etc.) worked to find solutions that would meet the challenges.

The meeting produced a number of proposals:

*Sea level – daily variations and extremes*

- Build a new dam at the eastern end of the fjord. At high tides the dam will prevent flooding of the inner fjord. Water from the hinterland could be pumped passed the barrier. At normal water levels the water from the river basin should be led through sluices. The disadvantage of this is that the global sea level rise would require large volumes of water being pumped from the inner fjord to the sea
- Use the water! The increased amount of water can be utilised commercially. This will call for the conversion of some areas. However, there is a considerable time in advance of the climate change to take place and this allows a long planning period. This calls for a long-term vision of urban development. A proposal was to build on floating structures.
- Attitudes about building in the port area and low parts of the town have to be challenged. Today new constructions are built with a plinth height of 2.20 m when plinth height should be around 3 m to prevent flooding in the next 100 years.
- Building a dynamic sea barrier which can quickly be set up by if the sea is rising. The wharf area should have closed roads and pedestal heights. The areas in between can contain regulated terrain. All together this would create a barrier against rising sea water.
- Sewage systems are separated into waste water and rain water.

*Increased knowledge*

There is a need for building up a dynamic groundwater/surface water model which will inform planners about the critical levels for sea level rise. Furthermore, the model could be used for the development and analysis of critical duration of sea level and precipitation. In addition, there is a need for an economic analysis of the different solutions.

*The local creek and precipitation*

- Seeping and retain water in the river basin – likely to be local solutions upstream. The more the better to prevent a massive volume of water from quickly entering the city. Examples like less draining in the agricultural fields, roofs made with acidophilous on top.
- To alleviate the water from the hinterland entering the city, lay a pipe from Bygholm Lake to the fjord outside the city.

*Planning*

- Instead of traditional planning in the prevailing planning period of every 2–8 years, take an alternative approach. Turn it on its head and start looking at how we want Horsens town to deal with water in 2100. This perspective might bring a broader vision and lead to pioneering solutions.
- There is a need to think about how we build today.

*First steps towards climate change adaptation in Horsens Town:*

- Establish a project group with the main task of developing a catalogue describing the challenges.
- Work on a political vision for 2100.
- Establish a groundwater surface model describing the hydrological cycle.
- Make a stakeholder analysis, including the directly and indirectly affected parties.
- Develop a project structure and pointing out the members of the project.

Horsens city is in a complex situation like many other Danish towns facing Kattegat. The case study shows how important it is to bring together knowledge and perspective to come up with alternative and more sustainable solutions.

What is interesting about the Horsens case, is not just the exact ideas, but the synergy of bringing together different sectors and expertise, and taking a long term holistic approach. Some of the challenges the town faces, can be met by agriculture many kilometres away. Other challenges can be met via local solutions, e.g. roof materials and the local diversion of water.

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## Session 1

# MEASUREMENTS AND MONITORING

# SPRING FLOOD IN LATVIA: A CASE STUDY OF THE LIELUPE BASIN

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During the flood the Lielupe basin is very sensitive to inundation of territories due to its specific natural factors. A vivid example of this proved in spring of 2010 when large populated areas, agricultural lands and territories of commercial activities were flooded. It caused financial, material and psychological damages.

The aim of this research is to describe the process and factors influencing the flood of the Lielupe basin in spring of 2010. The results are based on obtained and processed information of Latvian Environment, Geology and Meteorology Centre, using available hydrological and meteorological observations from the stations.

The important factor in the area of the Lielupe basin is the typical relief of lowlands and plains where slopes of rivers are very low. The average slope of the Lielupe River is 0.48 m/km. In its course from the confluence of two tributaries which form the Lielupe River to town Stalgene the slope is 0.1 – 1.4 m/km. But in its flow from town Stalgene to the mouth the slope is nearly zero. Moreover the Lielupe basin has a particular shape of the hydrographic net. In the relatively small area (specially in the vicinity of town Jelgava) several large tributaries flow in the Lielupe River (for instance, on the left bank the Svitene, Sesava, Vircava, Platone, Svete and on the right bank the Iecava, Garoze).

One of the main factors influencing the spring flood in 2010 was the cold and snow-rich winter. In spite of the increasing global warming tendency, sufficiently long winter developed without substantial thaws and formed thick snow cover (the average maximum snow thickness 35 – 45 cm). But short-term thaw began before the flood period at the end of February and the beginning of March with a little bit of snow melting and meltwater on ice. After air temperature decreased the meltwater froze and total ice thickness increased (forming ice 35 – 57 cm thick in the Lielupe River and 40 – 65 cm thick in its tributaries). The beginning of spring set in very fast. In the middle of March air temperature fell to –20 °C, but already on March 20 it reached +3 – +9 °C. It caused intensive snow melting and increase in discharge of rivers. This process was hastened by rain precipitation due to cyclonic activities. At the same time the thick ice cover had still remained.

All the mentioned factors in the Lielupe basin contributed to fast rise of water level and ice fracturing. Due to the increasing water level the ice cover was lifted and rivers flooded their banks. Wide territories were inundated because of the specific ice conditions, relief and the character of the hydrographic net. The ice jams formed at several areas during the ice shearing and floating. The highest water levels were reached only a few days after the beginning of snow melting.

The process of ice floating in the Lielupe basin began at upper reaches from tributaries (the major Musa and Memele) and continued to the North. The ice floating started on March 21, which was 1 – 3 days later if compared with the long-term average data.

Near town Mezotne (95 km from the mouth) a rapid rise of water level of the Lielupe River was caused by water resources from the upper course, snow melting waters and high ice thickness. The ice floating went quite fast (taking a few days) because of the higher slope of the river than in the lower part of the basin. The maximum water level of the Lielupe River near Mezotne was observed on March 22 in 2010 (7.98 m BS), which was 0.50 m higher if compared with the water level of long-term average maximum flood in this observation station (later in the text: long-term average).

Near town Stalgene (87 km from the mouth) significant ice jams were formed, which caused a rapid rise of water level and inundation of large territories. The process of ice floating was a bit longer than in Mezotne because in the down reaches from Stalgene the slope diminishes sharply. The maximum water level of the Lielupe River near Stalgene was observed on 24 March in 2010 (5.13 m BS), which was 0.65 m higher than the long-term average.

Near Jelgava (67 km from the mouth), which is the fourth major towns in Latvia by the number of inhabitants, was observed a rapid rise of water level of the Lielupe River when large areas were flooded. The thick ice cover and ice jams inhibited water discharge to the mouth in the down reaches. Water level almost rose to the mark indicating dangerously high water level, which could cause more serious threats to inhabitants. But the reached high water level remained unchanged several hours and gradually decreased when the river freed itself from the ice. The maximum water level of the Lielupe River near Jelgava was observed on March 25 in 2010 (3.32 m BS), which was 0.84 m higher than the long-term average.

Due to the fast rise of water level of the Lielupe River near town Kalnciems (48 km from the mouth) ice was lifted and also large areas were flooded. But significant ice jams did not form and ice was taken away by water force. The maximum water level of the Lielupe River near Kalnciems was observed on March 27 in 2010 (2.45 m BS), which was 1.06 m higher than the long-term average.

Near town Sloka (27 km from the mouth) the process of ice floating was quite fast without any remarkable ice jams. The maximum water level of the Lielupe River near Sloka was observed on March 28 in 2010 (1.30 m BS).

Although relatively warmer weather had set in, an ice foot had still remained on the coast of the Gulf of Riga near the mouth of the Lielupe River. This factor inhibited water discharge to the gulf. After the rise of the air temperature the ice foot gradually decreased. The total clearing of coastal ice was observed only at the end of March.

In general, values of maximum water level of the Lielupe basin were reached predominantly 1 – 3 days earlier if compared with the long-term average data. The observed maximum water levels were reached on average once in 5 years (probability 19 %) in the Lielupe River and once in 14 years (probability 7 %) in its tributaries.

The amount of flooded areas can be affected not only by natural factors, but also by anthropogenic factors, for instance, management of hydrotechnical structures. Unfortunately a great number of dams in the polder systems, which protect populated areas and territories of commercial activities from flooding, are in an inadequate technical state in Latvia and the Lielupe basin as well. Almost all of their canals are overgrown and foul.

In conclusion the sprig flood of the Lielupe basin in 2010 was quite substantial because of high water levels with low probability of being observed once more when wide areas were flooded. Although the most maximum values were not reached they reminded us about the large power of water and natural processes occurring in rivers.

# MONITORING OF DEPOSITION AND SOIL SOLUTION IN LEVEL II FOREST MONITORING PLOT IN LATVIA

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Forest monitoring have been date back to the early 1980s, when a severe decline in tree crown condition and health status of forests occurred across large parts of Europe. In order to objectively describe changes of forest health foresters and scientists all over Europe started to monitor indicators of forest health including deposition and soil solution within the scope of different national or international programs. Concern that the decline was triggered by air pollution led to establishment of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in 1985. Close cooperation between the European Commission and ICP Forests over the next 20 years led to rising of the Further Development and Implementation of an EU-level Forest Monitoring System (FutMon) project in 2007. ICP Forests and FutMon are coordinated by the Institute for World Forestry.

ICP Forests is the only field-based monitoring system providing continuous and tarns-nationally harmonized data on forests for the most of countries in Europe. The monitoring is implemented in two levels of intensity: 'Level I' (~ 6000 systematically selected plots in 38 participating countries) and the more intensive 'Level II' monitoring (~ 800 plots located in the most important forest ecosystems in 29 participating countries). ICP Forests is one of the largest of the historically running forest monitoring programmes in the world, covering over 200 millions of hectares (Institute of World Forestry, 2009).

Implementation of the Level II forest monitoring in Latvia was initiated in 2004 by establishment of single monitoring plot in Valgunde municipality, Jelgava district (parcel No. 10 in block No. 1 of Jelgava unit of the Forest research station). Characteristics of forest stand are:

- Growing stock of timber 289 $m^3$ $ha^{-1}$;
- Density index 0.9;
- Site index II.

The first floor of trees in the Level II monitoring plot in Valgunde consists of pine trees (*Pinus sylvestris* L.), spruce (*Picea abies* (L.) H.Karst.) dominates in the second floor. Ground vegetation consists of glittering wood-moss (*Hylocomium splendens*) and Schreber's Moss (*Pleurozium schreberi*) in the moss layer and bilberries (Vaccinium myrtillus L.) in the coalescent plants layer.

The water monitoring program in the Level II plot consist of collection and analysis of soil water samples from certain depths using semi-automated sampling system with lysimeters and sampling of precipitation samples (from open field, under tree crown and from stem surface) on regular basis using harmonized methodology. There are plenty of studies on qualitative difference between precipitations collected in open field, under tree crown and from stem surface in boreal forests demonstrating significant impact of woody vegetation on flow of chemical elements in forest ecosystems. Chemical characteristics of rain water change during a way through different levels of forest vegetation and soil due to impact of several factors like ion exchange, mineralization of organic compounds and weathering of minerals.

Two open type collectors of rain water are installed in open field (clear-cut area) in the Level II monitoring plot in Valgunde. Funnels are located 1.5 m above ground level to avoid impact of vegetation. Ten open type collectors are installed at the ground level under crowns of trees in forest. Water in these samplers is collected during vegetation period. Ten collar type collectors of precipitation are installed at 1.3 m above ground level to collect water flowing off the surface of stems of trees. These collectors also are used during vegetation season. Sampling takes place at the first, tenth and the last date of every month. Volume of water in collectors is measured and all collected water is taken for composition of average sample. A monthly average sample for chemical analyses is produced at the end of every month by proportional mixing all collected samples. Following parameters are determined in precipitations: pH, conductivity, Na, K, Mg, Ca, $NH_4^+$, $Cl^-$, $NO_3^-$, $SO_4^{2-}$, DOC, $N_{total}$.

Soil water samples are collected in 7 sets of lysimeters installed at 3 depths – in a zone of distribution of roots (10...20 cm), below the zone of distribution of roots (40...80 cm) and right below a humus layer. Sampling takes place 3 times per month simultaneously with sampling of precipitations. A manual pump is used to empty vessels connected to the lysimeters and located at 1.2 m depth. Volume obtained from each lysimeter is fixed thus producing monthly charts of water run-off through soil. At the end of every month samples from the same layer are proportionally mixed and 3 monthly composite samples are analysed. If amount of water is insufficient for particular analyses composite samples of several months are mixed together. Following parameters are determined in soil water: electrical conductivity, pH, DOC, K, Mg, Ca, $Al_{total}$, $NO_3$-N and $SO_4$-S.

Methodology accepted by ICP Forests is used during sampling, preparation, storage and analysis of water samples (ICP Forests, 2006) taking in account requirement for quality assurance.

Results of the Level II monitoring program in Latvia covers only 6 years, therefore they can be considered as preliminary, however some interesting trends in distribution of precipitation and dynamics of run-off through different soil layers can be estimated already now. For instance, measurements of pH of the rain water demonstrates clear trend of increase of alkalinity of water during last years. However the most of the benefits from these observations can be found at the European level, where fluctuations of different parameters at about 800 plots are compared.

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# SWISS HYDROMETRY: A MULTIPURPOSE NETWORK

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The Swiss hydrometric network was established in the second part of the XIX century and includes currently approximately 300 stations. Aiming mainly at ensuring the long-term monitoring of surface water and supplemented by approximately 500 measuring sites of groundwater, this network provides the hydrological foundation to national environmental policy in the domains of flood mitigation, water management and health. These different goals imply a differentiated optimization of network design and management.

Flood protection implies three complementary activities. First, the hydrometric network must be reliable even during extreme events in order to forwarding information to decision makers in due time. This implies on the one hand the installation of a robust chain of acquisition, transmission and storage of measurements which must be redundant and on the other hand to the availability of sufficient workforce during a crisis – which can last one week. Secondly, the measurement network must allow the elaboration of flood forecasts and warnings, including know-casting. Lastly, the hydrometric network must be coupled with an internet based platform of information on natural hazards. In Switzerland, the option was taken to provide decision makers at the national, regional and local levels integrated meteorological, hydrological and snow information on an unique internet website called GIN.

This same network must also be able to provide information on seasonal, annual and multiannual syntheses in the domain of water management. This in order to monitoring the availabilities for various uses but also to allow developments of strategies and concepts of water management.

The quantitative measurements network must be completed by a water quality network including nutrients, pollutants, temperature and turbidity.

Finally, the hydrometric network must also be able to provide bases for the hydrologic research, which implies not only measurements on larger catchments, but also on small ones, with more detailed parameters.

A rigorous management of such a multiple purpose hydrometric network is even more important as new issues appear, as for instance adaptation strategies for climate changes or the growing need for a general environmental observation system at local, regional, national and continental scales. In Switzerland, the national network is completed by cantonal and private networks: coordination is thus imperative in order to define common goals and avoid duplication.

In conclusions, it is necessary to carry out a permanent check of the performance of the hydrometric network and to ensure an early detection of new issues. Close cooperation within hydrometric organizations and with partners in the domains of meteorology, snow science, natural hazards, water management and water quality is required.

# DIEL FLUCTUATIONS IN STREAMFLOW: ARE THEY REAL?

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Introduction: The pattern of higher streamflow at dawn and lower streamflow during the afternoon was noted several decades ago (Troxell, 1936), but it was only with the advent of automatic datalogger systems that these variations could be studied in detail. They have been linked to a chain of causal factors, namely: increasing air temperature, which is a consequence of solar radiation, increases watershed evapotranspiration and decreases water recharge to groundwater. Thus, water tables decrease, causing a diminution in streamflows. Some studies have shown that trees are the main factor responsible for evapotranspiration within a watershed, as diel fluctuations have been observed in sapflows. Moreover, in losing reaches diel streamflow variation can also occur as a consequence of increased streambed infiltration during the afternoon. Lastly, snowmelt and freeze-thaw cycles can also contribute to the variation in streamflow, especially in alpine environments.

In spite of the accepted concept of diurnal fluctuation of streamflows, most studies do not critically examine the validity of patterns measured with different electronic devices (e.g., Constantz, 1998; Wondzell et al. 2007). Some studies do not even report what type of sensor was used. Common water-level loggers measure hydrostatic pressure in addition to atmospheric pressure, it being necessary to discount the latter by using another logger out of the water (barometric compensation). This discounting can generate an error in the measurements, which is greater if the external logger is not located correctly. In this research, we evaluate the validity of diurnal streamflow variations in three situations: i) field measurements with a logger under water with another logger located 10 m from it at 1.5 m above ground; ii) a detailed laboratory evaluation of logger behaviour under a controlled water level, with known pressure and temperature variations; and iii) a re-evaluation of field measurements, through relocation of the barometric compensation logger adjacent to the submerged logger, considering the patterns detected in ii).

Materials and methods: we monitored a small watershed (42,600 m$^2$) in the Valdivia Rainforest Eco-region of southern Chile (40°S, 73.5° W). It was composed of a central strip of native riparian vegetation (mainly trees and ferns), 26 m wide, surrounded by an exotic forest plantation of fast-growing *Eucalyptus globulus* trees.

Field measurements. We measured air temperature, streamflow, and stream temperature. To determine streamflow and stream temperature every 15 minutes, we constructed a V-notch weir (90°). It was equipped with a pressure/temperature logger (HOBO U20-001-01, Onset Computer Corporation, USA) (hydrological station). For barometric compensation, we installed another logger of the same model at 1.50 m above ground (the standard height for meteorological stations), 10 m apart and 3.5 m above the weir. This instrument registered air temperature and atmospheric pressure. The study period was from November 14, 2008 (spring) to April 14, 2009 (autumn).

In another field monitoring from December 2009 to February 2010, we changed the location of the meteorological station, by placing the logger immediately in front of the water-level logger, both of them below the water table. However, the former logger was placed in a PVC tube that was closed at the bottom and open at the top to allow the entrance of air and not water.

Laboratory measurements. We put a logger in a test tube with water up to different depths depending on the experiment (22-39 cm). The test tube was cooled/warmed by using a freezer/oven, respectively, or, in some cases, the ambient temperature was used when the initial water temperature was different from the ambient temperature. Generally, the external logger was placed immediately adjacent to the test tube. Data capture was every 15 s to 5 min, depending on the experiment duration.

Results: We detected a clear diel streamflow variation when the external logger was placed 1.5 m above ground, under a marked diel fluctuation in air temperature (mean 12 °C) and a dampened fluctuation in the stream temperature (mean 2.2 °C). That variation is equivalent to a water depth fluctuation in the weir of 1.34 cm (mean). In laboratory experiments, we proved that when the external logger is considerably warmer than the water-level logger, depth measurements can be underestimated by up to 1.5 cm. When air temperature is significantly lower than that of the water, water depths can be overestimated by up to 0.9 cm. These instrumental artifacts are large compared to the documented variation (1.34 cm) and are plausible in the field due to the strong diel oscillation of air temperatures and reduced variation in stream temperatures. Finally, when we relocated the external logger adjacent to the water-level logger, the results confirmed the pattern detected previously in the field, but streamflow fluctuations were 24% less accentuated.

Discussion: Diel fluctuations in streamflow are real, but they can be intensified by an incorrect location of the barometric compensation logger. When this logger is warmed by the air, its pressure records increase (and vice versa), which barely happens with the water logger that experiences a stable thermal regime. Thus, the barometric compensation is flawed. We recommend the location of the external logger immediately adjacent to the water-level logger. The reported artifact has great importance when the objective is either to document small signals in streamflow, to know the exact value of streamflow, or for the assessment of statistical relationships between variables.

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# ANALYSIS OF THERMOHALINE STRUCTURE OF THE BALTIC SEA DURING SPRING PERIOD: RESPONSE TO COLD WINTER 2010

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Water temperature in large water bodies at mid latitudes typically passes across the temperature of maximum density (Tmd) twice a year – in spring and in autumn – causing principal change in mixing regime in water body. The process of gradual transition may last up to several months, favoring the development of a specific front, known in limnology as a “thermal bar”. It was observed in many large lakes of the world (Ladoga, Onega, Baykal, Great Lakes of America).

Temperature of maximum density is above water freezing point for the salinity below 24.7 psu. Therefore, the direct analog of the thermal bar – seasonal thermally-induced front – can be formed also in brackish basins (for instance, the Baltic sea), where significant temperature gradients appear every spring/autumn due to heating/cooling from the surface. There are only a few publications on observation of such structural front in the Baltic Sea (e.g. Bychkova et al., 1987); any systematic investigation of such front in the Baltic was never published.

As it was reviled from field observation in Ladoga Lake (Naumenko, 1989), meteorological conditions are the key factor influencing the front formation and speed of its propagation. Typically, an obvious temperature jump is associated with the Tmd; its value depends on external conditions (for instance, severity of winter); typical temperature gradients in the frontal zone in lakes are of the order of $10^{-4}$ °C $m^{-1}$ (Naumenko, 1989).

Analysis of thermohaline structure of the Baltic sea after severe (2002/2003) and mild (2006/2007) winters (Demchenko et al., 2009, submitted) shows that, like in lakes, vertical mixing regime in brackish Baltic Sea water in spring is different on opposing sides of the Tmd-line. Under the same heating conditions from the surface, upper layer in colder northern part (which has a temperature below the Tmd) experiences thermo-gravitational convection, whilst in southern part water (above the Tmd) gets more and more stable vertical density stratification. The analyzed data have demonstrated that after severe winter, horizontal water temperature profiles across the Tmd have an obvious temperature jump, occurring in the vicinity of the Tmd; temperature gradient in this area is 20-100 times as big as the mean-annual one for spring time; width of the frontal zone is about 20-45 km. Temperature differences across the frontal zone after severe winter appeared to be 4 times higher than that after the mild winter. Obvious chlorophyll *a* jump, associated with the Tmd, occurs in spring and propagates from southern to northern Baltic. Horizontal extension of the chlorophyll *a* jump is about 200 km. Thus, a well pronounced frontal zone, associated with the Tmd, does exist in the Baltic Sea in spring period and influences the variability of the biological parameters.

Winter 2009/2010 was rather severe (www.io-warnemuende.de); a present study is devoted to analysis of a thermal and current structure in presence of the Tmd in the Baltic sea during spring period. The following field data were analyzed (1) Data of field measurements, performed by Laboratory for Coastal Systems Study of AB SIO on 25 of March and 8 of April 2010 on the bottom slope of the Gulf of Gdansk. 40 vertical CTD-profiles were performed every 500 m from 4 m to 68 m depth (total length of cross-section is about 20 km) and subsurface temperature and salinity along the mentioned above section was obtained during day-time of 25 March and 8 April. (2) The data of Leibniz Institute for Baltic Sea Research environmental monitoring of in frames of HELCOM program along a section in southern and central Baltic in spring period (17-27 of March; end of April – mid of May, 2010). (3) Subsurface temperature, salinity and chlorophyll-*a* along the section Travemünde-Helsinki, performed by Finnish Institute of Marine Research (Ship of Opportunity program) for the mentioned above periods (29-30 of March; 12-13 of April; 18-19 of April; 27-29 of April 2010).

Temporal development of fields of temperature and salinity, and coastal-offshore exchange in relation to the climate variability are discussed.

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# COMPARISON OF DIFFERENT INSTRUMETNS FOR DISCHARGE MEASUREMENTS IN RIVERS

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NVE is the national centre of expertise for hydrology in Norway, and one of our main responsibilities is the national hydrological database. The database contains long, continuous time series for discharge, and for several purposes the consistency of these data is of great importance. Changes in the way data is collected might corrupt the consistency, and we must investigate and document if new methods causes any systematic changes in the data.

On the vast majority of NVE's stream gauging stations, discharge is calculated from time series for stage, using common stage-discharge rating curves.

If new methods for measuring discharge give a systematically different discharge than older methods, it will lead the hydrologist to change the rating curves, since new discharge measurements do not fit to the rating curve. This in turn will change the time series for discharge, even if the actual discharge in the river has not changed. This apparent change in discharge has no basis in nature, it's merely a change in methodology, and if changes in methods are not well documented, it might easily lead to erroneous conclusions by the users of the data.

Until the mid 1990s the only methods NVE used for measuring discharge was the salt dilution method and mechanical current meters. Since then several new methods has been introduced, and the way the mechanical current meters are used has changed.

An ever increasing portion of our discharge measurements are made by using bottom-tracking hydroacoustic instruments. These instruments measure discharge by measuring depth, their own movement relative to the river bed and the velocity of the water.

Until five years ago hydrologists at NVE used computer-algorithms that mimicked the hand-drawing, graphical depth-velocity-integration method for calculating discharge from mechanical current meter data. This method fitted smooth curves true the point measurements to calculate vertical mean velocities, area and discharge. It was important for the hydrologist to measure velocities so that the shape of the vertical velocity profile was well measured.

Since then the ISO 748 reduced point methods has been used. When using these methods, the hydrologist samples velocities at pre-defined depths, mainly at 20 and 80 percent of the depth. Investigations showed that the vertical mean velocities and the total discharge for the two methods differed insignificantly. This will only be presented briefly, since the old method is agency-specific for NVE.

The main focus of this presentation will be the comparison between different hydroacoustic instruments, and between hydroacoustic and mechanical instruments. More specifically between:

- Rio Grande ADCP from TRDI;
- StreamPro ADCP from TRDI;
- Mechanical current meter (Ott C-31), iso 748 reduced point methods.

The comparison measurements are carried out in natural rivers by NVE's field hydrologists. Some of them as part of regular field-work, and some on dedicated comparison-measurement-campaigns.

The main focus is to compare discharge, so that the measurements are made simultaneously, but not always at the same cross-section. For those that are made at the same cross-section, both area and discharge will be compared.

# MEASUREMENT OF LIQUID WATER CONTENT IN SNOW AND ITS APPLICATION IN SNOW HYDROLOGICAL MODELLING

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Snow melt runoff is a dominating water resource in many alpine and high latitude regions, and hydrological model predictions are important for efficient management of for instance hydropower production. Uncertainties in snow melt runoff predictions typically emerge from uncertainties in the input data on precipitation and temperature, and there is a growing interest to make better use of snow data to improve the model predictions. Measurements of snow depth and snow water equivalent are typically made at the time of the maximum snow accumulation, and are valuable information for improving the predictions of total expected snow melt runoff. However, these variables do not provide information on the timing of the snow melt events. Obviously, measurements of snow moisture conditions could be an indicator of on-going snow melt. Furthermore, information on snow moisture content is important for correct interpretation of remote sensing data of snow water equivalent. In this study, a measurement system called SPA (Snow Pack Analysing System) is used to measure liquid water content of snow. The objective of the study is to first of all, evaluate the measurement system for observation of liquid water in snow, and secondly to investigate to what extent this information can be useful for assimilation into a hydrological model.

The SPA is an automatic in-situ system based on measurements of the complex impedance along flat ribbon sensors in combination with a snow depth sensor. The data is used to estimate snow density, the snow water equivalent and the contents of ice and liquid water in the snow. The SPA-sensor is a 6 cm wide flat ribbon sensor including three copper wires with a length between 3 and 10 m. The sensor can be installed horizontally at a given depth in the snow cover, or in a sloped position to gather measurement along the entire snow cover depth. The snow depth sensor is based on transit-time measurements of an ultrasonic pulse between the sensor and the snow surface.

In the current study, a SPA system with one horizontal and one sloped cable was installed at a mountain basin in mid-Sweden close to a hydropower reservoir in Lake Korsvattnet, with extensive measurements during 2008-2010. The experimental setup included a standard meteorological station, automatic measurements of snow water equivalent using a snow pillow, snow surveys using ground penetrating radar, and observations of runoff into the lake.

A snow hydrological model, representing the snow pack with one layer was developed and applied to the data. The model simulates the total snow mass and the mass of liquid water in the snow cover. Snow melt and refreezing may be calculated either with a day-degree or an energy balance parameterization. The water holding capacity of the snow is calculated as a fraction of the total snow mass. The basic input to the model is air temperature and precipitation. If the energy balance model is used, it is further required to use global radiation, windspeed and relative humidity to the model. A distributed version of the model is used for simulation of the snow melt runoff from the entire watershed of the reservoir lake. This model take into account the redistribution of snow by a simple parameterization based on wind direction and local slope, aspect, curvature, and elevation.

A data assimilation procedure, based on the Ensemble Kalman Filter method (EnKF) was implemented into the modeling system. It is used for assimilation of the measured snow data from the snow station into the model simulations. The EnKF method is able to account for uncertainties in both input and observed data, as well as in the model parameters. In this study, the EnKF was primarily used to assimilate the snow depth and snow water equivalent data, whereas the liquid water content data was used mainly for comparison with the simulated results.

Simulations without assimilation of the measured liquid water content showed that the liquid water content measured with the SPA agreed very well with simulated liquid water contents in snow, both in terms of timing of snow melt events and maximum liquid water content in the snow. The maximum liquid water content was about 4% by volume, corresponding to about 10% by mass. During the final snow melt event, the increase in measured liquid water content in the snow coincided with the onset of runoff to the lake. However, the main snow melt runoff event was not reach until several days after snow melt started at the snow station site. Simulations with assimilation of the measured liquid water content also resulted in good timing of the snow melt events. However, there was no further improvement compared to the simulations when the snow pillow data was assimilated.

We conclude that the SPA system can provide useful measurements of liquid water content in snow and indicate the onset of snow melt events. The data was successfully compared and assimilated into a snow hydrological model. Further studies will focus on investigating the potential of combining the SPA system and remote sensing data using data assimilation into the snow hydrological model.

# DETECTING NUTRIENT LOAD RESPONSES TO HEAVY RAIN EVENTS USING CATCHMENT-SCALE IN-SITU WIRELESS SENSOR NETWORK

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Sensor networks providing high-frequency data on a wide array of environmental parameters are increasingly studied and applied in environmental monitoring. So far much of the research has focused on sensor and communication technology, but operational applications are now emerging. One of the most promising areas in hydrology is flood monitoring and warning systems. However, sensor technology has potential to bring new understanding and new research tools for many watershed-level phenomena like different weather conditions and their responses in the river network.

Automatic continuous river and ditch monitoring is an effective way to estimate the water discharge and load of suspended solids and nutrients, also in occasions when water flow or quality are changing rapidly. Yearly levels of nutrient loading from agricultural cropland are greatly dependent on the time and allocation of rain during each year. Preliminary analyses of our data and earlier studies have shown that already a small number of heavy rain events may cause a significant part of annual nutrient loading. Thus, if the effect of heavy rains is not taken into account as one is interpreting the loading measurements, there is a risk that the effects of harmful agricultural practises or beneficial water protection measures on water quality are covered by annual variation in hydrology.

In this work we utilize a Finnish watershed-scale SoilWeather Wireless Sensor Network (WSN) (Kotamäki et al. 2009). We will locate and assess heavy rain events and their responses in river and ditch water flow and water turbidity. The work is carried out in Geographic Information System (GIS) at several spatial scales. The work is carried out 2010-2014.

SoilWeather WSN is located in the Karjaanjoki river basin (2000 km$^2$), Southern Finland and hosts 55 weather stations, 30 sensors for soil moisture, 18 sensors for water turbidity, 9 sensors for water level and 4 nutrient measurement stations. The basis of SoilWeather WSN was developed in co-operation of Agrifood Research Finland (MTT), Finnish Environmental Institute (SYKE), Finnish Meteorological Institute (FMI), and several commercial companies in 2007-2008. It provides measurement data all-year round and in near-real time on weather parameters (air temperature and humidity, precipitation and wind speed and direction), soil moisture, water turbidity, nitrate concentration and water level. The temporal resolution of measurements varies from 15 min to one hour. Data is provided to the users by internet-based data services after automatic, real time data quality control. Until now, SoilWeather WSN has been employed in crop disease forecasts, monitoring local weather, river water quality and constructed wetland as well as improving leaching, hydrological and soil moisture models.

Supported with calibration samples analysed in the laboratory, the SoilWeather WSN can enable a more accurate collection of hydrometeorological data than is possible by traditional methods. Automatic and wireless sensors enable spatially and temporally dense measuring and monitoring of environmental conditions at changing spatial scales. At the moment the network provides more than 30 000 single measurements per day. Data quality of sensor data is less controlled than data based on analysed water samples. We run simple automatic data quality algorithms on the data, but still it is critical that careful pre-processing of data is carried out, for instance to identify erroneous measurements and to perform necessary corrections.

In the study we analyse response that heavy rain events cause in river water flow and turbidity in areas differing in their size and land-use. Both spatial and temporal characters of the response are studied.

According to preliminary data analysis, significant local variation in precipitation is recorded within the basin. Using the dense weather station network, we will assess local variation within the area, and quantify the uncertainty in the measurements based on thorough data analysis and support from local calibration stations. In the response analysis we will use locally measured rain data instead of larger scale averages.

The study areas are run-off areas for selected turbidity measurement points, so that each holds a subset of SoilWeather WSN measurement points. The areas represent variation both in land use, management practises, and size. This set-up also allows for assessing consecutive turbidity measurement points along a river to analyse how the pulses of water flow and turbidity are developing in space and time.

In the selected study areas, we focus on time series that contain heavy rain events. With sensor network data, both the rain intensity and the state of the flow and turbidity in river or ditch water can be tracked at 15 min intervals. The analysis will include assessment and characterizing of the response, and relating that response to the size, land use and land cover of the watershed. Also other available GIS data (e.g. soil database, field parcel database, or soil moisture measurement preceding the rain event) will be utilized in the analysis. In the target area, the analysis can also be supported by Finnish watershed simulation and forecasting system (WSFS).

The study will help us understand the role of heavy rain events on soil erosion and nutrient discharge from agricultural lands under Finnish weather conditions. By studying the responses of heavy rain events instead of long term hydrological averages we could possibly separate the effects of hydrological variation from e.g. the effects of active watershed protection. If the presence of extreme weather conditions is neglected as one is assessing nutrient loading, one can argue that the measurements are not used up to their full potential. In addition we hope that our work will benefit other studies that are carried out utilizing sensor network data.

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# THE BALANCE OF WATER AND BIOGENOUS ELEMENTS IN DRAINED FORESTS ON PEAT SOILS

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Along with the material value of the forest, its ecological functions – carbon fixation and oxygen release, water regime regulation, etc. have an important role in the human and biosphere functioning. Among all the environmental factors, it is just the supply and circulation of nutrition elements of trees that could be easily influenced with the forest management. The influence can be either undesirable (losses or immobilisation of nutrients) or desirable (improvement of cycle and accessibility of nutrients). Though 95% of the dry mass of plants consists of carbon, hydrogen, oxygen and nitrogen, the successful growth and development of trees is mostly limited just by nitrogen, phosphorus, potassium, calcium and magnesium.

Having joined the European Union, Latvia should adopt its legislation in accordance with the international requirements. Such requirements for the environmental protection involve information about the water balance and cycle of nutrients. Recent information about output of biogenous elements with runoff is fragmentary and is generally related to the agricultural lands.

Water balance and cycle of substances in the Latvian forests is determined by local weather conditions and regional hydrogeological peculiarities. It is proved that the location of waterlogged forests in Latvia is not determined by the precipitation, but the areas of confined aquifer water discharge rich in calcium and magnesium. The forest stand productivity in the waterlogged and drained forests with a thick (0.3-4.5 m) peat layer is not depending from the peat layer thickness; the mineral nutrients required for the forest growth flow in by discharge of confined aquifer water (Залитис, 1983; Zālītis and Indriksons, 2003). To determine the dynamics of output of nutrients and the natural background of those in the groundwater of drained forests, long-term observations should be carried out.

To characterise the effect of hydrotechnical drainage on the forest stand structure and forest hydrological regime, the Vesetnieki Station of Permanent Ecological Research was founded in the area of Forest Research Station "Kalsnava" as early as in 1963. The 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ water confluence basins on the Veseta River left bank are located on drained deep peat soils, but the 4$^{th}$ and 5$^{th}$ basins on the right bank – on drained hydro-morph mineral soils.

Regime of runoff and precipitation in the forest water confluence basins, groundwater table fluctuations, role of confined aquifer water in the forest ecosystem were studied. Systematic ground-, confined aquifer-, ditch runoff- and precipitation water sampling and chemical analyses making was commenced in 1997.

Quality and quantity of the precipitation inflowing in the drained forest ecosystem is characterised with the use of 25 precipitation gauges. 5 gauges are located in an open place. 20 gauges are located in the pine, spruce and birch stands, as well as in coniferous young growth, 5 gauges in each stand. To estimate the output of biogenous elements, water samples were taken in each of the 5 runoff gauges, in three of which, water flow from the areas with deep peat soils was measured, and in two gauges – from the areas with hydromorph mineral soils. Analysis was made of water samples taken in 18 soil groundwater wells and 3 confined aquifer water wells at the depth down to 25 m, i.e. to characterise the background changes. The water samples are taken 2 times per month.

The amount of $N–NH_4^+$, $N–NO_3^-$, $P–PO_4^{3-}$, $K^+$, $Ca^{2+}$, $Mg^{2+}$ and active reaction pH was determined for each water sample. The chemical analyses were performed in the Forest Environment Laboratory of the Latvian State Forestry Research Institute “Silava”.

Input of $N-NH_4^+$, $N-NO_3^-$, $P-PO_4^{3-}$ and $K^+$ into the drained forest ecosystem with atmospheric precipitation, 14.8; 0.9; 1.4 and 11.9 kg $ha^{-1}$ $a^{-1}$, respectively, exceeds the output of the same substances via drainage ditches (7.1; 0.7; 0.2 and 4.2 kg $ha^{-1}$ $a^{-1}$), which indicates accumulation of the given substances in the forest ecosystem. On the contrary, output of $Ca^{2+}$ and $Mg^{2+}$ ions with ditch runoff in the forests on drained peat soil, 197.2 and 64.2 kg $ha^{-1}$ $a^{-1}$, respectively, exceeds many times the input of the substances with precipitation water (37.8 and 15.4 kg $ha^{-1}$ $a^{-1}$), both in the forests on deep peat and in the forests on hydro-morph mineral soil.

The heightened output of $Ca^{2+}$ and $Mg^{2+}$ with ditch runoff proves the significant peculiarity of the Latvian waterlogged forests in general – the confined aquifer water discharge from the upper Devonian dolomite layer plays an important role in the water balance incoming part and in paludification process. The results of research do not allow at the present to state that higher output from drained peat soil shall evidence high outwash of nutrients and exhaustion of such soil, as far as it has been clarified in other researches in non-drained areas and dry forests that outwash (runoff) of $Ca^{2+}$ and $Mg^{2+}$ from the ecosystem is higher than input with precipitation (Matzner, 1988).

When the water leaches through the forest canopy, the amount of $N-NH_4^+$ in it reduces slightly, the amount of $N–NO_3^-$ and $P–PO_4^{3-}$ reduces more, but the amount of $K^+$ increases; the amount of $Ca^{2+}$ and $Mg^{2+}$ as well as pH values do not differ significantly.

The research data in general show that the nutrient balance in the drained forest ecosystem at the period of one year or several years is to be assessed as equalised, i.e. the nutrient output does not exceed its input. Such relationship of input and output is a very important precondition for the forest ecosystem sustainability. At a longer time period (several decades) the amount of biogenous elements in forest ecosystem accumulates, thus increasing the stores of plant nutrients in drained forests.

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# APPLYING MOBILE TERRESTRIAL LASER SCANNING AND ACOUSTIC DOPPLER PROFILER IN RIVER DYNAMIC SURVEY – A VALIDATION APPROACH FOR 2D HYDRAULIC MODELLING

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The geomorphic processes of a meandering river channel are based on the complicated interaction between fluid flow and erodible materials. The flow passing through a meandering channel is a highly three-dimensional process because of the transverse secondary flow, which moves towards the outer bank near the water surface and towards the inner bank near the bed. The three dimensional flow conditions and the variations in riverbed material make meandering channel a complex research target.

The methods used in studying of the channel geometry and its changes have gone through major changes in previous decades. Both laboratory and field-based studies have been carried out. Old maps and aerial photography have also been exploited. Typical filed approaches include erosion pins and cross-section based surveys. Common for the traditional field techniques applied is that they have lack of spatial or temporal resolution and are labour-intensive.

Recently, the DTM (digital terrain model) based change detection has been exploited in field based studies. LiDAR (Light Detection and Ranging) technology uses laser pulses to determine a 3D point cloud describing the survey target. Laser scanning utilizes LiDAR technology in gathering geometric data of the environment for DTM creation. In the 1990's, a growing number of studies used airborne laser scanning (ALS) for depicting DTM's. Later, terrestrial laser scanning (TLS) has provided more accurate approach for gathering topographical data. Terrestrial laser scanner is installed on a static platform and thus a planar and steady bed for building the set-up is needed. Thereby, the areal coverage is rather districted and further, the data collection slow, if the device must be relocated in order to scan larger areas.

In mobile TLS, the laser scanner device is placed on a moving platform. It has been developed in order to overcome the shortcomings of the ALS and traditional TLS in mapping of the environment. It has much higher accuracy compared to ALS as well as more efficient survey capacity compared to the traditional TLS. Alho et al. (2009) introduced a mobile TLS approach for riverine mapping.

The use of computational fluid dynamics (CFD) in the modelling of flow structure and sediment transport increased remarkably during the 1990s and nowadays it is the state of the art method in river dynamic studies. However, the validation of models being developed has been mainly done in laboratory circumstances and the validation of CFD in natural streams is still virtually absent in the research. This is mainly due to the comprehensive field observations needed for the validation purposes, which, considering the shortcomings of the field measurement approaches makes the collection of a suitable data set challenging. In addition, it has been stated, that meandering channels require a 3-dimensional hydraulic model to simulate the complex flow field accurately, which in turn increases the field survey demands.

In this study, field survey approaches with the newest technologies available were utilized in validating a 2-dimensional CFD. The study was carried out on a 6 km long sand bedded meandering reach on the sub-arctic river Pulmanki, on Northern Finland. The flow conditions along the reach were investigated during a flood event using an ADP (Acoustic Doppler Profiler). The flood-related erosion processes on the meander point bars were examined using a mobile TLS based change detection. The flow field was simulated using a 2D CFD with a sub-grid-scale turbulence term. Finally, the simulation results were examined in parallel with the physically based field observations.

The mobile TLS approach proved to be a precise and efficient way of defining the geomorphologic changes on the point bars. The study reach was surveyed within one fieldwork day both before and after the flood event, during low discharge, in order to allow the mapping of the flood related changes. DTMs of the point bars were built based on the laser data sets. Standard deviations of the z-values of the DTMs varied between 3 and 7 cm on unvegetated areas, which is accuracy remarkably better compared to ALS (Airborne Laser Scanning). The sediment showed remarkable accumulation on the downstream sides of the point bars as well as on the edges of the chute channels that were formed across the point bars during the flood event.

The 3D flow field was detected from in total 13 cross-sections along the reach using Acoustic Doppler Profiler. According to the ADP data, turbulence was mainly settled near the banks, showing increase along the convex banks when moving downstream, being most significant on the bar tail. The movement of the high velocity core of the flow towards the outer bank along the upstream part of the meander bends were clearly noticeable both in ADP data and in the simulation results. The simulated bed shear stress values agreed with the chute channel formations perceived based on the DTM change detection. The increase in turbidity around the inner bank strengthening on the bar tail was, on the other hand, not possible to notice on the CFD results. Also the horizontal switch of the high velocity core on the channel was not possible to detect using the depth averaged CFD.

Mobile TLS based change detection could be further exploited in validation of sediment modelling. By integrating the LiDAR data with the river bathymetry and to reconstructing a complete geometry of river channel, including the riverbed bathymetry, the change detection may be further improved. The

ADP based approach will, in the future, provide boundary condition and validation data also for three-dimensional hydraulic modelling. In addition, a larger amount of flow events is to be surveyed in order to validate the results. While it is seldom computationally efficient to use 3-dimensional models in natural environment the further development of 2D models is also concern. For example by improving the physically based friction parameterization, more reliable results could be gained using 2D CFD. Thus, the usability of the mobile TLS data in the roughness parameterizations needs to be examined.

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# COMPOSITIONAL CHANGES OF DISSOLVED ORGANIC MATTER IN SURFACE WATERS OF LATVIA

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The number of studies of dissolved organic carbon (DOC) during the last few years is very much growing and the interest is more and more moving from sum parameters (colour, COD, TOC, DOC, BOD) towards parameters describing composition of dissolved organic matter (DOM). As far as dissolved organic matter is composed from a large number of individual molecules, their isolation and characterisation seems to be too complex task. Instead of that, the sum of parameters describing properties of majority of organic substances can be used.

The aim of this study is to analyze the character of compositional changes and factors influencing properties of DOM in the River Salaca, Lake Burtnieks and their tributaries.

The River Salaca basin was studied from January 2007 till March 2009. Water samples were taken monthly and concentrations of nutrients and organic carbon (IC, POC, TOC and DOC) were analysed. Information about discharge of the River Salaca was obtained from Latvian Environment, Geology and Meteorology Centre. The fluorescence spectra were determined on a spectrofluorometer Perkin Elmer LS55 at room temperature (25°C). The SSFS (synchronous-scan fluorescence spectroscopy) results were recorded at a speed of 500 nm/min, at a constant offset ($\Delta\lambda$ = 18 nm) between excitation and emission wavelengths, 7 nm (Ex) and 7 nm (Em) slit widths. Emission spectra were recorded at speed 500 nm/min, excitation 350 nm, 7 nm (Ex) and 7 nm (Em) slit widths. The fluorescence emission spectra were determined from 380 nm to 650 nm wavelength, and synchronous-scan fluorescence spectra were determined from 250 to 600 nm wavelength. Fluorescence index (FI) was a ratio of the emission intensity at a wavelength of 450 nm to that at 500 nm at an excitation wavelength 350 nm for the Salaca River basin.

The changes of DOC concentrations follow a pattern common for Rivers in Northern Europe and much depends on the river discharge regime. Average concentration of total organic carbon in the River Salaca basin is about 25 – 30 mg/l. Seasonal changes of concentrations of organic carbon are more pronounced in the tributaries than in the River Salaca. Higher concentrations of organic carbon are observed in autumn and other maximum occurs in spring, when leaching from catchment is the highest. During the low-water period in summer, concentrations of organic carbon are the lowest (approximately 10 – 15 mg/l).

In the pool of TOC, a major role is played by dissolved organic substances and only during spring and autumn seasons particulate organic carbon reaches up to 5 % of the TOC.

Spectral characterisation of DOM can be used as an efficient tool to study the composition of DOM. In this study analysis of UV and fluorescence (excitation-emission and synchronous scan) spectra has been used to study the differences between DOM depending on the seasonal processes and land-use character in the river basin.

Fluorescence spectra can support identification of autochthonous (mostly algal derived) or terrestrially derived DOC (McKnight et al., 2001). These spectra demonstrate that properties of dissolved organic matter vary between seasons. Comparatively lower fluorescence intensity is in summer, but higher in winter. Maximum of fluorescence spectra in summer and autumn samples (June-October) is shifted to about 442 nm. This indicates the dominance of autochthonous organic matter. Maximum fluorescence intensity at higher wavelengths (>450 nm) indicates on terrestrially derived organic matter. Proportion of allochthonous organic matter in the R.Salaca system is becoming more important from late autumn till spring, when higher water discharges are observed.

For quantitative comparison ratios of spectral intensity $E_4/E_6$ and $E_2/E_3$ of UV spectra or $I_{430}/I_{500}$ of fluorescence spectra can be used. This approach allows not only identifying dominant sources, but also gives an insight into their composition. The ratio of absorption $E_2/E_3$ correlates with relative size of DOM molecules. As molecular size increased, $E_2/E_3$ decreased because of stronger light absorption by high-molecular-weight chromophoric dissolved organic matter at longer wavelengths. The ratio of absorption at 465 to 665 nm ($E_4/E_6$) inversely is reported to aromaticity and humification of DOM (Helms et al., 2008).

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# LONG-TERM CHANGES OF DISSOLVED ORGANIC CARBON FLOWS IN LATVIA

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Source of dissolved organic carbon (DOC) in surface waters is decay processes of living organic substances and thus DOC concentrations can be influenced by many factors:

1) air and water temperature – higher temperature supports increased primary production and also increased decay rates of organic matter (Fenner et al., 2007; Worrall et al., 2003);
2) solar irradiation/sunshine intensity – main source of energy for primary production, but causes photomineralization of DOC;
3) amount and intensity of precipitation – intensive precipitation can "dilute" DOC concentration in surface waters, but also can cause washout of organic matter from catchment soils (Clark et al., 2008);
4) character of biological processes including microbial activity (Worrall et al., 2003);
5) geology, soil properties and land-use patterns in the catchment (Worrall et al., 2003);
6) human impact and other processes (Worrall et al., 2003).

Hydrological regime can influence DOC concentrations. Thus the actual concentrations of DOC in the surface waters are influenced by factors often acting in opposite direction and the balance of these factors needs better understanding at first at regional level. Trends of DOC concentrations in surface waters in recent years have received special attention considering their relation to the global climate change.

The aim of our study was to analyze character of long-term changes of DOC concentrations in surface waters of Latvia.

Information on monthly concentrations of dissolved organic matter and monthly mean river discharge were obtained from long-term monitoring data carried out by Latvian Environment, Geology and Meteorology Centre.

Seasonal pattern of changes of DOC concentration shows some general similarities within the studied rivers. Slightly higher concentration of dissolved organic matter is observed in spring during the snowmelt period and in late autumn. At the same time, differences depending on character of discharge regime, land cover pattern, human loading or intensity of biological processes are observed, especially between small-size rivers. As one of the most important factor affecting DOC concentration is discharge, however other interfering factors determines relatively poor correlation between DOC concentration and river discharge. Relatively higher correlations are common only for high water periods.

During the last decades, we can observe statistically significant *($P<0.1$)* increasing trends of DOC in 5 of 11 studied Rivers (Salaca, Aiviekste, Dubna, Iecava and Irbe), but trends of water colour are even more pronounced – significant increasing trends *($P<0.05$)* are found in 7 rivers.

River discharge can be regarded as one of the important factor determining flows of DOC, however, the impact of hydrological regime can be masked by other processes such as intensity of human loading or changes in acidity of precipitation.

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# HYDROLOGICAL EFFECT OF BEAVER DAMMING ACTIVITY IN DRAINAGE CHANNELS, LITHUANIA

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During the last decade beaver (*Castor fiber* L.*)* expansion into drainage channels (open drains) has been observed in Lithuania. Beavers have direct impact on geo-morphological and hydrological features of streams. The primary geomorphological significance of beaver is the propensity to build dams to impound water and create ponds in which they live. As a consequence of that the retention of water and the redistribution between constituents of water balance occurs in both the beaver-populated channels and the surrounding environment in general.

The objective of this work was to evaluate how much beaver's impounding activity in drainage channels can influence runoff and hydrological conditions of the particular terrain.

Investigations were carried out in the landscapes of moraine (89.4 % of research area) and ancient alluvial (6.4 %) plains as well as in hilly moraine eminences (1.0 %) of the Nevėžis River basin (Middle Lithuania). Nine catchments with the total area of 324.4 km$^2$ (198.1 km$^2$, 81.9 km$^2$, and 44.4 km$^2$, respectively to the above-mentioned landscape types) were chosen for the investigation of drainage channels. The investigated channels were adequate to the rivers of the first to fourth order. Their total length approximated to 455 km. A global positioning system (GPS) to map the chosen drainage channels and all available beaver-created structures therein was used; individual pond characteristics (length, width, and depth) were measured in situ. For the determination of the extent of damming, the number of beavers' ponds and the percentage of dammed channels were calculated. The average pond water volume as well as surface area, the impounded area and the average amount of retained water falling on one sq. kilometre of the catchment's area and on one kilometre of the channel were calculated in all chosen catchments too. The increase of water surface area due to the occurrence of beavers' ponds was calculated as the difference between the total surface area of a pond and the surface area of the un-dammed part of the bed, which would have been in the place of the pond if the channel was not dammed.

Beavers influence surface runoff while retaining water in the ponds. Because of the impoundment the part of water that evaporates and infiltrates into the deeper soil layers also increases due to the increased (in comparison with the un-dammed channel conditions) surface water area. Consequently, the possible impact on runoff retention in each study catchment was evaluated using long-term values of the average annual runoff rate and evaporation from the water surface.

Results have shown that the density of beavers' dams varied from 0.29 up to 1.50 (0.76 on average) per sq. kilometre, of these in drainage channels – from 0.27 up to 1.25 (average – 0.54) per kilometre. In fact, there were some differences revealed in densities of the dams within the various landscapes but it was very likely they were determined by the particular both farming practice and attitude towards beaver of local society that often issued in unequal extent of the destroyed dams and killed beavers. The following features characterized beavers' ponds: pond length – 258 m; pond area – $0.15\times10^4$ $m^2$ and pond volume – $0.9\times10^3$ $m^3$ on average. Though in most cases beaver-sites consist of several ponds their average parameters, in comparison with those of single ponds, were significantly larger, i.e. the area of ponds of one beaver-site measure up more than one or two hectares and the amount of water accumulated in them it chanced far exceeded ten thousand cu. metres.

The investigation showed that beavers had dammed approx. 14 % of the channels in the investigated area. During the last decade the number of dammed channels has increased more than three times (in 1997 the dammed channels made up 4.5 % of all channels). The increase in the length of dammed channels in some catchments during the same period varies from 3 to 10 times.

Calculations revealed that beavers' ponds have retained about $0.46\times10^3$ $m^3$/km of water in the channels and the dammed water surface covered $0.08\times10^4$ $m^2$/km. In each square kilometre of the study catchment the average volume of accumulated water and the area of damming were obtained to be equal to $0.60\times10^3$ $m^3$ and $0.11\times10^4$ $m^2$, respectively.

The volume of runoff retained in the dammed stretches of the channels (pond volume + evaporation + filtration from the pond) falling on the unit of each analysed catchment area fluctuated from $0.18\times10^3$ up to $3.85\times10^3$ $m^3$ per $km^2$ (1.66 on average). It made up from 0.11 up to 2.18 % (1.01 % on average) of the total annual runoff volume. In small catchments of drainage channels the retention due to beaver activities was much higher and can reach from 3.3 to 21.7 % of the total runoff volume.

According to the length of the dammed channels and the density of beaver-sites the relationships between the lengths of dammed channels or the density of beavers in drainage channels, on the one hand, and the impact of damming upon the runoff, on the other hand, were determined to predict the potential impact of beaver further expansion on runoff of drainage channels or in the particular terrain. Such types of dependences seem could be useful for water management and decision making when evaluating the hydrological impact of beavers populated in drainage channels not only for Lithuania but also for all the regions where physical-geographical and hydrological conditions therein are similar.

# EVALUATION OF NORWEGIAN SNOWPILLOW STATIONS

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The norwegian water and energy directorate (NVE) runs a network of 24 snowpillows in Norway. A snowpillow measures snow water equivalent (SWE) from the pressure snow exerts on the pillow. The NVE pillows measure a SWE max between 200mm and 1700mm. The pillows are situated 35-1500m above sea level, from 58°N to 69°N. Many of the pillows have long time series, the longest running one is from 1967. Snowpillows give valuable real time information on snow conditions and are used in flood forecasting. On most of the snowpillow stations manual measurements are done once a month during the winter season. 14 of the stations have a snow depth sensor in addition to a snowpillow. The information it provides is used to assess the quality of the measurements from the snowpillow, as well as to detect faults in the instrumentation.

Experimentation with leakage. Most of the pillows are filled with a mixture of water and ethanol. To measure snow pressure correctly it is important that the pillows have no leakage. Some of the pillows have registered negative values after the end of the winter season, witch means leakage, without having any visible damage. This might be caused by diffusion of liquid through the pillow fabric, fluid seeping out through the welds in the pillow, or through the screw connections. A third considered possibility is evaporation from the riser pipe.

To test for diffusion through the snowpillow membrane three mini pillows of 40×40 cm was used. The pillows were made of white PVC coated polyester fabric with a welded on fill valve. The test pillow differ from the real snow pillows in that they lack a stretch relief liner. They were filled with respectively glycol (with a coloured liquid), ethanol and water. The weight of the pillows themselves and the liquid in them were registered, and they were placed outdoor for the period May 26 – June 29, 2009. The experiment showed a weight loss of 16.35% from the ethanol filled pillow, a 1.2% loss from the water filled one, and a 0.05% loss from the glycol filled pillow. The texture of the ethanol pillow was completely changed over the test period, with the pvc seemingly being dissolved and the material more brittled. When emptying the pillows the ethanol had gone "milky" white. The two other pillows showed no material change. Ethanol is aggressive to pvc and according to the fabric manufacturer so will glycol be, but at a lower rate. The test pillow filled with a coloured liquid (glycol) shows fluid seeping out through the side edge of the welding. It is a small source of error as the total weight loss from this pillow was very small. It has been evaluated whether evaporation from the riser pipes can be of significance. The evaporation surface is small and the present air is stagnant as the pipe is capped. Hence the fluid transport away from the riser pipe is small.

Experimentation with snowpillow size. Ice and crust layers in the snow have often caused problems with the use of snowpillows. Ice/crust layers provide pressure/pressure relief on the pillows, causing them to register more/less snow than the actual condition. NVE is investigating whether the size of the pillow may have any impact on the pressure/pressure relief.

NVE and the Norwegian university for science and technology (NTNU) have a snow science site at Svarttjørnbekken in Trondheim. The site has been operational since 2006, with four squared 2×2 m snowpillows (overlapping giving a total 4×4 m pillow), a circular snowpillow of 2 m diameter and a circular snowpillow of 3,7 m diameter (installed in 1998). In autumn 2009, NVE established a snow science site at Filefjell (953 metres above sea leve). The site has one circular snowpillow of 2 m diameter, four square pillows, overlapping giving a total 5×5 m pillow, and a digital snow weight of 5×5 meters. Data from these two stations will be used to test the hypothesis that the bigger the snowpillow, the less pressure relief from snow bridges. Data will also be analysed to see whether a digital weight and a snowpillow will record the same SWE.

Data from Svarttjørnbekken has not shown evident major pressure/pressure relief caused by ice/crust layers on any of the snowpillows. The pillows measure differences of up to 14 mm of water equivalent. Manual snow courses near the pillows show that this may reflect real differences in the accumulation of snow at the site.

At Filefjell it has been observed an icelayer extending from above the snowpillows to the outside ground. This icelayer has not been observed on the snowscale. This could be caused by the thermodynamics of the snowpillows or of the psysical instalation of the pillow/scale. At Filefjell the snow layer directly in contact with the ethanol pillow has melted at times when the snow above the glykol pillow has not been melted. This could be a result of diffusion. We will be doing further investigations on ice/crust layers and snowpillows.

# ANNUAL AND TEMPORAL VARIATION OF PERCOLATION IN FOUR GROUNDWATER STATIONS IN DIFFERENT PART OF FINLAND

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Percolation is a part of water cycle. Knowledge of water movement and storage in the soil is important in order to define the parameters of water balance equation. Precipitation and melting waters are percolating from the ground surface to an aquifer. Changes on it will impact to groundwater recharge and to groundwater levels. Infiltration experiments were carried out using lysimeters. In this case, these are plate vessels, of diameter 1,4 m to 1,6 m and depth 1,7 m, which are buried into the soil. Both the type and surface vegetation in the vessels correspond to those prevailing in the area. The natural stratification and the podzol zones in lysimeter vessels are disturbed. The amount of water filtering through the lysimeter into the collection vessel below in unit time was measured using a recorder. This presentation is summary of the lysimeter measurements made at the Oripää groundwater station in 1973-2009, at the Siuntio groundwater station in 2000-2009, at the Karijoki groundwater station in 1995-2009 and at the Sodankylä groundwater station in 2005-2009. The chosen lysimeters are representing typical groundwater recharge areas were the soil type is mostly sand and gravel. Those places are situated in different parts of Finland and they show the climatic variation of percolation on different part of land. The Oripää lysimeter serie is clearly longest and the other series are shorter ones.

There are four seasons in Finland. Snow cover and soil frost in winter are decreasing percolation, snowmelt in spring is increasing it. Precipitation and temperature have an effect on percolation in summer and autumn. The mean annual percolation from the Oripää lysimeter was 403 mm. It amounted to 61 % of the mean annual uncorrected precipitation. The spring season (March-May) contributed 130 mm, or 32 % of the annual percolation, 24 % occurred in summer (June-Aug), 29 % in autumn (Sept-Nov) and 15 % in winter (Dec-Feb). There was not much difference in mean values from Oripää between periods 1973-1995 and 1995-2009. The mean annual percolation from the Siuntio lysimeter was 396 mm, from the Karijoki lysimeter 422 mm and from the Sodankylä lysimeter 238 mm. The spring season contributed from Siuntio 111 mm (28 %), Karijoki 154 mm (37 %) and Sodankylä 109 mm (46 %). Corresponding numbers in summer: Siuntio 44 mm (11 %), Karijoki 77 mm (18 %) and Sodankylä 80 mm (34 %), in autumn: Siuntio 125 mm

(32 %), Karijoki 118 mm (28 %), Sodankylä 46 mm (19 %), and in winter: Siuntio 116 mm (29 %), Karijoki 73 mm (17 %), Sodankylä 3 mm (1 %).

Percolation from lysimeter represents mainly the lysimeter itself. The palaces of lysimeter vessels in Siuntio and Sodankylä are situated in the sunny southern slope. Snowmelt happens quickly and evaporation begins when soil surface become exposed. Evaporation from upper zone of the soil will produce an upward flow and on the other hand, strong precipitation will create an increase in the water content. Karijoki and Oripää are situated in snowy upland areas and deep in the forest few hundred kilometres from the coast. Summer is not hot at all by the forest shade. In addition precipitation varies in different part of Finland. The annual infiltration sum curves are explaining climatic conditions and changes on it very well. There was not to be plain evidense on climate change in percolation except that spring seems to become earlier a bit. The temporal changes are dominating. Years are not similar ones. The short time series from Siuntio, Karijoki and Sodankylä (10-15 years) tells nothing about temporal changes yet.

# AUTOMATED DISCHARGE MEASUREMENTS USING DYE DILUTION METHOD – PROJECT "AUTOQ"

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Building rating curves for natural profiles is often time-consuming and labour intensive. A large number of distinct measurements covering all relevant stage-discharge relations are needed, leading to numerous and costly field trips. In particular small and mountainous rivers with quick response to precipitation and snow-melt can be almost impossible to measure, as the events of interest, that be low or high flow, passes before field personnel can reach the site.

The aim of project AutoQ has been to build a system that automatically conducts discharge measurements without the need of field personnel except for installation and planned maintenance in the deployment period. The system uses the dilution method for discharge measurements and is suitable for streams and rivers up to 50 $m^3/s$ where stretches with good mixing conditions can be found. Rhodamine WT is chosen as dye tracer. Multiple tracer sensors can be connected to the system and measure in parallel, thus enabling a method for validating the measurements. It is not always possible to make good measurements at one location for both low and high flow. The use of multiple sensors also makes it possible to accommodate for this by placing sensors at different locations, covering either low or high flow conditions.

AutoQ is made self-optimizing in the sense that it constantly derives an a priori rating curve. This curve is used to optimise dye dosage, both to economize the use of tracer for prolonged deployment time and to better utilize the measurement range of the Rhodamine sensors. Bayesian statistics is used to automatically generate and update the rating curve after each measurement cycle.

The AutoQ system is built around a field-ready data logger with custom-made control-software and off the shelf industrial components. The focus has been on building a robust, light-weight system for easy field deployment. Discharge measurement results, together with operational data, can be monitored remotely using standard, commercially available data acquisition software. In remote areas, the system can, if needed, be left without remote communication using local data storage alone. AutoQ is designed for battery-operation and can operate without charging or battery-replacement for periods of up to 3 months.

The system has been extensively tested under lab-conditions and also proven to work in field. Final field-testing and validation will be conducted in the early spring and summer 2010. Two test-sites are selected. The first site (TS1) has a well-known, artificially V-profile, mean annual discharge of 0.11 $m^3/s$ and mean annual flood of 2.6 $m^3/s$. The second site (TS2) has a natural rock-based profile with an established, good rating-curve, mean annual discharge of 6 $m^3/s$ and mean annual flood of 45 $m^3/s$.

A preliminary analysis from TS1 shows good correlation between established rating curve and measurements from AutoQ. The average absolute deviation between measurements and rating curve is 6 % (*including* obvious outliers) and median absolute deviation of 4 %. These findings are based on 60 measurement cycles ranging from 0.05 $m^3/s$ to 0.7 $m^3/s$.

# SPATIAL-TEMPORAL VARIATION IN THE THERMAL STRUCTURE OF LAKE LADOGA

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The amount of heat stored in the lake changes throughout the year as indicated by the changes in the temperature at all depths. Lake temperature cycles are important for studies of most aquatic processes, especially for numerical models that are intended to simulate annual bio-geochemical cycles. Changes in lake temperatures, possibly resulting from changes in global climate, may have significant impacts on Lake Ladoga, the largest dimictic lake in Europe. Lake with large thermal inertia can substantially modify thermal and moisture properties of air flowing over them. More generally, lake thermal structure is the direct link between meteorological forcing and seasonal response of the lake ecosystem. Water temperature was implicated as an important ecological factor influencing geographical and species distribution of fishes and could affect fertility and growth rates. Lake thermal structure can also influence distribution of food resources and habitat space. In addition, changes in water temperature as a result of climate warming could stress fish population of the Lake Ladoga basin.

The thermal regime of Lake Ladoga is determined by primarily incoming solar radiation, wind-induced mixing and depth distribution. Thermal regimes of the large lakes Ladoga and Onega in North-West Russia have been investigated by A.Tikhomirov (Naumenko and Karetnikov, 2002) on the base of data for 50-80 years of last century. This paper deals with new calculations of seasonal climatological cycles of water temperature and heat contents of Lake Ladoga to examine of the thermal structure of the regions. Depending on the morphometric regions we describe the time-depth variations of water temperature parameters for Lake Ladoga during the whole year.

We used average seasonal course of water temperature and heat content to examine of the thermal structure of the lake regions. Data were taken from a numerous data base of Institute of Limnology of the Russian Academy of Sciences, which includes more than 260,000 measurements. The principal factor defining the temperature distributions in Lake Ladoga is the bathymetry, which partitions the lake into six distinct compartments. The limnological regions are delimited by isobaths 18 m, 50 m, 70 m, 100 m and 140 m (Naumenko and Karetnikov, 2002). Digital morphometric model has been created to calculate the heat storage for whole lake and its parts.

The present study is based on all of the data collected at the six limnetic regions from 1905 through 2003. Statistical analysis was used to calculate descriptive statistics. We have found that the climatologically averaged surface temperature cycle in the open waters of the Lake Ladoga can be accurately estimated a ten-days averaging with lag 5 days for all limnetic regions that has allowed to smooth high-frequency temperature fluctuations. The water temperatures and its main statistical characteristics on 8 horizons (0, 5, 10, 20, 30, 40, 50 and 100 m) were calculated for each of Lake Ladoga limnological regions from January to December.

The ice cover lasts for 172 ± 3 days in average from the early November until the mid-May. Lake Ladoga seasonal climatological cycle of depth-distributed water temperature, density, their vertical gradients, stability, water temperature dispersions and vertical diffusivity have been discussed. It is obviously shown the gradual warming in the spring, the rapid rise to summer maximum and the slow cooling in the fall. In spring the thermobar phenomenon which divided stratified water from the cold central water occurs (Naumenko et al. 2003). The thermal bar advances toward the centre of the lake as heating progresses and when the central portion reaches 4°C the thermal bar disappears (Naumenko and Karetnikov, 2002). The period of thermal stratification was determined for each region. The dates when stratification of Lake Ladoga morphometric regions is complete ranges from mid-May to early July.

These climatological time-series can be interpreted in terms of changes in water temperature, showing seasonal and inter-annual variability of formation of the thermal bar, and disappearance of the 4 °C surface isotherm, thermocline depth, and duration of thermal stratification period. Spring turnover occurs from mid-May to mid-June depend on the region.

The quantitative analyses of a seasonal course of water temperature for the regions in connection with their depths have been made (Naumenko and Karetnikov, 2002). We determined maxima and minima of temperature for different depths from surface to bottom. During the period of stratification there are temporal lags between the time of maximum surface water temperature and the time of maximum temperature on lower depths.

Temperature variability is the highest in the very shallow region. For every limnetic region the largest variances in surface temperature arise during the warming period, 20-30 days before the maximum temperature is reached, when a stable stratification begins to form. After this period the variance decreases and the maximum values shift to the deeper areas.

In fall when surface temperature drops, and convective mixing keeps an upper layer at uniform temperature throughout named mixed layer. The mixed layer deepens with subsequent heat loss until the temperature is uniform over the entire depth. In that way the heat moves at bottom depth and bottom maximum temperature becomes equal the surface temperature. It means that the downward penetration occurs and the first fall turnover exists when the surface water temperature reached 5.8±0.2 °C in the deepest region at the beginning of November.

Owing to Lake Ladoga large area and basin morphology, there is considerable horizontal and vertical heterogeneity in the temperature of Lake Ladoga in all seasons except the ice cover period (Naumenko and Karetnikov, 2002).

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# SEASONAL AND DIURNAL VARIATION OF CURRENT VELOCITY IN MACROINVERTEBRATE DRIFT STUDY IN LATVIAN LOWLAND STREAMS

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Macroinvertebrate drift is the downstream movement of invertebrates (insect larvae and other groups) in the stream currents (Waters, 1972) and it is important part of the stream ecosystem functioning (e.g. dispersal mechanism, food source for young salmonids). Complex of biotic and abiotic factors influence the drift (Brittain and Eikeland, 1988). Flow, associated hydraulic forces, channel morphology and sediment transport have been suggested to affect invertebrate drift (Wilcox et al., 2008).

Macroinvertebrate drift samples were collected by using three drift nets (frame size of 0.25 x 0.25 $m^2$, mesh size of 0.5 mm) at four streams in three seasons, eight times per twenty-four hours with exposition period of 30 minutes in 2007 (Korge stream was studied also in 2008).

At Korge stream and Tumsupe stream (with different sized lithal substrates) sampling and measurements were done upstream and downstream to the riffle section. Whereas at Strikupe and Korge streams (with sand-gravel bedrock), downstream to the stream reaches with different dominance of substrates (sand-detritus, sand-macrophyte biotopes).

Current velocity was measured in the front of the each drift net and discharge was estimated for the each sampling net.

Seasonal and diurnal changes in the current velocity and depth (m) were observed. At Tumsupe stream and Koja stream fluctuations in the current velocity and discharge were caused by the impact of small hydroelectric power stations. The most stable hydrological conditions along the all seasons were at Strikupe stream, which obtain waters from groundwater springs in addition. At Korge stream extreme low water level and discharge was in 2007 comparing to 2008. However, the influence of hydrological factors on macroinvertebrate drift rate was not the determinant. Drift rate was mostly affected by invertebrate life cycles and behaviour.

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# ARCTIC-HYDRA: A PAN-ARCTIC CONSORTIUM FOR THE STUDY OF THE ARCTIC HYDROLOGICAL CYCLE AND ITS ROLE IN THE GLOBAL CLIMATE SYSTEM

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Temperature records, hydrological data, observations on glaciers, ice caps and permafrost and data on sea ice extent and thickness all provide strong evidence for Arctic warming in the past decades. Evidence is emerging for surface based amplification of Arctic warming since 2000 and results from atmospheric modeling predict greater 21st century temperature changes at high northern latitudes than anywhere else in the world.

Studies of the Arctic Hydrological Cycle form a key component of scientific research aimed at increasing our understanding of the role of the Arctic in Earth's climate system. The past 20 years have seen a decline in hydrological observation networks in most regions of the Arctic and no monitoring systems exist within large areas that contribute runoff. Modeling efforts aimed at advancing our understanding of the causes and impacts of climate changes in the Arctic are still limited by a lack of knowledge on the hydrological characteristics of water basins.

The Arctic-HYDRA consortium was originally initiated as a cluster of several IPY projects with a hydrological focus, involving all Arctic countries and drawing on support from the Nordic Council of Ministers and WMO. During the IPY period, representatives of national hydrological institutes teamed up with academic departments to develop a science and implementation plan for Arctic-HYDRA*. A major aim of the consortium is to produce a new, quantitative picture of the state of the pan-Arctic Hydrological Cycle at a time when rapid Arctic warming is affecting several domains of the climate system. Focus will be on defining the state and fluxes of freshwater systems and their geographic and temporal variations that characterize the Arctic in the first two decades of the 21st century.

Arctic-HYDRA will aim for the creation of an Arctic Hydrological Cycle Observing System (Arctic-HYCOS), which will form a regional constituent of the World Hydrological Cycle Observing System (WHYCOS) operated by WMO. Arctic-HYCOS will be organized around the main objectives of: 1) developing an optimal design for hydro-meteorological monitoring networks to record variability and enable assessment of water cycle change; and 2) developing an integrated pan-Arctic data consolidation and analysis system for the water cycle, uniting data from in situ, modeling, and remote sensing sources to generate an integrated view of key components of the pan-Arctic hydrosphere.

# THE ROLE OF A LOWLAND RESERVOIR IN THE TRANSPORT OF NUTRIENTS AND MICROPOLLUTANTS ALONG THE RIVER CONTINUUM

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According to the River Continuum Concept, various ecological processes and pattern of river ecosystems are changing continuously along the river (Vannote et al., 1980). Therefore, large reservoirs are considered as constructions with negative effects on the structure and functioning of river ecosystems. According to Miller (1995), one of the main negative impacts of large dams on the environment was expressed as degradation of the river continuity, which influences the hydrological regime below the dam. Nevertheless, in the face of the global climate change, large reservoirs may also play an increasingly important role in protecting the water resources, contributing to human development by providing reliable sources of drinking water and irrigation, hydropower, recreation, navigation, income and other important benefits (WCD, 2000). Moreover, they are considered as an efficient trap for sediments and consequently the associated chemical toxicants, including nutrients and PCBs (Devault et al., 2009). The decrease in the flow velocity and the increase of flocculent settling in constructed reservoirs create perfect conditions for sedimentation and deposition of pollutants. It was estimated that 97% of released PCB in a water column was retained in sediments (DiPinto et al., 1993), which serve as storage compartments for micropollutants (Knezovich et al., 1987). Thus, reservoirs act as a sink for micropollutants and therefore are important for pollution studies and monitoring of ecosystem stress. The main objectives of this study are, therefore, 1) quantification of suspended sediment matter, nutrients and PCB transfer along the Pilica River continuum and 2) evaluation of the role played by the Sulejów Reservoir in their deposition and retention.

The Pilica River watershed is located in central Poland (the length: 342 km, the catchment area: 9258 $km^2$). In 2006, its average and maximum discharge (Q) were 19 $m^3$ $s^{-1}$ and 48 $m^3$ $s^{-1}$, respectively, (the town of Sulejów gauge). Agriculture is present in over 60% of the Pilica catchment area and results in an increased supply of nutrients, micropollutants, humic substances and other pollutants from non-point sources into the river and the Sulejów Reservoir.

During the hydrological year 2006, water samples for analyses of the Suspended Particulate Matter (SPM), Total Phosphorus (TP) and Total Nitrogen (TN) were collected every four to ten days from two stations located in the middle course of the Pilica River (above and below the Sulejów Reservoir). In the research, daily discharges of the Pilica River and outflows from the reservoir's dam have been used. TP was analysed according to the ascorbic method (Ostrowska, 1991) and TN was analysed using the persulfate digestion method (HACH's method).

The sediment samples for PCB analyses were collected once during the autumn period of 2006 from 7 stations situated along the Pilica River including 2 stations situated on the Sulejów Reservoir. PCB congener's extractions, clean-up and analysis were performed according to US EPA 1668 Method and PN/EN 1948: 3 2002 Norm. Identification and quantification were performed using HRGC/HRMS (HP6890, Hewlett Packard/Autospec Ultima, Micromass) with an isotope dilution method.

In 2006 the total inflow of the Pilica River into the Sulejów Reservoir amounted to 1070 million $m^3$, and the outflow from the reservoir was 592 million $m^3$. The research results showed the following reduction of the PSM and concentration of nutrients in the water inflow and outflow from the Sulejów Reservoir: 45% of PSM – the mean inflow concentration (m.i.c.) 13.56 mg PSM $dm^{-3}$, the mean outflow concentration (m.o.c) 7.48 mg PSM $dm^{-3}$; 28% of TP – m.i.c. 220.1 $\mu$g TP $dm^{-3}$, m.o.c 159.2 $\mu$g TP $dm^{-3}$; 34% of TN – m.i.c. 3865 $\mu$g TN $dm^{-3}$, 2540 $\mu$g TN $dm^{-3}$. Also 29% reduction of total PCBs concentration was observed along the reservoir, from 9.21 ng $kg^{-1}$ d.w. in the middle section to 6.54 ng $kg^{-1}$ d.w. in the dam section of the reservoir with the lowest value below the reservoir (2.92 ng $kg^{-1}$ d.w.).

The results obtained indicate that the concentration and transfer of analyzed pollutants along the river continuum might be diminished by anthropogenic retention through construction of reservoirs, in which deposition and burial of PSM TN, TP and PCBs in reservoirs' sediments and biota have been suggested as an important purging mechanism.

The research was supported by the Polish Ministry of Science and Higher Education, Project: N N305 365738 "Analysis of point sources pollution of nutrients, dioxins and dioxin-like compounds in the Pilica River catchment and draw up of reclamation methods" and 2PO4 G08830 "Accumulation of dioxins and dioxin-like pollutants in the food chain of Sulejowski and Wocawski Reservoirs: chemometric analysis and toxicological estimation". Part of this research was developed within the framework of the Pilica River Demonstration Project under the auspices of the UNESCO and UNEP.

# ELECTRONIC SYSTEM OF FLOOD MONITORING AND VISUALIZATION

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Flood-protection is especially important for territories, which may become a subject of catastrophically influence of high waters. Carrying out anti-flood actions results in reduction of actual damages caused by flooding, however it demands significant expenses and exploitation charges. As it is impossible to completely exclude flooding, the priority is to adapt economic activities as much as possible to probable extreme conditions and thus minimize the damage. Electronic systems of flood monitoring are developed in bounds of that strategy nowadays for high-risk areas. Here we present one of such systems – the distributed hardware and software complex of flood monitoring and prediction, which is moving to the end of its development cycle for rivers of Byelorussian Polesye but uses rather universal approaches and software parts and is not highly special to spoken above territories.

Developed complex of distributed hardware and software includes the united information center (UIC), which processes data streams from the distributed network of autonomous hydrological devices (AHD), placed in control points of the river basin.

The query of data is transferred from AHDs to UIC by means of GSM-network. The UIC functions as calculating server: it collects the information through a cell communications channel, and shows the degree of river bottomland flooding. Calculations may be based not only on data from AHDs but also on discussed earlier statistical data of hydrological measurements, mathematical models of watercourses movement and 3D maps of the terrain (Volchak et al., 2007).

AHD construction includes (Kozak et al., 2008) ultrasonic sensors (UPTs), a micro-controller, embeddable GSM-modem, power supply and signal amplification systems. Three UPTs are used in the AHD: one operates in combined radiation and receive mode as a depth meter; information about water level is acquired from a delay between the radiated signal and its reflection from the water free surface. Measurement of flow speed uses radiating and receiving UPTs and can be carried out by one of two methods. Firstly, speed of water flow can be determined on Doppler shift of frequency of the accepted signal concerning frequency a radiated one. Secondly, time delays can be also registered when sound spreads alongside the water flow direction and opposite to it.

Primary processing of UPTs response as far as all necessary operation modes switching and calculations are done by Texas Instruments MSP430 microcontroller. Measurements can be carried out along with specified schedule or initiated by the command from UIC for the operational control. AHD is powered by the industrial lithium battery which allows several months of usage, depending on the sessions a GSM-modem, which is the main electric charge of a system. Using solar cell extends the device unattended operation up to 1-2 years.

AHD software is combined of two parts: the MSP430 program stored on a flash-memory and the calibration program which runs on a personal computer to configure AHD (base speed of a liquid, measurements schedule, duration of the feed pulse, time corrections, data transfer parameters, indication modes, etc.).

Due to developed construction AHD can function autonomously for a long time, carrying out planned measurements having no connection with UIC. Communications protocol allows to initiate measurement manually and to read the UPTs flash-memory for previously carried measurements. System of commands includes reading/setting date and time, performing depth/speed measurement or getting previously saved data achieved in a stack-like structure, as far as reading/writing time period for autonomous measurements.

Software of UIC includes the interfacing module with AHDs and also forecast and visualization modules. Hydrological database keeps received measurements values and also may be manually filled with data from non-automated hydroposts.

Artificial neural networks were chosen while considering the mathematical basis for near forecast in UIC (Volchak et al., 2009). Sets of hydrographers representing measurements of previous years were used as input data at training network for forecasts in addition to real-time AHD data. A multilayer perceptron was used as the forecasting network. Acceptable accuracy was mainly achieved at 5 predicted values (daily periodicity of measurements was used in accumulated statistics). Effectiveness of near forecast, received with trained neural network, also makes it purposeful in some cases to use a superposition of data from neural-based method and ones of statistics-based forecasts while estimating the flood situation. Particularly, developed system uses mechanism of sliding frame in statistical data array as the realization of analogy method for extended forecasts.

Flood visualization is carried out on the basis of digital elevation maps and the information about water level in control points, where AHDs are placed. Rendering the segments of the triangulated terrain model is asynchronously done in OpenGL graphics with LibMINI library. Segments are loaded into memory at their appearance in the visible area. Being the function of the terrain complexity, mesh density is increased near the coastline.

The source for the triangulated terrain model is a 2D isoline diagram. Original map data are taken from raster digitized maps, vectorized by the semi-automated method. Level of the water mirror is semilinearly approximated on the basis of AHDs data and/or manually submitted level marks for a control points in the river axis. Then 3D inclined plane roughly circumscribing water mirror are plotted, and their crossing with terrain surface is determined to find out the flood water zone and to render its area (the water surface incline angle is supposed to have no changes between two control points).

Water surface can also be visualized on hydroposts statistics from previous years, previously entered into UIC, and, finally, on forecast data.

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# VARIATIONS IN THE ANNUAL RUNOFF ON AN EXAMPLE OF THE WEST DVINA RIVER


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The West Dvina River is representative transboundary European river which is flowing past on the territory of three countries: Russia, Belarus and Latvia. The river is referred to the West Dvina hydrological region. Length of the river compounds 1020 kms, basin space is 87.9 thousand square km. The basic inflows of the West Dvina River on the territory of Belarus are the rivers Usacha, Obol, Polota, Drissa, Kaspia, Luchosa, Ulla, Disna and Druyka.

The river is characterized by the mean incline of water surface 0.12 % and communal dip of the level on territory of Belarus 38 m. The river flows past in direction from east to west on Surozhskaya lowland, between Gorodokskaya and Vitebsk high grounds. Power supply of the river mixed (in the greater extent snow and ground). The feature of water regime is the high spring full-water, small summer-autumnal low-water with often rain full-waters and stable winter mean water. The annual runoff of the river compounds 666 $m^3/s$ (Dzisko et al., 1994).

One of the major performances of the water regime of the river is its annual allocation of the runoff (AAR). The last results of basic researches of the AAR of the West Dvina River are referred to 60-th years of the XX century (Resources of day waters of USSR, 1966). The happening climatic variations and strengthened anthropogenic affecting essentially have influenced on AAR.

The purpose of the study is the estimation of the AAR variation in the West Dvina River under influencing of the natural factors and anthropogenic affecting in the period since 1961 till 2005 in relation to the period of observations since 1877 till 1960.

The AAR variations are investigated on three hydrometric stations of the West Dvina River on the territory of Belarus (Vitebsk and Polotsk).

As input data the series of long-term observation by monthly average runoff for the period since 1961 till 2005, given by republican meteorological center of the Ministry of natural resources and environmental protection of the Republic of Belarus, and also results of studies of AAR on the West Dvina River (Resources of day waters of USSR, 1966) are used.

In study the method of layout of seasons is accepted. According to this method for the West Dvina River for a limiting period the summer-autumn and winter are accepted, and for a limiting season summer-autumn is accepted.

For considered stations the hydrographs of the runoff for following groups of years on liquid water content are constructed: very much full-water (P = 5 %), full-water (P = 25 %), mean (P = 50 %), low-water (P = 75 %), very much low-water (P = 95 %).

The comparative analysis of hydrographs of the runoff of the West Dvina River is held in two acting stations (Vitebsk and Polotsk) during the period of observations of 45 years. The analysis has allowed revealing an abatement of the runoff in spring season and its magnification in winter season. The summer-autumnal runoff in Vitebsk station was diminished, and in Polotsk station was augmented. However data of variation are insignificant and do not exceed limits of natural oscillating. As a whole, mean annual allocation of the seasonal runoff of the West Dvina River looks like this:

1) Vitebsk station: spring (56 %), summer-autumn (29 %), winter (15 %);

2) Polotsk station: spring (55 %), summer-autumn (29 %), winter (16 %);

AAR for hydrological regions on seasons are: Ic – 48 %, 31 %, 21 %; Id – 57 %, 23 %, 20 % accordingly.

It is established that the shape of hydrographs has altered. Most legibly it is tracked for group of very full-water years. At first, the amount of freshet periods was augmented up to four; secondly, spike of an autumnal high water was offset. For example, in station of Vitebsk there was an offset since one month November for October. In mean on liquid water content years during observations since 1877 till 1960 the spring and autumnal high waters were supervised in April and November accordingly. In the last period since 1961 till 2005 two high waters (in April and December) also are supervised. For very low-water years the identical amount of high waters for last period and for the fist period is generic. Per full-water years in a Holocene the high water in a winter season was added. The hydrographs of the runoff for the low-water years for two stations are various. So, in station of Vitebsk three high waters in one year for two considered periods are fixed. The high waters differ only by month of passing. In station of Polotsk the high waters in the spring and autumn are supervised. The spring high water is necessary for April, and autumnal in 1961-2005 was offset since October for November. The rounded aspect of hydrograph of the runoff constructed for the last period is detected.

In the last period of observations (1961-2005) reallocating of the West Dvina River runoff in the course of the year takes place. It express in an abatement of fraction of the spring runoff and magnification of fraction of the winter runoff. The fraction of the summer-autumnal runoff was diminished in station of Vitebsk and, on the contrary, was augmented in station of Polotsk. Is detected, that the data of variation are insignificant and do not exceed 5 %.

The hydrographs of the runoff of very full-water and full-water group of years are characterized by many freshet periods come for April, January and October (November) months. In mean water years the offset of an autumnal runoff for December is detected. In turn, the hydrographs of the runoff for low-water years have more rounded shape.

Thus, natural-climatic factors and the anthropogenic affecting have rendered definite influencing on the runoff of the West Dvina River. Thus the playing key role in forming the runoff in considered period belongs to the natural-climatic factors.

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**Session 2**

# WATER MANAGEMENT WITHIN THE CONTEXT OF EUROPEAN DIRECTIVES

# RIVER BASIN PLANNING IN LATVIA WITHIN THE CONTEXT OF EUROPEAN DIRECTIVES

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Coming to Riga it is not so easily to imagine you are standing on the land recaptured from the sea, lagoon lakes, rivers and bogs less than one thousand years ago. Partly these lands were formed by natural accumulation and sedimentation processes, but man made water management practise by erecting hydraulic structures and introducing new land management is the baseline for the Riga Port development and for the City itself. Alongside with establishing of first water mills and fish ponds in the Livonia, came first water level records, first records of ice breaking in ports and soon first legislative trials fixed the ,,best practice'' of this ,,learning by doing'' period before the modern science.

Nobody can name these old water management works as the river basin planning, but it's difficult to deny some high complexity of hydrological and technical context included in the development of the Daugava River shipping lane almost 20 km long from the Riga City to the Gulf of Riga, planning of the Daugava River HPP cascade development or carrying out pre project works for the Daugava-Dnieper shipping canal at the length more than 2000 km more than hundred years ago.

Before 1940 wide investigation and planning works on affected waters and land were performed before some great water management projects like erection of the Kegums HPP, regulation of the Aiviekste River and Lake Lubanas, big land reclamation projects including polders etc. were successfully implemented.

Soviet time can be characterised by well developed central and regional water planning institutions, but all final decisions were taken in Moscow. Politically backed command economy deformed majority of the good scientific or technical solutions, promoted total land reclamation and large scale river training exercises, uncontrolled abstraction of drinking quality ground water for industries etc, thus making a very bad footprint to the environment and to the water quality in particular. Even such technically complicated buildings like the Plavinu HPP and the Riga HPP were performed close to maximally available exploration of water resources and by high technical risks and many connected problems like flood protection and land use were left later, voluntary decisions destroyed many of historical and nature monuments. Therefore at the end of nineties local specialists consolidated to stop the work at the Daugavpils HPP spot partly to demonstrate the local technical opposition to the Moscow's imposed solutions thus making the first accords of the singing revolution which came some years later.

However nobody can disclaim good methodology available for the water management planning at the river basin level, for example all Latvian river basins were covered by the water management plans already in late seventies and early eighties and in 1985 the Daugava River management plan was finalized in good cooperation with water authorities in Belarus and Russia thus covering all Daugava/Zapadnaja Dvina catchment basin area. Of course, one can say these plans were implemented only partly and the water quality components were not developed enough. Just remember that these plans were prepared more than twenty years before the adoption of the EU Water Framework Directive (WFD)!

After regaining independence Latvia was reshaping water management structures according to the needs and financial capacity and with more focus on water quality as society was not satisfied with the water management approach used before focussed mainly on the water quantity problems. The newly built institutions were turning very fast to the water quality aspects by undervalue water quantity or moved from one ditch to another.

As the big technical asset towards implementation of the EU WFD the Swedish-Latvian Project on Daugava River basin planning 1999-2003 should be underlined. Project was launched long before adoption of the WFD and in the beginning was one of the first pilot projects even between old EU Member States, but due to limited resources and lack of political support Latvia was not able to keep this speed for longer time and to transfer knowledge to others. Nevertheless this project was first experience of involvement of all stakeholders and society in river basin planning exercise and helped much to the public hearing process carried out in 2009 before the Daugava, Venta, Lielupe and Gauja river basin plans were finalised and sent to the EU.

Generally Latvia is rather quick and effective on the EU legislation transposition issues but the implementation of course is much more difficult. Even if after good motivation we have got several transitional periods for implementation of drinking water, urban waste or municipal waste legislation, time is running fast and this time reserve for implementation the old EU Directives is melting.

Looking to the preconditions for good implementation of the EU water sector legislation, Latvia has even worse natural and economic positions as the other Baltic Sea countries. As we are getting more than 50% of water as transit from other countries, besides transitional nutrients N and P load we are living with limited information on priority substances upstream and under permanent risks of spillages of chemical substances. These threats might ruin the aims fixed under the WFD, Nature 2000, Bathing Water Directive, Priority substances Directive and in many other sectors. Therefore Latvia actively supports the EU neighbourhood policy developments and mentions the transboundary aspects among the priorities of the EU Baltic Sea Strategy.

Next national problem is abundance of water bodies reaching 12000 streams and more than 2000 lakes. Latvia has declared 463 inland water bodies according to the WFD and even for those the available information is not exhaustive not talking about perfect monitoring. But the good message is that generally water quality is not bad and majority of water bodies will comply with quality requirements already in 2015.

Majority of EU member States have rather dense population with 200-400 inhabitants per square kilometre and many of directives are fitted to such conditions plus the heavy pressures to the environment and water resources management. Latvia excluding the Riga agglomeration is scarcely populated therefore implementation of the EU Law according to the legal letter requires introduction of costly monitoring systems or heavy and regular control which is ineffective use of resources as the pressures are low. For example the Latvian ground water monitoring will never be compared with the Benelux countries as they have dense population and intense agriculture. The Urban Wastewater Directive requires expansion of collecting systems in agglomerations close to 100% of population equivalent to be connected to the WWTP what is really a challenge for Latvian Cities usually with large green territories inside and scattered housing. And these requirements are heavily conflicting with available local finances and restricted co-financial resources of EU Structural Funds. If these directives will be perfectly implemented the maintenance costs will be very high and will painfully influence the tariffs for the services thus reducing availability of these services to the population.

# POSSIBILITIES TO USE THE SAILING MEANS ON LITHUANIAN LAKES ACCORDING TO LEGISLATION

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The objective of the article is to analyse the possibilities to use the sailing means on Lithuanian lakes. It was sought by the article to explore the effect of sailing means on inland water bodies and in such a way to substantiate the necessity to limit the usage of sailing means on the lakes. The article analyses legal regulation of usage of sailing means on Lithuanian lakes, factors influencing the use of different sailing means and investigates distribution of lakes in the territory of Lithuania according to possibilities to use sailing means.

Non-self propelled sailing means has long been used for fishing and transportation purposes. Power boating in particular has increased quite significantly since the 1960s. The targets of use expanded – they were start used recreational, sporting, pleasure trips purposes. In Lithuania, power boats and water motorbikes are increasing at a rate of 16-18 %. The number of Lithuanian people participating in water-based recreational activities continues to grow.

The effect of sailing means on the ecosystems of lakes may be grouped into physical, chemical and biological. The greatest effect on lakes is made by using powerful motor sailing means, water motorcycles and water skis.

Limitations of the usage of sailing means on the lakes may be divided into 5 categories: 1) limitations for morphometric parameters of a water body, 2) limitations of speed and capacity of a sailing mean, 3) limitations of sailing time, 4) limitations to sail in certain part of a water body, 5) limitations related with the protection status of a water body.

From 1990 to 2010 620 legal acts, in the texts of which the use of sailing means on water bodies were mentioned, were issued in Lithuania. Stricter regulation of the use of sailing means on Lithuanian lakes was started in 1998 when the legal acts directly related with the use of sailing means on water bodies were adopted. Those who want sail on lakes by vessels and other means intended for sailing must follow the set environmental requirements.

In Lithuania the use of self-propelled sailing means is allowed on lakes larger than 10 ha only. On lakes larger than 200 ha more powerful (from 8 kW (10.8 HP) to 110 kW (150 HP)) sailing means are allowed while the use of water motorcycles is allowed on lakes larger than 500 ha only. The use of self-propelled sailing means is especially strictly regulated in preserved territories where it is allowed to sail on lakes larger than 50 ha only, capacity of sailing means is limited, the use of water motorcycles is prohibited. Lithuania has a list of lakes, on which the use of motor sailing means is prohibited or limited.

The larger the lake area is the more different sailing means may be used on it. Self-propelled sailing means are allowed on 33 % of all Lithuanian lakes larger than 0.5 ha. On 15% of lakes (larger than 200 ha) more powerful (from 8 kW (10.8 HP) to 110 kW (150 HP)) sailing means are allowed and the use of water motorcycles is allowed on 10 lakes only (0.4 % (larger than 500 ha)).

Lithuanian lakes according to the possibilities to use sailing means on them may be divided into 4 levels:

*Level I* – very high level of lake protection (lakes in natural, biosphere reservations, botanical, ornithological sanctuaries, conservation areas, lakes included into the List of water bodies where sailing by certain sailing means is forbidden or limited). Only non-self propelled sailing means may be used on the lakes in this level.

*Level II* – high level of lake protection (lakes in national, regional parks, national sanctuaries except botanical and ornithological ones; lakes less than 10 hectares in non protected areas). In this level *Level IIa* may be excluded (lakes less than 50 ha in protected areas and less than 10 ha in non protected areas) where non-self propelled sailing means may be used only, and *Level IIb* (lakes larger than 50 ha in protected areas) where low-capacity self-propelled sailing means may be used.

*Level III* – average level of lake protection (lakes 10-200 ha, situated in non protected areas) where self-propelled sailing means low than 8 kW (10,8 HP) may be used.

*Level IV* – low level of lake protection. *Level IVa* – lakes larger than 200 ha (in non protected areas) where more powerful (from 8 kW (10.8 HP) 110 kW (150 HP)) sailing means may be used; *Level IVb* – lakes larger than 500 ha (in non protected areas) where is allowed of water motorcycles.

# HARMONIZATION OF EU DIRECTIVES IN WATER MANAGEMENT OF DOVINĖ RIVER BASIN: IMPLEMENTATION PHASE

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The project "Management and Restoration of Natura 2000 sites through an Integrated River Basin Management Plan of the Dovinė River, Lithuania" funded by the Dutch Ministry of Agriculture, Nature and Food Quality and the Dutch Ministry of Foreign Affairs through the PIN/Matra Program was initiated to halt the loss of biodiversity of one of the oldest nature reserves in Lithuania, the Žuvintas Biosphere Reserve with Žuvintas Lake. This project took the Birds and Habitats Directive and the Water Framework Directive (WFD) as a starting point for designing the measures required to reverse the down going trend. The Water Framework Directive as well as the Birds and Habitats Directive have clear ecological targets; the WFD aims to improve the ecological condition of all water bodies in the EU while the Birds and Habitats Directive aim to maintain the habitats and species that are of European importance in a "favourable conservation status".

Despite the analogous objectives there are hardly any experiences with the harmonisation and tuning of the implementation of the Directives mentioned above neither in the "new" member states nor in the "old" member states. It was therefore agreed to use the Dovinė River Basin, in which the Žuvintas Lake is located, as a demonstration area to test the combined implementation of these directives and to use the project to enhance the required co-operation between the water management sector and the nature protection sector in achieving the ecological objectives of the Directives. To increase the understanding of the involved experts and policy makers in the Directives a number of training workshops were organised in the course of the project.

The main project objective was to produce an Integrated River Basin Management and Restoration Plan as a framework for tuned and co-ordinated planning and design of water management, river and wetland restoration activities, nature management, the development of sustainable agriculture and fish breeding in the Dovinė River Basin. Being a modified river (dams, canalised and large-scale melioration works in the 80-ties of the last century) the WFD requires the restoration to the reference conditions. Both the obligation to maintain the favourable conservation status of the Žuvintas Lake, adjacent wet grasslands and bogs (based on the Habitats Directive) and the obligation to restore the reference situation of the Dovinė river (according to the WFD) make the area an excellent pilot for integrating of the protection and restoration of nature values of European significance into integrated river basin management (Gulbinas et al., 2007).

The project produced one nature management plan (for the Amalvas wetlands) and one draft nature management plan (for the Žuvintas Strict Nature Reserve) both designated under the Birds and Habitats Directive and produced proposals to improve the ecological status of the water bodies in the Dovinė River Basin which was included in the program of measures of the River Basin Management Plan of the Nemunas River. Nature management plan as strategical planning document for Amalvas was approved by the Order of Minister of Environment on 22 of October, 2007.

One year earlier (on 23 of June, 2006) the Government of Republic of Lithuania approved Žuvintas biosphere reserve management plan as territorial planning document for whole territory of reserve. This plan was produced within the PHARE project "Development of the management plans in protected areas of Lithuania". In all prepared planning documents the recommendations and proposals elaborated during PIN/Matra project on harmonization of Directives became as a background for planning decisions.

The first steps implementing proposed measures by planners were started during UNDP/GEF project "Conservation of inland wetland biodiversity in Lithuania" (www.wetlands.lt). Project executor is Public Institution Nature Heritage Fund (NHF). Management activities, for example, cutting Žuvintas lake vegetation with amphibian reed mower or construction of nature path suitable for disables nearby Žuvintas visitor centre were started right after approval of management plan. In addition to management carried out by staff of the reserves, contracting of local farmers and entrepreneurs is involved for cutting of bushes, trees in the areas foreseen for meadow restoration, managing of grasslands, blocking the drainage ditches.

In 2009 NHF started LIFE+ project "Restoring Hydrology in Amalvas and Žuvintas wetlands" (http://wetlife.gpf.lt/en). The main objective of the project is to restore hydrology and ecological functions of the Amalvas and Žuvintas wetlands so to secure achievement of favourable conservation status of bog, swamp wood and lake habitats of pSCI. Such activities were planned within the project:

- reconstruction of the Amalvas polder bordering the Amalvas mire area in the north. Drainage and embankment system along with water pumping regime would be optimized to maintain high ground water level in the polder;
- blocking of the drainage system in the southern part of the Amalvas mire area;
- re-naturalisation of water level in the eastern part of the Amalvas wetland by reconstructing the embankment and the sluice-gate of the Amalvas lake outlet into permanent overflow type spill weir;
- blocking of the drainage channels in the Žuvintas raised bog;
- re-naturalization of water level in the Žuvintas wetland complex by reconstructing sluice-gate of the Žuvintas lake outlet into permanent overflow type spill weir and improvement of dams.

Big part of planned measures are started or implemented for the moment and will be presented during the conference.

Continuing the implementation of measures proposed by PIN/Matra project and fixed in above mentioned planning documents one more project was initiated. Together with the partners from Sweden, Denmark, Germany and Latvia NHF prepared the project "Wise use of Wetlands" and applied for INTERREG programme funds. The restoration (reconstruction of sluice-gate, cleaning of river waterbed, installation of stone rifts, excavation of sediment ponds) of the part of Dovinė River flowing to Žuvintas Lake is the main goal of the project.

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# MULTI-OBJECTIVE OPTIMISATION OF THE MANAGEMENT OF SØNDERSØ WATER WORKS, DENMARK

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In Denmark 99 % of the fresh water used for private households, industry and irrigation comes from groundwater, and in the last 10 years, the abstraction of groundwater has been around 600 million $m^3$ of water per year. Groundwater is a limited resource and the energy consumption for the water works is considerable. An improved groundwater management can increase the exploitable groundwater, save energy, protect the groundwater from contamination, and ensure the water quality.

A well field model has been developed, which can simulate the hydraulic head in and around a groundwater well field. The well field model is a combination of a groundwater model, a well model, and a pipe network model. With this model it is possible to obtain good predictions of the groundwater level in the well field and the pressure in the distribution pipes and thereby also good predictions of the energy used for abstracting the water. In addition, the well field model can be used to simulate the effect of groundwater abstraction on surface water resources.

Søndersø water works is used as case study. It is located northwest of Copenhagen and abstracts 8 million $m^3$ of water per year from 21 wells. West of the well field is a contaminated site, and it is paramount for the water works to avoid polluted water entering the wells.

Multi-objective optimisation is performed to find the best way of operating the water works with regard to the two objectives, minimizing the energy consumption and minimizing the risk of pollution from the contaminated site, subject to the constraint of providing a given demand of water. The control variables are the status of the pumps, which can be either on or off. Optimisation results will be compared with historical management strategies.

# SCALE ISSUES FOR ASSESSMENT OF NUTRIENT LOSS FROM AGRICULTURAL LAND IN LATVIA

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Water balance of the humid soils causes nitrogen and phosphorus, dissolved from natural, agricultural and urban sources, to run into rivers. Elevated levels of these nutrients are of concern because they can cause eutrophication, which harms the water environment affecting water ecological status and use for human needs. A nutrient concentration also strongly correlates with use of arable land in agriculture – the main sources being non-point source run-off and poor handling of the animal manure.

The accelerated nutrient enrichment or eutrophication of water bodies from anthropogenic sources has become a significant water quality problem in most EU countries. In 1991, the Nitrates Directive was imposed with the aim of reducing concentrations of nitrogen in water ecosystems. The later European Water Framework Directive, imposed in 2000, introduced new targets for water quality at levels close to those which would be seen under natural conditions, without considerable human impacts, i.e., good water quality should be reached in 2015. Nutrient criteria are the basis for regulatory values such as standards, permit limits, and critical load values. Nutrient criteria's will also be valuable as decision making benchmarks for management planning and assessment of the efficiency of planned measures e.g. Action Programmes (Nitrate Directive) and Programmes of Measures (Water Framework Directive).

Water quality evaluation requires consideration of water body types at different spatial and geographical scales. This can be analyzed at several different scales: (1) river scale, (2) small agricultural catchments' scale, (3) drainage field scale. Multi-year sampling is necessary because large annual variability can occur annually in the intensity of nutrient/algal problems, due to timing of weather (primarily scouring storm events or persistent low flow events with long residence time) and seasonality of nutrient run-off. Ideally, water quality monitoring programs produce long-term datasets compiled over multiple years, to capture the natural, seasonal and year-to-year variations in waterbody constituent concentrations. Agricultural run-off monitoring data collected since 1994 in small catchments' and drainage field scale has been used for assessment of water quality. Recommendations for the evaluation of water quality in agricultural areas are presented in this study.

# VALUE – A NEW DOCTORAL TRAINING PROGRAM ON INTEGRATED CATCHMENT AND WATER RESOURCES MANAGEMENT

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Finland has a unique doctoral training system, where the Finnish Ministry of Education awards funding for engaging full-time doctoral students. The selected students will be appointed for full-time positions preferably and utmost for four whole years. The system was taken into use in 1995, and at first the funding decisions were made by the Finnish Ministry of Education after hearing the Academy of Finland. In 2008 authorization to make the decisions were handed over to the Academy of Finland. By 2010 there were in total 1600 doctoral training positions in 112 different graduate schools funded by the Finnish Ministry of Education.

Postgraduate education that is supported by the Finnish Ministry of Education and supervised by the Academy of Finland is facing major structural changes in the near future. The development work was started on 2008, and the new guidelines will be adopted by 2012. The final decisions on the new structures will be made in April 2010. The aim has been to increase transparency and predictability of researcher careers. The aim is to have more systematic approach to doctoral education and increase the quality. Supervision responsibilities need to be clarified, and doctoral student follow-up groups need to taken into use in every doctoral school and program. In Finland, the average age of new PhDs is quite high, and thus there are needs to create educational processes which assure the possibilities to graduate in less than four years when working full-time.

In 2010, only two new doctoral programs started, one of them being VALUE – Doctoral school on Integrated Catchment and Water Resources Management. VALUE is nationwide with eight participating universities and six research institutes from different parts of Finland (Table 1), and it is coordinated by the University of Oulu. The focal idea in VALUE is to cover the whole hydrological circle and to examine the interactions between the interfaces. The VALUE partners are the main actors in Finland on issues widely related to integrated catchment and water resources management. The organization of VALUE has been planned to meet the new doctoral education requirements set by the Academy of Finland. Student selection processes have been transparent and the selection criteria have been based on the scientific merits of the applicants. In the beginning of 2010, a total of 26 students were selected for student or matching funding positions. The proportion of foreign students is about 20 %, which is also the aim set by the Academy of Finland.

Systematic education in VALUE includes scientific research, studies on the disciplines and on the fields of studies as well as studies to improve transferrable skills. Each partner, especially the universities, has the right and responsibility to arrange courses and seminars. Some of the events are common for all, and students are expected to take part in them. So far, VALUE has arranged one common event, the Opening Seminar on February 2010, which gathered about 45 students and supervisors.

Table 1. VALUE partners

| Universities | Research institutes |
|---|---|
| ○ University of Helsinki<br>○ University of Eastern Finland<br>○ University of Jyväskylä<br>○ University of Oulu<br>○ University of Turku<br>○ Tampere University of Technology<br>○ Aalto University, School of Science and Technology<br>○ Åbo Akademi University | ○ Geological Survey of Finland<br>○ Finnish Forest research Institute<br>○ Agrifood Research Finland<br>○ The Finnish Meteorological Institute<br>○ Finnish Game and Fisheries Research Institute<br>○ Finnish Environment Institute |

At the moment, VALUE is starting its activities, and is actively seeking also for foreign partners for cooperation in research, education, and student and teacher exchange. One main aim is also to benchmark the practices of arranging systematic doctoral education. Discussions on cooperation have been carried out with some Scandinavian and Irish postgraduate programs.

More information on the doctoral program VALUE is found on the web pages of the program: http://value.oulu.fi/.

# APPLICATION OF SWAT MODEL TO THE BERZE AGRICULTURAL CATCHMENT

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The European Water Framework Directive aims to control and reduce the water pollution. The modelling of water quality can help its implementation, particularly in agricultural areas where non-point source pollution risks are high. The validated models can be used to develop strategies for remedying the current pollution problems and to protect water bodies.

Presently, the Soil and Water Assessment Tool (SWAT) has become widely used and could be considered as an important tool for watershed-scale studies due to its continuous time scale, distributed spatial handling of parameters and integration of multiple components such as climate, hydrology, nutrients pollution, erosion, land cover, management practices, and channel and water body processes (Twigg et al., 2009).

The Bērze as an agricultural run-off monitoring site is situated in Nitrate Vulnerable Zone and represents the area of intensive farming in Latvia. The application of high rates of mineral and organic fertilizers contributes to the excessive nutrient loads in soils and water bodies. For the assessment of agricultural pollution of water bodies, an agricultural run-off monitoring was implemented in Berze small agricultural catchment (3.68 km$^2$).

The SWAT model defined 11 hydrologic response units (HRU) within study area. Each HRU is unique combination of six land use types, one soil and one slope class. The SWAT model results was calibrated and validated using crop rotation and fertilizer application data for the period 2005 – 2008 and meteorological, discharge and water quality data from small catchment monitoring station for the period 1995 – 2008.

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# THE DANISH WATER RESSOURCES MODEL – TOWARDS A UNIFORM NATIONAL BASIS FOR THE IMPLEMENTATION OF THE WATER FRAMEWORK DIRECTIVE

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In Denmark there is a long tradition for applying numerical models in administration of the groundwater resources. Ending in 2003 the first version of a national water resources model (DK-model) was established, which provides an integrated description of the surface- and groundwater system. Implementation of the groundwater related issues of the Water Framework Directive has to a large extend been based on model results from applications of the DK-model (Højberg et al., 2007; Henriksen et al., 2008; Müller-Wohlfeil and Mielby, 2008). The extent to which models have contributed to the formulation of the first River Basin Management Plans (RBMP) have, however, varied widely across the country, reflecting differences in physical properties (particularly in terms of geology and climate), anthropogenic impacts (predominantly related to groundwater/water management and land use) and political/administrative traditions.

The main objective of the paper is to i.) provide background information on the use of regional numerical models and the DK-model in different parts of Denmark, ii.) and iii.) specify needs for further development of the DK-model.

Until recently, regional water management was carried out by 14 counties. While adhering to national and international legislation, the counties could define their own methods for issuing abstraction licenses. Moreover, no common standards where agreed upon as to the degree of detail that should be used to delineate groundwater bodies. This becomes obvious, for example, when looking at the number of groundwater bodies per water district, which varied across the country ranging from 3 to more than 1400. This big variety can only partly be justified by geological differences but was, more importantly, caused by differences in the political and administrative system of the counties.

As part of a restructuring of the public services in 2006 the counties were replaced by seven regionally based sections of the Ministry of Environment, being responsible for all tasks related to groundwater mapping and river basin management plans. The fact that the restructuring was effectuated after the counties have commenced the river basin management plans has caused a number of challenges affecting the work by the seven environmental centres: i.) in many cases the administrative areas of the environment centres do not correspond to the boundaries of the former 14 counties and most of the centres have to handle data from several of the previous counties, ii.) the ministry decided that the diverse number of groundwater bodies had to be homogenised to a total of 400 groundwater bodies (compared to more than 1900 before 2007) and iii.) groundwater bodies have been represented in various different ways in the regional databases. The differences among the counties also resulted in interregional differences in model applications. Model use for regional hydrological and water balance assessments and as a database comprising essentially all integrated geological knowledge of the specific regions was thus only well established in few regions.

A major challenge in for the environmental centres has therefore been to define a standardized approach to water management based on a uniform basis and methods. Among other actions it has been decided to employ the DK-model to apply a uniform basis for the water management at the regional scale. Since 2007 the environmental centres have funded a significant update of the DK-model, including a revised hydrological description based on more than 50 local models developed by the former counties, a refinement of the spatial scale and the representation of hydrological data.

The development of the DK-model is and has been performed as part of the by the national groundwater monitoring programme, which is currently under revision. Accordingly, strategies for long term model update and development has been discussed but not finally settled. Current work focuses on detailing the spatial resolution of the river network, improved coupling to national hydrological and geological databases, as well as studies on groundwater – surface water interaction and upscaling.

The geological and hydrogeological knowledge is continuously updated by the national groundwater mapping programme running to 2015. To ensure that water management is based on the most updated knowledge, the national water resources model must similarly be updated at frequent basis. Furthermore, the requirement of an integrated approach to water management set by the WFD poses great challenges in describing the groundwater – surface water interactions and ecological aspects. Parallel to a model update, further development of the DK-model is therefore necessary, addressing revised process description and upscaling challenges. Finally, to ensure a uniform application of the model results, more model based methodologies must be developed.

During the next phase of the national monitoring programme, covering the period 2011 – 2015, it is, among others, planed to revise and extent the currently applied methods to i) estimate regional long-term water balances, ii) describe groundwater / surface water interaction, iii) chemical transport (particularly related to nitrate), iv) irrigation. Moreover, development is needed to preserve the characteristics of the local models once it has been integrated in the DK-model, such as catchment zones for large well-fields.

A major challenge in this aspect is how local scale heterogeneity can by supported in the DK-model without introducing over-parameterisation of the model.

The implementation of the WFD involves the establishment of action plans at the municipality level. The municipalities require tools to assess whether these actions are successful or not. Tools are also needed to evaluate impacts of revised abstraction strategies. Both tasks should be based on application of the same models that have been used for the establishment of the River Basin Management Plans. Accordingly, further development of the DK-model should include facilities that enable municipalities to perform water balance and runoff scenario analyses related to, for example, increased or decreased groundwater abstraction.

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# SCENARIOS FOR REDUCTION OF NUTRIENT LOAD FROM POINT SOURCES IN ESTONIA

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Eutrophication of inland and coastal waters is one of the main environmental concerns in the Baltic Sea Region (Ulen and Weyhenmeyer, 2007). Recently the ministers of the environment of the Member States of HELCOM adopted an action plan to considerably reduce the anthropogenic nutrient load to the Baltic Sea and restore a good ecological status by 2021. To achieve this, country-wise annual nutrient input reduction targets were proposed. The target levels for Estonia are 220 tons of phosphorus and 900 tons of nitrogen. During the past 15-20 years considerable efforts has been put to improve the waste water treatment efficiency in Estonia, especially in larger cities. This is the major reason for more than 70% decrease of nitrogen and phosphorus load to the recipient water bodies (EER, 2010). Almost 80% of wastewaters passed advanced tertiary treatment in 2008 and only about one percent is released to the environment without any treatment. The overall situation is rather good now, although treatment quality is varying temporally depending e.g. on the use of chemicals for phosphorus removal. In smaller settlements the treatment is still insufficient. In larger municipalities the number of households and industries connected to the sewerage systems has grown, increasing the amount of nutrient-laden wastewater delivered to the treatment plants. This is probably the main reason for the increasing trend in phosphorus concentrations in some rivers in Estonia (Iital et al., 2010).

The aim of the study was assessment of possible scenarios for further decrease of point source nutrient load to reach the target levels set up by the Helcom action plan. 2007 was selected as a base year for sceanrio building. In 2007 the total wastewater load to inland surface water bodies and directly to the sea were about 1400 tons of nitrogen and 130 tons of phosphorus when not considering cooling waters and those pumped out due to mining activities. Possiblity to decrease the P and N load has been assessed based on the requirements set up by Estonian and the EU legislation as well as the HELCOM recommendations. Scenarios were developed for four urban pollution load classes with different requirements for waste water quality at the outlet of the WWTPs. For the settlements with more than 2000 population equivalent (PE) the EU requirements and Helcom recommendations should be followed after transition period. According to the Water Act all Estonian water bodies are defined as pollution sensitive. Therefore, limit value for the total phosphorus for settlements below 2000 PE proposed by Helcom was lowered to the level of 1.5 mg/l.

The load of phosphorus directly to the sea or to inland surface water bodies can be reduced by 68 tonnes when following the most stringent Helcom recommendation. The largest decrease of nitrogen load (352 tonnes) will also occur when following this scenario. The least efficient measure with regard of phosphorus will be following only the Urban Wastewater Directive of the EU when the amount of possibly decreased phosphorus is only 27 tonnes. When comparing these possible reductions with the target we can conclude that only bit more than only about 30% of P and nearly 40% of N can be removed by following and implementing existing regulations with regard of waste water treatment in the near future. Retention of nutrients in surface water systems was not accounted in our calculations and therefore the real river load of phosphorus and nitrogen to the sea is somewhat lower.

After implementing required measures with regard of the maximum allowed concentrations in the outlet of the WWTPs the Gulf of Finland receives about 90% of Estonian wastewater nutrient load. The rest is discharged to the Gulf of Riga. Approximately the same was the division between these sub-catchments of the Baltic Sea in 2007.

Waste water load to the Baltic Sea from Estonian territory can be reduced considerably when following different requirements set up by national and the EU legislation or Helcom recommendations. This reduction is still not sufficient to fulfil nutrient reduction targets set up by The Baltic Sea Action Plan, especially with regard of phosphorus. This decrease is insufficient despite of the fact that retention of nutrients was not accounted in our assessment. Therefore, further decrease can mostly be possible by lowering diffuse load, mainly from agricultural areas that can also be problematic.

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# RETENTION AND SOURCE APPORTIONMENT OF NUTRIENTS IN SURFACE WATERS OF LITHUANIA

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The assessment of the type of human activity on the basin area that may cause an impact on the status of a water body is needed for successful implementation of the EU Water Framework Directive. The lack of necessary information often makes it difficult to perform the task. Therefore, statistical model MESAW (Grimvall and Stålnacke, 1996; Vassiljev and Stålnacke, 2005) based on export coefficients approach has been used in this study for evaluation of the impact of different sources of nutrients on the water quality in large-scale river basins in Lithuania. This approach is based on the idea that nutrient load exported from a basin is the sum of the losses from individual sources and on the assumption that specific land use will yield characteristic quantities of nutrients to a receiving water body.

The study was done in the Merkys, Žeimena, Nevėžis and Mūša River basins ($A=2777\div6141$ km$^2$) situated in different regions of the country. The four basins represent diverse hydrology and nutrient load conditions from anthropogenic and natural sources.

Monthly water quality sampling data of total nitrogen ($N_{tot}$) and total phosphorus ($P_{tot}$) for the period 1996-2007 from 24 sites along with digital information for delineation of sub-basins and a database on the point source emissions and atmospheric deposition provided by the Lithuanian Environmental agency were used. The digital CORINE land cover map was also used to derive land use statistics for each of the sub-basins. The load of each water quality constituent was calculated as a function of daily concentration of the constituent and the stream discharge. Daily concentrations were estimated by linear interpolation between the values measured at two sampling events. Annual loads were obtained by accumulating the daily load values. To estimate the loading contribution for each land use type multiple regression analysis described in the MESAW methodology was applied. The dependent variables were the annual loads of constituents and the independent variable was the land use proportion in each sub-basin. The advantage of the MESAW is that the values of export coefficients and riverine retention of nutrients are evaluated simultaneously. This is based on an optimisation procedure which finds the minimum sum of squares of absolute differences between observed and calculated riverine nutrient transport.

The results indicated that the land use categories used as independent variables explained a large proportion of the variability in loadings. The estimated mean export coefficients for agricultural land, forest and wetlands (combined) as well as for pastures and meadows (combined) were 16.1; 2.1 and 3.5 kg $ha^{-1}$ $year^{-1}$ for $N_{tot}$ and 0.26; 0.14 and 0.20 for $P_{tot}$, respectively. All the coefficients were significant at $p<0.01$. The higher emissions were estimated in the basins where light-textured soils prevail.

The comparison between the constituent source apportionment of the basin input and of the river load can give an insight into basin behaviour and help to identify the sources that most affect the water quality. Therefore, using the MESAW it was determined that in all the basins, the input of nutrients was dominated by agricultural and point sources. Human activity (agriculture and point sources) contributes from 49 to 93% and from 44 to 78% to the total loads of $N_{tot}$ and $P_{tot}$, respectively. Natural areas (forest and wetlands) contribute to lesser extent – by 15% and 22% on average accordingly. Atmospheric deposition is responsible on average for 1.3% of the riverine load of nitrogen and 7.1% of phosphorus.

The contribution of different sources to the total riverine load depends on the inputs and on the ability of hydrographic network to retain nutrients. The results from this study indicated that streams and standing water bodies can substantially retain N and P. According to the obtained estimates the total retention in the study basins varied from 29 to 75% for N and 40-64% for P.

In the MESAW, the retention in lakes and in river network can be parameterised separately. Thus, the attempt was made to distinguish between the retention in lakes and stream network in each of the sub-basin. Calculations revealed that from 11 to 24% of nitrogen and from 12 to 15% of phosphorus are retained in lakes and ponds. The in-stream retention appeared to be slightly lower and varies from 7 to 23% for N and from 8 to 14% for P, respectively. The highest retention of N and P was estimated in the sub-basins with the highest lake percentage. The lower retention was in the sub-basins with lower proportion of lakes and ponds.

The analysis showed that the approach based on export coefficients is very useful for estimating the total annual loads of nutrients to a water body from diffuse sources and therefore serves as an important tool for source apportionment, particularly in circumstance where limited data is available for assessment. The MESAW model proved to be a simple and powerful tool for simultaneous estimation of sources and retention of nutrient loads in a river basin.

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# MODELING OF INFLUENCE OF HES DAMS' HEIGHT IN SMALL RIVERS ON SEDIMENT RETENTION

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To employ renewable energy, the hydroelectric stations (HES) are built. However, the ponds created by dams change the already existing natural conditions of the riverbeds flow, herewith the living conditions of aquatic fauna and flora gets worse. Consequently, a lot of time is needed to form a new equilibrium. Therefore, it is necessary to analyze these processes and reduce their negative influence by choosing the optimal methods of hydro energy employing.

The most important processes that are getting changed with arrangement of HES ponds are the water quality, the sediment transport, and the deposition dynamics. Many factors influence these processes therefore they are quite complex. In this work the influence of HES ponds with various dam heights on sediment deposition in the valleys overflowed during the floods has been modeled mathematically. The 10 HES cascade of the small Lithuanian river Virvyte has been modeled. The obtained data can help to choose the optimal dam heights for small river cascades.

When the dams are not high, the ponds go in the riverbeds, and then the valleys are inundated only during the floods. In the grass covered areas of the floodplains the sediments washed from fields (wash products) get intensively settled (much more intensively than in the river beds) and the river water quality then is greatly improved. However, when the dams are high, a part of upland floodplain areas is always dammed, and is not covered with grass. Then the floodplain area useful for sediment deposition and retention is decreased. Consequently, it influences the water self – purification process.

We had some difficulties with modeling sediment retention in flooded grass-covered valleys, as this process has not been sufficiently investigated yet. The necessary field investigations were performed during the floods in the river Nemunas delta and in flooded areas of the Nevėžis valley. A method of sediment deposition calculation in such areas has been created (Rimkus et al., 2007).

In deep ponds there are other not favorable conditions influencing water quality. Stream velocities in the large ponds are low; therefore the favorable conditions for algal and small vegetation growing are formed. The decayed fine vegetation becomes a water pollutant. Silt sinks on the bottom, however increased flow velocities can lift it up. The velocities are being increased during the performing of the daylong power regulation. After increasing the turbine discharge, the washed organic silt is resuspended and mixed with water. Oxidation of these organic materials decreases the amount of dissolved oxygen in the long interval of the river.

The most of the ponds of the river Virvyte are going in the riverbed and only some of them overflow into the valley. In the modeled interval, the pond of HES Kapėnai contains 30 ha of dammed valley. It decreases the sediment deposition. In the many years period the main volume of the sediments settled in the floodplain falls during not large but frequent floods. In the modeled interval the area of 60 – 70 ha is flooded most frequently. Therefore it is natural that in the many years period sedimentation in this interval is decreased even to half. In the many years near the river bed the average sediment deposition is equal to 2 – 3 t/hectare/year. (The similar quantities were found and during the field investigation in the flooded valley of the river Nevėžis.)

As one can see, the high dams in small rivers are not desirable from ecological aspect and can be necessary only for clear energetic demands, for example for the daylong regulation of power. Therefore, it would be useful to have one a bit higher pond in the upper station of cascade, which could regulate the water discharge for all lower plants.

The majority of the ponds of the river Virvyte go in the riverbed and only some of them overflow into the valley. However, it was sufficient for considerable decrease of sediment retention for a long time.

On the river Virvyte there are 10 hydropower stations grouped in two cascades. In the lower one the upper Sukončių station has the pond sufficient for daylong power regulation. However, when the river discharges are low such regulation is now impossible because of installation in these stations only of 1-2 large turbines (economic reasons). They function usually with much larger discharges than the river ones; otherwise their utility coefficient would be very low. After working down the water level in the pond to the permissible limit, the power units are stopped and only the sanitary discharge is passed, until the pond is filled again. Such regime is very unfavorable for the environment.

It would be necessary to install at least one Kaplan type turbine with lover power in the each station. When the power stations on the river Virvyte were designed, the necessary lower power turbines were not foreseen, as the summary power of all stations was small compared with that of the whole system. Therefore, the high fluctuation of HES power seemed to be not important. Besides, then the possible ecological damage was not treated seriously.

In addition, changing turbines to the more perfect ones would be economically viable in time perspective. Regulation of power would allow utilizing the whole river water discharges except the surplus flowing during the floods. In addition, it would be produced more electricity adapted to the usage changes. In this way both the ecologic and the energetic demands would be coordinated.

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# ADVANCING EUROPEAN WATER POLICY DISCOURSE IN THE SERIES OF EUROPEAN SEMINAR ON GEOGRAPHY OF WATERS

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Over the last decades, the water geography has received increasing attention from researches, practitioners and policy-makers in Europe. The environmental and socioeconomic impacts of climate change enhance the debate on sustainable water policies across countries and stakeholders. Discussions among academia, industry, agriculture and government, and importantly communities has considerably enhanced the knowledge, interpretation and implementation of the key provisions of the Water Framework Directive (WFD), and it has been considered as a very powerful tool for sharing good practices (Balabanis et al., 2005). Such cross-society integration considers environment, not narrowed just to water systems, by all relevant policies, interactions of various environmental implications, socio-economic development and human welfare.

The article introduces the development of the water geography paradigm reflected by thirteen European seminars on geography of waters held in the framework of advanced postgraduate (summer) schools across Europe since 1994. The series of seminars are held in the framework of the Erasmus Intensive Programmes, the Life-long Learning Programme, formerly Socrates programme. The background, aims, approaches, educational programme, and didactics are discussed for advancing pan-European water policy, its methods, debates and applications.

On the research level, the postgraduate seminar series activates an agenda and upgrades a platform of curriculum and scientific exchange on various interdisciplinary water subjects between academicians of the participating countries. First, the geography of waters graduate course enhances a schools of geography, know-how, experiences, as well spirit of collaboration between participating universities (up to 30) from Italy, Germany, UK, France, Spain, Hungary, the Czech Republic, Estonia, Bulgaria and Romania. The main Erasmus programme-related objectives of the seminar have been to improve quality and increase volume of student and teaching staff mobility throughout the Europe, and to facilitate the development and sharing of innovative practices on water subjects from one participating country to others. The seminar concept is based on multidisciplinary and multi-scale approaches to sustainable water policy and management. As a robust European road mapping, every region represented by the partner university has its more characteristic problems regarding implementation of WFD where they are more experienced and this reflects also in case studies and teaching programs.

The geographical aspect is stressed as it affects the nature of water problems in various ways: geographical location (dry, moderate or wet climate), location in relation with neighbouring countries, for example cross-boundary implications of water bodies and their management (Lake Peipsi, Estonia-Russia in the 2005 seminar; Danube, Bulgaria-Romania in the 2008 seminar; karst, Italy-Slovenia in the 2009 seminar), scale and size (big rivers ver. small tributaries in the 2001 seminar in Germany; big lakes ver. small lakes in 2005 seminar in Estonia; mass tourism versus nature tourism in 2008 seminar in Bulgaria).

Different aspects of water security relation to global environmental change, climate change and changes in hydrological cycle were given from the beginning of the seminar series since 1994. The case studies to exemplify water security and management were elaborated during field visits and discussions with wide spectrum of stakeholders *in situ*. The European Union enlargement was reflected by the eastward enlargement of the academic consortia, involving Estonia, Czech Republic and Hungary in the first wave. The seminars were held in these countries during 2003-2005 contributing to the WFD implementation in water basins and governance in institutional settings. Bulgaria, Romania, and Croatia were comprised in the second wave since 2006 for discussing the know-how transfer and best practices to smooth development pressures, structural change and water poverty in rural communities.

In 2006, the seminar focused on water scarcity and drought in Spain as well across the Europe, Seville. The seminar in Bulgaria in 2008 focused on the following subthemes: water in the world – risk related to the water in different parts of the world; dimensions of water security; water security problems in the Bulgarian coastal zone, and international rivers and water security problems: case study of the Danube River (Roose, 2009). Water management of sub-mountainous catchments, lagoon environment and cross-border karsts are debated in the Udine seminar in 2009. Interrelations between spatial planning and water management, groundwater pollution, and mineral waters are elaborated in the Transylvanian case studies in Cluj-Napoca, Romania in 2010.

The mutual relationship between urban and rural water approaches is discussed through the seminar series. The participatory approach is stressed while solving conflicts between values, goals and interests on stakeholder level. Pressures between economic development, social welfare and environmental protection are covered comprehensively by all seminars. Uncertainty and instability in the economic-social process affect water management, including WFD implications as well numerous case studies of developing countries presented by teachers and postgraduates.

The Erasmus seminar on geography of water reflects and advances the pan-European water geography discourse enabling up-to-date integration of postgraduate programmes in the European universities as well promoting a practical dimension of European water policies implementing the Water Framework Directive in the ethos of sustainable development.

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# SEEKING SOURCES AND NEW WATER MANAGEMENT SOLUTIONS OF ACIDIFIED RIVERS

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Extensive drainage of acid sulphate soils (AS soils) causes widespread environmental problems in running waters in Western Finland. Great proportion of the rivers in coastal area is classified as only moderate or poor state. Land use, as agriculture and forestry promotes oxidation of sulfide materials in the subsoil because of the lowering of ground-water table. This leads consequent production of sulfuric acid and severe acidification of the runoff water. Warm and dry periods in summer also stimulate the oxidation of sulfide materials in soils (Österholm and Åström, 2008). Heavy rains in autumn then leach acidic loads to river water. The most crucial effects of the acid and metal peaks to the aquatic biota are observed during high-flow periods in spring and autumn. In spring decreased pH disturbs the reproduction of fishes and damages juvenile fishes (Urho et al., 1990). Decreased pH increases also the soluble aluminum concentrations in water which is toxic to aquatic biota. Water management of river basin and soil has the potential to reduce negative effects of acidification. For example leaching of acidic sulphuric compounds to river water can potentially be prevented by hindering the ground-water table lowering. In addition, the natural buffer capacity of rivers can be improved by increase contact between running water and catchment soil and through liming operations. The goals of the river management methods are to improve the chemical and ecological state of the rivers, increase recreational use and recover suitable conditions for salmonids.

The objective of this research is both to seek sources, mechanisms and ecological effects of acidic load of river water, and develop new solutions to prevent this load to rivers. Agricultural AS soils and their environmental effects have been well studied, but the effects of forestry are partly unknown. In this research different kinds of water management solutions in forestry area will be studied and their application to prevent river acidification by increasing natural buffering capacity. This means enhancing the water storage capacity in catchment area, regulate runoffs during high-flow periods, decreasing drainage depth of ditching area and raising pH-value through liming. The functions of these methods are tested in practice during this research. It is important to know the exact mechanisms of acidification in boreal northern streams so that restoration methods can be targeted correctly and cost efficiently. The effects of climate change and the anticipating of it will be also studied in this research.

According to our study, state of the acidity has not changed remarkably during decades in rivers of Western Finland (Saarinen et al., submitted). The most critical period concerning about acidity appeared in the 1970s, when extensive drainage of AS soils and watercourse reconstruction were carried out. Hydrological and climate factors were also key factors explaining acidity of river waters. Precipitation and discharge had a negative relationship with water acidity in high runoff periods, especially during autumn, indicating that future climate change may influence on water quality. Estimation of the effects of climate change to acid loading from the catchment area will further be studied in most remarkable rivers related to AS soils according to climate change forecasts. The results will give new information of the effects of climatic fluctuations, as droughts and high runoff periods to the river acidity. The effects of supplementary ditching to acid load from AS soils and possibilities to prevent acidification will also be studied by measuring the runoff water quality and quantity discharged from the ditched forest area. We will assume that the depth of ditches and the lowered ground water level will induce sulphide oxidation in forest sub-soil and therefore influence strongly on the water acidity of the runoff water.

Acidity problems caused by AS soils are among the most serious factors impairing the ecological state of Finnish rivers and are thus one of the major challenges facing water protection in Finland. Sustainable water protection methods and land use planning concerning river basins affected by AS soils need intensive investigation, as do the impacts of climate change on the acid load to river water. The results of this research can be applied in planning of acidified rivers management and decision-making for example the use of river management strategies according to EU Water Framework Directive.

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# DAMS WITH HYDROELECTRIC STATIONS IN SMALL RIVERS: SEDIMENT AND NUTRIENR RETENTION

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Rivers and riversides, functioning both as pathways and buffer zones (1) assist in migration and prevention of losses of chemical elements, nutrients, organic matter, and inorganic solids within/between/from landscapes; (2) provide the niche conditions for an array of plant and animals, herewith acting both as the migration corridors and sites for the successful bio-diversity; (3) supply people community with fresh water for drinking, irrigation, recreation, and, finally running water is potential to be employed as kinetic power. Definitely, that is why river channels and valleys were being dammed for a long time. For example, there were operating 52,649 dams with reservoir capacities more than 50 acre-feet at the end of last century in the Continental United States (Graf, 1993), i.e. somewhere 0.6-dams/100 km$^2$. Approximately at the same time, there were 354 river dams (ab. 0.5 dams/100 km$^2$) in Lithuania (Gailiušis et al., 2001).

Dams, however, segment river channels into dammed and undammed reaches resulting in the changes in integrity of free-flow conditions and greatly disturbing the hydrological regime herewith the equilibrium of the above mentioned ecological features of rivers and their riparian zones, coherent with the suspended sediment ant nutrients both transport and retention. The changes are even more complicated when the dams are completed with hydroelectric stations (HES) or other hydropower plants. The aim of the work was to learn about and assess the measure of the influence of dams with HES on the retention and the downstream transport of the suspended sediment and nutrients in small and average rivers of lowland environment. Also, some comparison to beavers' obstructions in drainage channels was made.

The investigations were carried out in Lithuania and involved 17 dams built on four rivers of the 3rd to 4th order. The height of the dams and the capacities of their reservoirs ranged from 2.25 to 14.50 m and from $28\times10^3$ to $15{,}500\times10^3$ m$^3$, respectively. All the dams were completed with HES. To bring water to the HES turbines, the power-channels there were equipped to all the dams lower than 5.5 m; whilst the higher ones were completed with the power-conduits, which submerged intakes were installed about three metres below the water levels in the reservoirs. For comparison, there were two beaver-created cascades of 5 and 15 dams in drainage channels of 2nd order selected. The dam heights in the cascades ranged from 0.90 to 1.65 m and from 0.85 to 2.50 m; the capacities of all ponds of each cascade totalled $5 \times 10^3$ and $21 \times 10^3$ $m^3$.

To determine, the concentrations of suspended solids (SS), total nitrogen (TN), and total phosphorus (TP), water samples were taken about 50 m from each dam, both upstream (reservoir) and downstream (river). The sampling depth was about 0.3–0.5 m below the water surface in either side of the dams and the turbines of the entire HES have been operating when sampling. Moreover, there were the bed substances both of the reservoirs and rivers (up- and downstream from the dams) sampled to determine their grain-size compositions.

It was established that natural regimes of SS was changed by all the dams when water was flowing via the reservoirs and downstream through the HES turbines. All the reservoirs have been trapping most SS including the finest of them. As a result, the percentage of the particles with diameters < 0.01 mm in the reservoir bed substrates increased about threefold in proportion to the river bed ones. The direct correlation with the coefficients ranging from 0.35 to 0.94 was found between the reservoir capacities and the deposited amounts of these particles. It was also found the reduced concentrations of SS due to water delay in the reservoirs. However, these concentrations would increase appreciably in water downstream from the low dams always when HES were operating, but would not be observed in cases of high dams (Actually, the armouring of river channel beds was established being in progress downstream from the dams without reference to their heights).

The concentrations of total nitrogen and total phosphorus mostly demonstrated the antithetic correlation to the reservoir capacities (the coefficients ranged from -0.68 to -0.98), except the concentrations of TN in the category of low dam reservoirs. Moreover, the concentrations both of TN and TP showed alike behaviour when water would drain off via the turbines from the reservoirs despite the dam heights. The concentrations, though marginal, were found less downstream from the dams: for TN, by 3–15 %, and for TP, by 9 % on average. Although, it was established the concentrations of TP were higher by about 5 % downstream from the low dams when HES did not operate in low water period.

The TN and TP concentrations decreased in about 11–13 % when the water was delayed in the beavers' pond cascades. However, the concentrations of TN demonstrated the further drop of 0–8 %, when water would leave the pond cascades, whereas the concentrations of TP showed particular similarity with those that occurred downstream of the low dams when HES were not operating, i.e. they increased in about 0–5 %.

The data available involved a period of winter and a half of spring of one year, so was not abundant. Notwithstanding, they showed the reservoirs of dams (with HES completed) constructed in small rivers possessed the feature to retain TN, TP, and SS, the finest particles including. In this aspect, the reservoirs demonstrated a certain similarity to the nature-created, i.e. beavers' ponds. Even so, the HES of low dams equipped with power-channels did not protect the downstream reaches from the enhanced supply of SS finest particles when operating. The latter consequence suggests the project makers have to be careful when (1) selecting rivers for damming on purpose to install HES, (2) choosing the constructive elements for the particular HES; the pros and cons related to the generated electric power and loss of earth and natural meadows with often rare or even endemic flora species after inundation of valleys are to be objectively weight.

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# FR NUMBER FOR SMALL HYDROELECTRIC STATION IMPACT ON BIOTIC ENVIRONMENT

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Buildings across river sections like weirs or dams of hydroelectric stations (HES) have seriously affected the character of our rivers. Dams and reservoirs impart changes in the environment simply through their presence in the landscape, with the magnitude of change unique to each facility. In the water storage area upside these dams the flow velocities reduce, which leads to an increased accumulation of sediments and afflicts the system of gravel vacancies (interstitial). The rate of turbulence combined with less substitution of gas and by organic strain of water results in oxygen attrition. The impounded river develops typical characteristic of stagnant water and the stream liking species are replaced. River flow in downstream reach remains in initial border and there are no evident changes, but dams and reservoirs may impart change in the environment though facility operations over a sustained period. Operational impacts develop through discontinuity in downstream gradients (e.g. sediment supply, water quality) and modification of the natural flow regime. Chains of power plants increase this effect. These impacts lead to secondary changes in fluvial and floodplain processes, affecting the high spatial and temporal variability of available habitat characteristic of river – floodplain systems (e.g. hydraulic –thermal regime here will be rather different from initial). As a result, the lower reaches of HES are influenced by hydro-peaking surges of a power plant. The switch between low flow and surge conditions causes rapid changes of the water level (up to 2 cm/min), several times a day with varying timing and duration (Vaikasas and Poškus, 2009).

Thus, mechanism of interaction between HES and surrounding is complex and multiple. River flow is the most important element of this mechanism. Any change of river flow hydraulic characteristic and regime leads to distortion of equilibrium and following long lasting adjustment of the regime to the system of environment. For example, periodically fluctuated velocities change sediment transport deteriorating spawning grounds. Increase of mean flow velocity in 2 and more times in regulated rivers prevents fish fry to move against the stream that is uncomfortable and sometimes may prove fatal for juvenile. Increase of turbulence up to a certain limit may be favourable for benthos and fish juvenile, because turbulent oscillations of flow velocity are the only source of oxygen in the bottom layer, but simultaneous increase of both fluctuations of velocity and pressure result in negative impact on habitat conditions.

Thus, interaction of river and environment is crucial, and a link between the biologically and the hydraulically defined habitat units needs to be estimated. However, the target "good ecological status of river reaches" cannot be measured on a common scale and must therefore be broken down to a number of hydraulic parameters that affect the ecological status of the water. In the case of HES it means that the impact on habitat quality changes must be estimated by the hydraulic parameters such as velocity, water depth, turbulence and sediment regimes fluctuation. In such context, the aim of the present research was to find the likely impact of Lithuanian's small HES on river environment and possible hydraulic criterion for it estimation as well.

The study of different characteristics of the stream shows the importance of the set of conditions concerning flow velocity, turbulence intensity and pressure. Growing evidence suggests that flow complexity provides important habitat for aquatic organisms. It was observed that habitat metrics should not simply measure a physical attribute, but rather a physical attribute which has biological significance. The link between "functional habitats" (biologically defined habitat units) and flow "biotopes" (hydraulically defined habitat units) was found (Kemp et al., 2000). Using Froude Number Kemp test the hydraulic habitats of three species of macroinvertebrates by recording velocity, depth and water surface slope and found that functional habitat occurrence is well described by Froude Number $Fr = v^2/g\,h$. Studies of functional habitat distribution have revealed that the different habitat have different optima in terms of depth h and velocity v. It also suggests that water velocity affect river plants, with some species preferring slower and the others faster conditions. Thus, it was found that Fr (the ratio of inertial to acceleration forces) is the most reliable complex hydraulic variable (complex hydraulic criteria) to describe river habitats in terms of hydraulics. It can better describe the preference of many species than the flow velocity, the depth or the substrate type because complex criteria is a combination of physical variables and is capable of explaining a greater proportion of the variation than a single variation alone. The approach used was to examine the relationship between functional habitat occurrence and Fr number, with the aim of developing habitat preference curves.. The results provide of the first evidence that Froude number and therefore flow biotopes are ecologically significant and that river flow regulation impact on habitat conditions of the lotic reaches of HES dam impounded river can be estimated by this criterion.

Measurements of Fr number and flow environment in the Lithuanian Virvyte river shows the overall impact on flow characteristics and of 10 places in natural, directly and indirectly impacted HES cross-sections. To predict this influence, Fr number criterion and number of hydrophytes was compared. The results of measurements and calculation the association between functional habitat occurrence and Fr number indicate that there were three distinct types of habitat response associated with HES impact: negative, positive and non-signed or not impacted. In pounded reaches nearby above HES dam low Fr number habitats ($0.04 > Fr > 0.0007$) were created and negative dam impact was observed. Only silt as bottom substrate and roots, marginal submerged plants and submerged, broad-leaved macrophytes was found in this river reaches. Habitats that tended to be associated to higher Froude Number (0.26>Fr>0.10) were sand and gravel or cobles. Some of them were natural reaches far above the pond not impacted of HES, and below not directly influenced others. However, positive impact on environment below the dams was lessened number of hydrophytes only, and a surge wave harmful impact on fish community when turbines are operated was evident (Vaikasas and Poškus, 2009).

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# DRAINED PEAT SOILS AS SOURCE OF DIFFUSE POLLUTION

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The European Union Water Framework Directive (WFD) requires assessment of the pressures from human activity, which, combined with the information on the sensitivity of the receiving water body to the pressures, will identify those water bodies at risk of failing to meet the environmental objectives of the Directive. Lack of the hydrochemical data for most of the rivers in Estonia requires a methodology for the evaluation of the potential danger of pollution sources for the rivers without monitoring of water quality. WFD CIS Guidance Document No.3, the evaluation of diffuse sources may be done also with the help of the export coefficients (EC) of nutrients. This simple approach is based on the idea that the nutrient load exported from a catchment is the sum of the runoff from the individual sources and on the assumption that, for a given climate, specific land-use will yield specific quantities of nitrogen and phosphorus to a receiving water body. The export coefficients obtained by MESAW model (Grimvall and Stålnacke, 1996) was successfully tested for calculation of the nitrate losses from catchments in Estonia (Vassiljev et al., 2008). Nevertheless, the results obtained by model showed large differences between measured and modelled values of the nitrogen load for some watersheds. This fact indicates presence of unaccounted source of nitrogen on the watershed.

Aim of the study was to show that leaching of the nitrogen from drained peat soils may be very high. Eighteen streams with different percentage of peat soils on the catchment area have been sampled to investigate the possible impact of drained peat soils on the formation of the nutrient runoff from the watersheds.

Percent of peat soils on the watershed was calculated on the basis of digital soil map. Water runoff was measured simultaneously with water sampling at the all observation points. The chemical analysis of water samples was performed in accredited laboratory.

The analysis of hydrochemical and hydrological data showed that concentrations of the total nitrogen in rivers noticeably increase with increase of the water runoff. Analysis showed that the content of total nitrogen in river water increase with percentage of peat soils at the catchment area. The measured concentrations of the total nitrogen in rivers were higher than limit for good status of river water quality (3 mg/l in Estonia) when area of the peat soils exceeds 20 percent of the total watershed area.

The investigation also revealed that export coefficients of nitrogen from drained peat soils depend on content of nitrogen in soil, thickness of drained soil, density and age of drainage system, degree of decomposition of organic matters and so on. The quantification of the contribution of each individual factor is complex and needs much more data than is available now. However, the analysis of data obtained within frame of this study showed that rough estimate of nitrogen export from drained peat soils may be calculated by formula:

$$EC = 0.04r + 5.6 \text{ kg/(ha*year)},$$

where, *EC* – export coefficient, *r* – depth of runoff in mm/year

The results obtained showed that drained peat soils must be considered as additional noticeable diffuse source of nitrogen in Estonia. However, the additional investigations are needed to quantify leaching of nutrients from different type of peat soils.

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## Session 3

# COLD CLIMATE HYDROLOGY

# SNOW MELT RUNOFF SIMUALTIONS USING ENSEMBLE KALMAN FILTER ASSIMILATION OF DISTRIBUTED SNOW DATA

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Hydropower industries are relying on good forecasts of the runoff. In alpine and cold climate regions the most influential runoff event during the year is the snow melt. The snow melt's effect on runoff is dependent on properties of the snowpack, for example the snow water equivalent (SWE), which can be modelled by numerical models.

However, modeling of SWE in mountain areas can be difficult because of complex topography which influences snow drift and the scarcity of meteorological observations. One way of improving the model's ability to correctly estimate the SWE is to make snow measurements. Such measurements can be distributed either in time or in space, for example by manual snow surveys, automatic snow depth and snow mass observations by ultrasonic and snow pillow instruments, respectively, or by ground penetrating radar (GPR) surveys.

At this time various data assimilation techniques are becoming more and frequently used in hydrological modeling. One of these methods is the Ensemble Kalman Filter. This method has been shown to be useful for snow data measurements (see for instance Andreadis and Lettenmaier, 2005). One of the advantages of this method is the systematic treatment of uncertainties in all steps of the modeling chain; uncertainties in the forcing data, the model parameters and in the observations can be acknowledged in a similar way, and the results are connected to an uncertainty bound.

The objective of this study is to investigate if data assimilation of distributed snow measurements using the Ensemble Kalman method can be used to improve the simulation of snow melt runoff for a mountain basin in Sweden. More specifically, we will investigate how different choices of model structures, assimilation strategies, and spatial distributions influence the model results.

In order to make best use of the distributed information from the measurements, a distributed snowmelt model was used. Different type of distributions were tested, either hydrological response units based on topographical properties such as local slope, aspect and curvature, or fully distributed on a two dimensional grid.

We have conducted our study in a mountain basin in northern Sweden used for hydropower production, where extensive snow measurements have been made during the last three winters 2008-2010. A climate station is located at the outlet of the regulation lake, including automated point measurements of snow depth, snow mass (snow pillow), snow wetness and snow temperature. Distributed snow cover data was sampled using ground-penetrating radar from snow mobiles. Measurements were taken at the time of the maximum snow cover, providing a data set with snow depth, snow density, and snow water equivalent along 20 km long transects in representative areas of the basin.

Simulations for the years 2008-2010 were performed. Different combinations of snow observations and model structures have been tested to find out what kind of combination that is best suited for accurate runoff simulations.

The results show that the assimilation of GPR-data strongly improves the simulated results of snow melt runoff. This is most likely due to the information of snow distribution as result of snow dift and uneven snow precipitation represented by this data. Assimilation of the automatic data from the snow station also improves the runoff simulations, but not to the same extent as the distributed data. The snow station data was also valuable for calibration of the snow model parameters governing snow melt, compation, and albedo. The best results were obtained when distributed GPR-data was assimilated together with the daily observations from the automatic snow station.

Further studies will be performed to see whether other combinations of model structures and assimilation techniques can improve the runoff simulation even more. For example, it will be highly interesting to compare the results obtained with the GPR data to results obtained using satellite remote sensing data of the SWE.

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# MODELLING CLIMATE CHANGE IMPACTS ON SOIL TEMPERATURE AND SNOW DYNAMICS IN THE SWEDISH BOREAL FOREST

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Climate change may have serious consequences for the functioning of boreal forest ecosystems. Warmer temperatures and changing patterns of precipitation are expected to alter patterns of snow accumulation and melt, leading to changes in soil temperature and biogeochemical functioning. Credible estimates of future soil temperature and snow dynamics are needed if we are to make projections about carbon, nutrient and contaminant cycling in the boreal forest.

Mellander et al. (2007) have previously reported effects of changing mean monthly temperature and precipitation on snow and soil temperature in northern Sweden. Here, we present results from a new statistical downscaling technique operating at a daily time step coupled to a new model of daily soil temperature and snow dynamics for boreal forests.

Most downscaling methods based on frequency distributions are able to provide credible representations of temperature but often perform poorly when simulating precipitation as they do not readily reproduce changes in the number of days of rain or snowfall. We developed a new technique based on the strong relationship between large-scale atmospheric circulation and local weather in Scandinavia, especially during winter. Any effects of climate change on rainfall are unlikely to be uniform for all weather situations. So, rather than modifying the entire rainfall series as one distribution, our approach assigns each day a weather class, and then modifies the rainfall for all days in each class separately. This is as an important step in translating the climate change information from the GCM scenarios into climate scenarios for the individual sites in a realistic way. Thus, the downscaling procedure incorporated changes (derived from the GCM simulations) in both the probability of rainfall and the distribution of rainfall amounts to be projected onto historical and GCM-simulated precipitation time-series.

We present daily time series of downscaled temperature and precipitation from 1961-2100 based on scenarios for SRES A1B for the ECHAM5 and

NCAR CSM models. Both temperature and precipitation are projected to increase. Temperatures are projected to increase in all months, with the largest increases in the winter. The most significant precipitation increases are projected to occur between June and August and November and January. Future cold season (October-April) precipitation is projected to increase, with a greater proportion falling as rain. Rain on snow events, which can be important for nitrogen cycling in the boreal, are also projected to increase.

The soil temperature used here extends the model of Rankinen et al. (2004) which simulated soil temperature at a discrete depth from air temperature and snow cover using average soil thermal conductivity, soil specific heat capacity, specific heat of freezing and thawing, and an empirical snow parameter. The model presented here also simulates snow accumulation, snow melt, the effect of snow pack aging on heat transfer and heat transfer from below the depth at which the simulation is performed. We calibrated the model to long-term (1995-2002) soil temperature time series from the Svartberget catchment ($64^{o}$ 14' N $19^{0}$ 46' E ) in northern Sweden. Incorporation of snow pack aging and heat transfer from below significantly improved model performance during winter (NS is 0.51 when calibrating to dates with observed soil $T < 2^{0}$ C).

Using the parameter set derived from present-day soil temperature calibration and the daily time series of downscaled temperature and precipitation data, we projected future soil temperatures and snow dynamics. Model projections suggest that both the number of days with snow cover and the average depth of snow will decline after about 2020. While the number of days with soil temperatures $<0^{o}$ C is projected to decline, the minimum annual soil temperature is not projected to increase. This may be a result of less effective insulation by the snow pack in the future. These projected changes may have important implications for soil carbon cycling in the boreal forest.

Future work will explore the hydrological and biogeochemical consequences of the projected future climate presented here. Changes in timing and amounts of flows will affect surface waters in the boreal forest. Warmer, wetter conditions may have negative consequences for carbon, nutrient and contaminant cycling in the boreal forest.

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# MAPPING DEPTH AND EXTENT OF ICE JAM INDUCED INUNDATIONS: A CASE STUDY FROM SOUTH ICELAND

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Thresholds in depth of flooding and flow velocity are parameters widely used for flood hazard rating. In many countries of Europe and in Northern America, resulting classification of areas prone to inundations has become regulatory and is associated with restrictions in land use planning. A design flood, based on discharge probabilities ($Q_{100}$ typically), is generally used as input value in hydraulic simulations from which extent, depth of flooding, and flow velocity are obtained.

In arctic regions, the use of discharge scenarios is sometimes inadequate for insuring comprehensive assessment of flood hazard. In South Iceland for instance, 40% of the flooding events recorded in the lower Ölfusá basin over the past 200 years have involved ice jams at specific river sections, causing water encroachment and submersion of areas that are not flooded under open water conditions. Boundaries and extent of those inundations depend essentially on the location of ice jams, irrespective of the discharge. A complementary approach, emancipated from discharge, is therefore clearly needed for insuring relevant flood risk zoning. However, because of the peculiar topography of the Ölfusá basin and absence of forests in the flood plain, water levels attained during ice jam induced inundations cannot be estimated from bechevniks or tree scars.

The lecture will present mapping at high resolution of ice jam induced inundations according to pictures and aerial footage taken during flooding events. A DTM of 10 cm accuracy in elevation is used for the calculation of boundaries and depth of flooding. Results provide robust information for flood risk zoning.

# MODEL FOR TEMPERATURE, MOISTURE AND SURFACE ENERGY BALANCE IN BARE SOIL WITH SEASONAL FROST CONDITION IN CHINA

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Soil heat and moisture balances are linked to each other especially during low temperatures. To clarify such phenomena a physically based surface energy balance approach (CoupModel) was applied to simulate soil heat and water balances of black soil under seasonal frost condition in China. The uncertainties in parameters and measurements were examined by the GLUE uncertainty framework. Four different constrains of model performance indices were proposed: based on soil temperatures only (1) and soil moisture only (2), or combination of soil temperature and soil moisture (3 and 4). By these differences in constrains because of observed data we could study how the coupling of soil heat and moisture in the models influenced calibrated parameters and equifinality. The different constrains resulted in 266, 261, 6 and 112 of behavioural simulations of 25000 simulations by calibrating uncertainty ranges for 26 selected parameters. The high agreement between measured and behavioural simulated soil temperature and moisture with the combined constrains demonstrated that using simultaneous measurements of both temperature and moisture to constrain the model could help us to predict both of them reasonable well. To avoid over-parameterized the model, the less demanding of combined constrains (criteria 4) reproduced more robust behavioural models. Besides, temperature measurements improved the model for the moisture simulations concurrently. However moisture measurements resulted in great biased mean values for temperature simulations.

Most sensitive parameters were related to heat transport process, soil evaporation and freeze-thawing process. The simulated water storages in different depths showed systematic underestimations during the whole period. This indicated a correspondent uncertainty of measurements of soil water contents and soil physical properties.

In most cases a single simulation using mean of accepted parameter values had an ability of representing the ensemble mean of simulations. Nevertheless, in some cases the mean value deviated substantially especially for soil moisture demonstrating the high importance of non linear behaviour of the model.

In general, the CoupModel reproduced much better performances of soil temperature than soil moisture. The larger uncertainty bands of soil moisture usually were found with the increase of soil depth. During the winter conditions the uncertainty bands of soil temperature was larger than that during the rest of year, probably because of the higher complexity during freezing/thawing when also the soil properties may change in a way that is not fully considered in the model.

# EVALUATION OF EVENT DISCHARGE IN A SMALL CATCHMENT IN NORWAY DURING THE WINTERS OF 2009 AND 2010

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Several factors combine during cold periods to increase the potential for large runoff events, including reduced infiltration capacity due to frozen soils and increased water stored on the landscape in the form of snow. Increasing runoff in spring period also might increase the losses of sediment and nutrients. The capability for accurately modeling catchment-scale hydrological processes during periods of snowpack creation and ablation is currently limited. Research into appropriate snowpack and snowmelt modeling tools is integral to gaining an understanding of the hydrologic processes which occur within a catchment during cold seasons. The presentation shows results of a 2009 and 2010 measurement campaign to quantify water flow path, quantity and quality in a small agricultural catchment in Norway. The measurement setup and data will be presented where runoff, sediment and P concentrations have been analyzed during a snowmelt period. Results show that during spring discharge most sediment and P losses are produced by overland flow, where during the growing season most losses are caused by drainage water. Modeling results using the LISEM model coupled with snow and snowmelt modeling will be presented. The snow dynamics modeling is done using the UEB model. It showed that results from the snowmelt model to predict the snow water equivalent and melt water produces accurate input for the LISEM model to be able to calculate the hydrograph and sedigraph from single events.

# COLD CLIMATE URBAN HYDROLOGY EXAMPLES FROM NORWAY AND ICELAND

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Climate encompasses the statistics of precipitation, temperature, humidity, atmospheric pressure, wind, and in a given region over long periods of time. Cold climate hydrology is characterized by high variations in the weather by the seasons, having warmer summers and cold winters.

Cold climate affects the hydrology by changing the hydrological cycle. In winter time the temperature is often below zero and surfaces and the ground may freeze. The precipitation occurs in form of sleet and snow, and is be stored in snowpack and often transported by drifting or by snow disposal. Freezing and thawing periods and snowmelt occur, often including rain-on-snow. Such events can create extreme runoff conditions. The hydrological cycle, as usually described in the literature for warm-weather conditions, becomes much more complex in cold weather.

Urbanization fundamentally changes the hydrologic cycle from a natural predevelopment state to an artificial post-development state. The flow regime is changed, when the natural drainage system is modified, impervious areas increase and the local microclimate change. Increase in population may increase the drinking water demand and the installation of sewerage systems for both domestic and stormwater drainage may cause increase in waterborne waste. These problems may be worse in cold climate, having frozen ground, snow accumulated on ground etc. Therefore, cold climate and urbanization is having a great impact on the hydrology that may create extraordinary challengers on urban water management, including integration of water supply, stormwater, wastewater components of the urban water cycle.

Norway is running from Lindesnes at 57°05'N in south to North Cap at 71°11′N in north i.e. over 14 latitudes. The climate varies greatly from south to north, i.e. in the city of Stavanger to City of Tromsø and from coast to inland i.e. from City of Bergen to City of Røros and City of Karasjok. Karasjok is an inland town at high latitude, having relatively warm summers and very cold winters. The coldest temperature ever measured in Norway was in Karasjok on 1st January 1886, –51.4°C. Bergen is coastal city at moderate latitude, having positive average temperature year around, but extremes may occur. In Norway we find different climate zones, according to Köppen, covering cold temperate maritime, cold continental climate and mountain (alpine) climate, and in high north, arctic (polar) climate.

Urban water management (UWM) in cold climate, including water supply, sewerage, wastewater management, stormwater management, water quality questions and other water questions, may rely on more complex solutions, than in warmer climate. Thermal considerations may be as important as the hydrological and hydraulic aspects in planning, design and operation of the urban water systems, protecting facilities from freezing, by insulation, adding heat etc.

Water and sewer pipes have to be protected from freezing. Therefore they are often laid under the so-called frost-free depth, which is varying very much throughout the country. In permafrost areas, the pipes may be laid above ground.

To avoid traffic hazards snow removal is needed, and measures to safeguard traffic safety. Spreading sand, gravel and salt (NaCl) on traffic areas is a common practice during winter. This may cause pollution and even harm the environment. The use of salt is now under debate. In Norway the salt use on highways has grown from 30.000 to 170.000 tons/yr in the ten years period, 1996 to 2006. Also other pollutants such as heavy metals, because of corrosion and organic micro pollutants from poor burning and substances from winter tires and asphalts may contaminant water supply sources and can harm the aquatic life in recipients. They have often diffuse sources and are difficult to remove before discharge.

In the City of Bergen, the winter 2009 – 2010 has become extreme. The dry and cold weather since November has resulted in very low levels in drinking water reservoirs. Very high water demand combined with low precipitation in week no. 46-2009 to 6-2010 the drinking water situation is very difficult. Water pipes have frozen, causing leakage, even local floods. To avoid freezing, people let water flow continuously, so-called frost bleeding, increasing the water demand by 25-30%. This may result in rationing drinking water in the city which is famous for its huge precipitation, 2-3000 mm/yr.

When considering urban runoff in cold climate, the access to representative data is crucial. In addition to short term precipitation, there are need for data on both short-term and long-term high intensity precipitation, air temperature and amount of snow accumulated in the catchment. Such data are rare for winter time in cold climate regions.

At Risvollan Urbanhydrological field laboratory in Trondheim, such data are collected since 1986, see http://www.ivt.ntnu.no/ivm/risvollan/.

The Figure shows the Norwegian national short term precipitation gauge, an unheated tipping bucket, PLUMATIC, covered by a black garbage bag, while the heated Lambrecht gauge is running year around.

**Session 4**

# CLIMATE CHANGE IMPACTS AND ADAPTATION STRATEGIES

# BALT-HYPE – A TOOL FOR EVALUATING THE COMBINED EFFECT OF MEASURES FOR NUTRIENT LOAD REDUCTION AND CLIMATE CHANGE IMPACT

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The Baltic Sea Action Plan (BSAP) was approved in 2007 by the countries surrounding the Baltic Sea to improve the ecological status of the sea. An important part of this plan is reduction of nutrient inflows from the land surface into the sea (HELCOM Secretariat, 2007). Required nutrient reductions have been apportioned to the countries within the Baltic basin and these countries are now planning the remedial measures required to meet the plan's requirements. However, an important factor that remains to be considered is how well the planned nutrient reductions improve nutrient inflows into the Baltic Sea in a changed future climate. Nutrient inflows from land to sea are a result of point-source emissions from industry and urban sources, atmospheric deposition, erosion, subsurface, leaching from soil, diffusion from river and lake sediments and biochemical processes in the freshwater system. With the exception of the point-source emissions, these factors are temperature and precipitation dependent and are therefore affected by changes in climate. Scenarios that have been modelled to assess future nutrient reduction measures have thus far not taken into account potential climate change.

To evaluate the impact of climate change on nutrient loading to the sea, and the effect on nutrient measures, the HYPE (Hydrological Predictions for the Environment) model (Lindström et al., 2010) was applied for the entire Baltic Sea basin. The HYPE model introduces the ability to model detailed hydrological processes at high resolution simultaneously and homogenously across many river basins (Donnelly et al., 2009). When using a modelling tool to assess water resources and their quality for a basin entailing several political entities, it is an advantage that the methods and data used are homogenous across such political boundaries.

Readily available, regional and global databases were used to set up HYPE to the Baltic Sea basin (i.e. Balt-HYPE). The model inputs includes topography, precipitation, temperature, land use, soil-type, and nutrients from atmospheric, agricultural, industrial and urban wastewater sources, over the entire model domain on 1.8 million km$^2$. The input data was stream-lined on subbasin level using the recently developed World Hydrological Input Set-up Tool (WHIST) (Strömqvist et al., 2009). In total, the basin was divided into 5128 subbasins (i.e. on average 325 $km^2$ resolution). Forcing data, i.e. temperature and precipitation, was achieved from the database ERAMESAN for the period 1980-2004 and 11 km resolution (Jansson et al., 2007). Daily river runoff data from the Baltex and GRDC databases was used to calibrate and validate the parameters describing runoff processes, while monthly and seasonal data from the European Environment Agency's WISE database were used to calibrate and validate the water quality parameters in the model.

The results from modelling the present climate show that the Balt-HYPE model is able to reproduce measured daily flow variations and magnitude in both large and small waterways across the model domain. In addition, measured seasonal variation and overall magnitude of nutrient fluxes to the Baltic Sea is captured in the simulations of the period. Total annual volumes of discharge, total nitrogen and total phosphorus also compare well to published figures for total fluxes to the Baltic Sea (Helcom PLC-group, 2008). Concentrations in rivers are within a 40% error level. However, larger errors were achieved for phosphorous in some Finnish rivers, which may be a result of problems in modelling the organic soils there. Moreover Lielupe had poor results of phosphorus concentrations. For nitrogen, major problems were found in northern Sweden, where concentrations were overestimated in the model. This is probably a result of missing lakes and thereby retention processes in the model set-up. Hence, some further model development is necessary. The authors would like to invite other research teams and modellers in the region to cooperate in developing a common hydrochemical model system for the region. The Balt-HYPE can be a starting point as it has an open source code.

The validated model has been applied to examine the effects of different climate and remedial measure scenarios for both the land regions of the model domain, and influxes to the Baltic Sea. So far, one climate scenario from ECHAM5 was applied after regional downscaling by the RCA model. According to this, the water discharge will increase in the western part of the basin and decrease in the eastern part. Regarding nutrient fluxes, results show a lessened effect of the remedial scenarios tested for future climate scenarios at the end of this century. This indicates that the BSAP will not be enough to recover the Baltic Sea if the climate change projection is to be realised.

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# BIAS CORRECTION MODELS FOR REGIONAL CLIMATE SIMULATIONS: COMPARATIVE ANALYSES IN THE CONTEXT OF HYDROLOGICAL IMPACT MODELLING

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The water balance of basins is affected by several variable boundary conditions.

In addition to anthropogenic influences like water management measures variations of hydrometeorological variables induced by climate change are important. In general climate models provide information about future climate conditions.

Since models only represent an abstract picture of the complex earth system, hydro-meteorological variables derived from dynamical climate models deviate from observed values. In many cases this gap between simulation and reality is too large for direct application of the climate projections in hydrological impact modelling. Therefore different bias correction models were developed.

This contribution discusses the impact of bias correction of regional climate model simulations on mean and low flow indices. For different gauges state of the art discharge projections based on regional climate model data are compared with a reference simulation forced by observed hydrometeorological data. Several bias correction models varying in complexity and statistical characteristics are considered.

The discharge time series are derived from simulations with the conceptual, semi-distributed hydrological model HBV-SMHI in a daily time step. The model area covers the international catchment of the River Rhine up to the German-Dutch border in a spatial subdivision into 134 sub basins with a mean area of approximately 1120 km$^2$ and a total area of about 150000 km$^2$.

# THE ROLE OF SUBSURFACE DRAINAGE SYSTEMS AND SCALE IN RUNOFF GENERATION PROCESSES IN AGRICULTURAL DOMINATED CATCHMENTS

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It is well known that farming practices, soil type, topography and climatological conditions are important factors in nutrient loss generation from agricultural dominated catchment. However, Vagstad et al. (2004), when comparing nutrient loss in small agricultural catchments in the Baltic and Nordic countries found that the hydrology can play a major role in explaining the differences in nutrient loss between catchments. Catchments having a large contribution of groundwater runoff in the total runoff, in general had lower nitrogen losses. Other studies have shown that longer residence times in the Baltic catchments partly could explain the lower nitrogen loss compared to Norwegian catchments. Also catchment scale might play an important role in nutrient loss processes, demonstrated by a decrease in nitrogen concentration with an increase in measurement scale for a Latvian catchment. Artificial drainage of agricultural land can lead to an increase in nitrate-nitrogen runoff. However, its magnitude is very much influenced by the soil type and drainage system, characterised by its drain spacing and – depth (Skaggs et al., 1986).

An analysis has been carried out on measured runoff in catchment of varying size in Latvia, Estonia and Norway. It is anticipated that such an analysis will increase the understanding of the hydrological processes in agricultural catchments, or more specific to obtain information about the dominating flow processes and their impact on nutrient – and soil loss. By including catchments of varying size also insight in retention processes might be obtained. In the majority of the considered catchments, runoff was measured using automated discharge measurement structures, however in the larger catchment the discharge was measured based on a known head-discharge relation. Almost all catchments are operated as part of national monitoring programmes.

In many of the catchments discharge was recorded at hourly time intervals. The analysis has been carried out on both hourly as well as average daily discharge values. By taking into consideration these two time resolutions it was anticipated that the analysis would provide improved insight in the dynamics of hydrology, the dominating flow processes and their impact on nutrient and soil loss processes in agricultural dominated catchments. The improved knowledge also will aid in the choice and implementation of suitable mitigation measures to abate present and future pollution problems and in the design of hydro-technical implementations. This becomes even more important when considering climate change scenarios which predict, in addition to an increase in temperature, an increase in precipitation especially after the growing season from autumn until spring which can have serious effects on runoff and nutrient loss from small agricultural dominated catchments.

Characteristic for most of the smaller catchments was that the generation of the yearly runoff is confined to a limited number of days. However significant differences can exist. Sometimes it takes one month or less to drain 50 % of the yearly runoff while 90 % is drained within 4 – 5 months. In general runoff generation during the summer season is small compared to the other seasons. In many cases catchment discharge has a large variation and is extremely outlier prone, the coefficient of variation (CV), skewness and kurtosis giving an indication of this. For many of the Norwegian catchments a significant increase in skewness and kurtosis occurred when analysed on hourly – instead of average daily discharge value which is an indication of the presence of significant in-day variation in discharge. Another indication of the large diurnal variation in discharge was the difference in maximum specific discharge based on average daily and hourly discharge respectively. Considerable differences were found for the smaller Norwegian catchments, while they were relatively small for the Baltic catchments.

The flashiness index (Baker et al., 2004) in a way combines the results of characteristics like CV, skewness, kurtosis, specific discharge. The highest values for the flashiness index (FI) in general were obtained for the smaller Norwegian catchments while the larger catchments had the lowest values. Measurements carried out on smaller subsurface drained fields, nested within larger catchments, showed similarities in the FI at both scales, indicating subsurface runoff as major contributor in the total runoff. The relatively large FI in the smaller Norwegian catchments compared to Baltic catchments of similar size is mainly caused by the high intensity of subsurface drainage systems. However, also factors like soil, type and topography may contribute in this. For many smaller Norwegian catchments a considerable increase in FI was obtained when calculated on hourly – instead of average daily discharge, reflecting the large in-day variations in those catchments. While there was a significant increase in the FI for the smaller catchments, this was absent for the larger catchments. The main reasons for this can be attributed to scale and the reduced share of agricultural land. The large increase in FI at the smaller scale compared to the small increase in FI at the larger scale, when using hourly discharge data, also provides more realistic information about the retention. It shows that an analysis on daily values hides the real information about flow processes and when using hourly values, retention would get a different meaning.

The analysis indicates that the use of high time resolution runoff data can improve our understanding of hydrological processes in agricultural dominated catchments. This knowledge has to be used in assessing the effects of climate change scenarios on runoff and nutrient loss and in implementing cost-effective mitigation measures to improve water quality. Climate change scenarios with increased rainfall also suggest the use of high resolution runoff data in the design of hydrotechnical implementations in smaller agricultural dominated catchments.

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# FLOOD RISK ASSESSMENT IN SEASHORE-RELATED RIVER BASINS OF LITHUANIA

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Intensive summer rain showers in 2005 and 2007 caused flood in most rivers of Lithuania, and they were similar to spring or late-winter ones, but quicker in appearance. The majority of problems occurred in the basins that are adjacent to the seashore such as ones of Akmena (Dane) and Minija rivers. Occurrence of large runoff volumes resulted to the extremely high river level. Spring floods caused by heavy rain or thawing of snow are possible to be predicted, avoiding any possible dangerous consequences at the same time. Rapid river level raise during unexpected high flood can result to the breaching dams, thus being the reason of natural calamities. It is especially evident when high sea level in the Baltic Sea caused by deep cyclones results to additionally raised river level that exceeds extreme gauge readings.

The current research focuses on the consequences of past present and future possible dam breaching in the mentioned river basins. Modeling of possible impact of other dam-protected reservoirs is also analyzed in the vicinity of some other processes, including extremely high river level raises, caused by storm water surges from the sea or coastal lagoon.

# ADAPATATION TO CLIMATE CHANGE IN TAMPERE REGION, FINLAND

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Mitigation of climate change is a global issue in which local actors have their own contributions but local impacts of climate change cannot be prevented by local mitigation actions. However, adaptation to the consequences of climate change is mainly a regional and local issue because these impacts are different in different parts of even relatively small countries.

In Tampere region (Pirkanmaa) the responsibility of adaptation to climate change belongs mainly to the Centre for Economic Development, Transport and the Environment for Pirkanmaa (CETEP). Also local communities have interests in the adaptation issue. The city of Tampere together with its neighbouring communities developed a climate strategy in which main attention was paid to mitigation but adaptation was also considered to some extent.

CETEP is a regional governmental organization which has taken the mandate of the former Pirkanmaa Regional Environment Centre (PREC) in the beginning of the year 2010. PREC conducted research on the impacts of climate change on lakes, rivers and their catchment from 1990, at first within the national climate change research programme SILMU and thereafter in several national and international projects. PREC was specialized to developing and applying mathematical water quality models, and modelling approach was its method in climate change studies. Particular attention was paid to the impacts on eutrophication and hydrological conditions in lakes. On the basis of this background CETEP has good possibilities to develop adaptation strategies which are based on quantitative scientific estimations of the impacts of climate change. Cooperation is carried out with the Finnish Environment Institute (SYKE) that is today responsible for research into climate change impacts.

One of the most important topics of adaptation to climate change in Tampere region is the change of discharges and water levels. The watercourse of the river Kokemäenjoki is mostly regulated and the regulation strategies must be re-evaluated. Particular attention must be paid to possible floods and droughts, damages caused by the floods to buildings, agricultural fields and roads. Preliminary results of the impacts of climate change on discharges and water levels in the drainage basin have been calculated by SYKE. A preliminary investigation of the needs to change regulations in Tampere region will be carried out at CETEP in 2010.

Another important issue on which climate change will have great impact is water management planning according to the European Water Framework Directive (WFD). CETEP is responsible for the implementation of the WFD in its region. Climate change will have many kinds of impacts on lakes which must be taken into account in planning the programmes of measures for the different catchments, as expressed e.g. by Frisk and George (2010). In future climatic conditions the leaching of nutrients will change, partly due to changed hydrological regime, partly due to changed land use and agricultural practices. One question that has to be addressed is the extent to which the reference conditions used to define the ecological status of waters will need to accommodate the changing background conditions. Colour of waters which is one of the main criteria in the typology of lakes will change along with increasing leaching of humus from the catchments. The impacts of climate change will occupy an increasingly central position in water management planning also in Tampere region.

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# CLIMATE CHANGE IMPACTS ON HYDROLOGY AND ADAPTATION NEEDS RELATED TO WATER RESOURCES MANAGEMENT IN NORWAY

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Climate change, in particular increasing temperatures and changes in precipitation, will significantly alter regional and local hydrology, which in turn will lead to potential impacts that must be accounted for in the planning and management of water resources. Although Norway is regarded as a country with a high capacity for adaptation, there is nevertheless a need to develop strategies which will avoid putting human lives at risk and will minimise economic losses. Adaptation may also be required to utilize the potential benefits of changes in climate and hydrology

A Select Committee, constituted by the Norwegian government in December 2008, is presently working on a report on Norway's vulnerability to climate change and needs for adaptation. The committee consists of 17 experts from national authorities and research institutions, and the Norwegian Water Resources and Energy Directorate (NVE) is contributing to this report. In addition, NVE is currently developing a more detailed adaptation strategy with respect to how climate and hydrology will affect water management and associated needs and possibilities for adaptation

As a basis for considering appropriate climate change adaptation strategies, the Select Committee commissioned a study compiling available knowledge about observed and projected changes in climate and hydrology (reported in Hanssen-Bauer et al., 2009). It is anticipated that temperature will increase in all seasons during the year throughout the country. Increases in precipitation are also expected, particularly during the autumn, winter and spring. Summer precipitation, however, may decrease in some parts of the country. Local extreme precipitation events are expected to become more frequent in all seasons throughout the country. Annual river flow will generally increase, but increases will be largest in the winter and spring seasons due to the combined effect of increasing precipitation and a larger portion of winter precipitation falling as rain, rather than snow. River flow in the autumn is also expected to increase in large parts of the country due to increased precipitation during this season. Summer river flow, however, will decrease in large parts of Norway, particularly in the southeast, reflecting both decreases in precipitation and increased evapotranspiration. As a result summer droughts will become more severe in these regions. Spring snowmelt floods are expected to decrease in the major rivers where snowmelt is the dominant flood generation process. In rivers currently dominated by rainfall floods, floods are expected to increase in the future. In particular, smaller tributaries will yield more frequent rapid, and possibly, flash flooding caused by localised cells of intense precipitation.

Climate and hydrological projections are inherently associated with uncertainty. However, despite differences in the magnitude of projected changes, the direction of changes in climate and hydrology are clear and, hence, there are no grounds for delaying progress towards adaptation. An important part of an adaptation strategy, in fact, is an assessment of how this uncertainty should be taken into account.

Adaptation strategies consider a number of issues such as awareness rising, capacity building, allocation of responsibility, planning processes, amongst others. Here, adaptation directly related to changes in climate and hydrology and their implications for water resources management is discussed. In general, if the planning horizon is short, *i.e.* 10-20 years in the future, it is recommended that historical climate and hydrological records are used as a basis for planning decisions. For long-term planning, *i.e.* towards the middle and end of this century, updated climate and hydrological projections should be used. However, because of the uncertainty in specifying the magnitude of anticipated changes, pragmatic approaches, which can be used in practise, are needed.

In this paper, we present an example of an adaptation strategy based on the application of climate scenario projections in flood risk management. The Norwegian Water Resources and Energy Directorate (NVE) is currently evaluating how to respond to projected changes in flooding with respect to flood inundation maps and their use in areal planning. Hydrological projections, derived from several climate scenarios in conjunction with hydrological models, form the basis for the assessment. Six climate scenarios for the period 2071-2100, together with multiple HBV models for individual catchments, were applied to estimate likely changes in the 200-year flood, relative to a 1961-1990 reference period. The hydrological projections are used to distinguish regions and catchments in which flood magnitudes are expected to increase in the future (due to increased rainfall) from those areas which are likely to experience a decrease in the magnitude of the 200-year flood (due to a continued dominance of snowmelt floods in the future). In addition, changes in the occurrence of rainfall vs. snowmelt floods in the annual series between the reference and future period have also been considered (Lawrence, 2010), and regions where the dominant seasonality and flood generation mechanisms may be altered under a future climate have been identified. Regions where the largest increases are projected have been prioritised for further study, and more conservative building restrictions along the rivers in these regions can be expected. The example illustrates how, despite their underlying uncertainties, climate and hydrological projections can be applied in the development of pragmatic approaches to adaptation which will help to ensure that society minimises its vulnerability to climate change.

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# IMPACTS OF CLIMATE CHANGE ON HYDROLOGY AND LAKE REGULATION IN OULUJOKI WATERSHED

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Oulujoki watershed is located in central Finland and has an area of 22 900 km$^2$. The watershed includes two main river routes flowing down to a large central lake, Lake Oulujärvi, from which the water flows downstream through River Oulujoki to the Bothnian Bay. The climate change is estimated to increase the annual mean temperatures by 2-4 ºC and precipitation rates by 5-20 % in Oulujoki watershed by the middle of the 21$^{st}$ century. This will change the seasonality and the magnitude of inflows to the lakes and river routes. In this study the possibilities to adapt to these changes by adjusting current regulation practices in regulated lakes are estimated by taking into account the lake recreational use and flood protection.

The effects of climate change on the inflows and water levels of the regulated lakes in Oulujoki watershed are simulated by the Watershed Simulation and Forecasting System (WSFS). The WSFS is based on a conceptual hydrological model and it is used for watershed forecasting and research purposes in Finland (Vehviläinen et al., 2005). The effect of climate change is transferred to the hydrological model by delta-change method. The monthly mean temperature changes between reference period (1971-2000) and future period (2040-2069) are added to the observed temperatures of the reference period taking into account the possible changes in temperature distribution. The precipitation changes (in percentages) are multiplied in a similar way to the observed precipitation rates. The inflows, outflows and water levels of the main lakes and discharges in River Oulujoki power plants are simulated for the future period 2040-69 and compared to the simulations of the reference period. Altogether 17 different climate scenarios are used including 4 global climate models (GCM), 4 regional climate models (RGM) and 3 emission scenarios.

The lake regulation in WSFS is done by the regulation table, in which the outflow of the lake depends on water level and time of the year. The tables are fixed to follow the current regulation rules and practices. In the climate change simulations the regulation tables are first slightly modified to operate more reasonably in the changed climate, but the current regulation rules are still followed. In the second simulation the lake regulations are adjusted to diminish negative consequences of the changed hydrological conditions.

Veijalainen et al. (2010) have studied the impact of climate change to 100-year floods in unregulated part of river routes upstream from Lake Oulujärvi. The results showed that most of the floods will still occur in spring and the magnitude will decrease significantly by the end of the century. The main concern in the regulation planning of the regulated lakes in upstream river routes will focus on spring draw down of the water levels, which should be lowered and made earlier due to shortening snow season and decreasing snow accumulation. Slight improvements are required in current regulation rules to keep the summertime water levels in satisfying height for recreational purposes.

On contrary to regulated lakes in upstream river routes the regulation of Lake Oulujärvi will be more challenging in the future. The increasing precipitation rates in autumn and winter together with later onset of winter and occasional snow melt fill up the lake close to regulation limits. The increased inflows in winter would require almost twice as large maximum discharges as used in the reference period. The estimated magnitude of 100-year floods would increase 5-35 % in the River Oulujoki, if the current regulation rules and practices were followed. The maximum discharges in River Oulujoki could be decreased about 15 % by lowering the water levels of Lake Oulujärvi early in autumn approximately 40 cm below the currently typical water levels. In addition, the current draw down in spring should be lowered about 50 cm, so that the water levels can be raised to summertime target limits for lake recreational use.

The effects of climate change in Oulujoki watershed are quite similar compared to other large watersheds with high lake percentages in Finland. In the upstream river routes the spring inflow peaks and largest floods will decrease significantly. However, the increased precipitation rates in autumn and winter fill up the large central lakes, in which the delay of the inflows is much longer than in the upstream lakes. This leads also to increased discharges in downstream rivers. The similar impact is described by Veijalainen et al. (2010) for watersheds of Vuoksi, Kymijoki and Kokemäenjoki. The increased discharges due to climate change in River Oulujoki can be decreased to some extent by changing the regulation practices, but the largest floods are still estimated to increase 0-15 % depending on used climate scenario.

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Veijalainen, N., Lotsari, E., Alho, P., Vehviläinen, B., and Käyhkö, J. 2010. National scale assessment of climate change impacts on flooding in Finland. Submitted to Journal of Hydrology.

# MODELLING HIGH RESOLUTION DISCHARGE DYNAMICS NEARBY ROAD STRUCTURE, USING DATA FROM SMALL CATCHMENT AND 3 DIFFERENT MODELS

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The climate change may lead to an increase in the frequency of extreme precipitation events and floods as well as changes in frost/thawing cycles. This will have impacts on the performance and life time of road infrastructures. The frequency of road closures and other incidences will probably increase. Stronger demands will be placed on the function of road drainage and dewatering systems.

This paper is based on an ongoing collaboration with ClimRunoff project financed by the Norwegian Research Council and driven by Bioforsk in Norway. The results from this cooperation will be used in the research project financed by the Swedish Road Administration named "Adaptation of road drainage structures to climate change".

This study has started with the focus on quantifying discharge of catchment areas draining towards roads. The first priority of this study is to create a model that can evaluate the run-off situations under spring situation (i.e. overland flow due to snowmelt and partially frozen soils). This modeling study has just been carried out for a small agricultural catchment in Norway using 3 different models (Mike She, LISEM and CoupModel). This study aims at:

- Evaluation of suitable hydrological models to quantify the spring discharge
- Identification of problems with available data and models to quantify the role of climate impacts
- Identifying the specific role of groundwater and surface runoff to the discharge dynamics

The models evaluated differ with respect to aggregation level (time and space) and representation of the hydrological processes within the watershed. Especially winter related processes as snow accumulation, melt and infiltration into partially frozen soils are discussed.

# ICE REGIME OF LATVIAN RIVERS IN THE 20TH CENTURY

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Ice on the rivers of Latvian territory is present during 2.5 months on average. It has serious hydrologic impacts, including winter and spring flood events caused by ice jams, a low winter stream flow and related ecological and water quality consequences. Data series analysis shows the sensitivity of the ice regime to changes in climatic conditions. The trends of the freeze-up and break-up timing are consistent with changes in air temperature. An important question is what impact climatic change will have on the frequency and severity of extreme ice jams and low flows.

Saldatova (1993) reported on changes in river ice conditions on the former Soviet Union territory (FSU); for the European part of the FSU the freeze-up delayed from 7 to 10 days per 100 years. Several Latvian studies examined trends in the river ice freeze-up and break-up. Oganova et al. (1969) identified "marine" and "continental" regions. The spatial distribution of the AFDD (accumulated freezing degree days) among Latvian territory confirms this interpretation. The ice cover formation on rivers is usually interrupted by thaws, especially in the "marine" region of the Latvian territory where winters are much milder. The thaws there last up to 55 days. Thaws in the "continental" region observed during a winter season are shorter than 30 days. The air temperature during the thaw rises to 8-10 ºC.

The aim of the present study is to examine the ice regime of Latvian rivers, and to identify recent trends that may be linked to climatic variations.

Temporal differences in the ice regime of Latvian rivers link to the climatic variables namely air temperature.

For analysis 13 daily air temperature data series for the period 1926-2008 and 28 freeze-up, break-up and ice cover duration annual data series from 1920 to 2008 were used. The winter flow data series were defined as a series of the 30-days average water runoff for the winter (DJF) low flow period.

Analysis of the spatial distribution of the changes in the ice regime parameters and the accumulated freezing degree-days within Latvian territory was made on a 3 km grid.

Magnitude of trends in the timing of freeze-up and break-up, and the ice cover duration as well for the period 1920-2008 and in the slash and ice jams duration for the period 1977-2008 is expressed by slope of the Kendall – Thiel Robust Line.

For evaluating changes in the relationship between the ice cover duration and the AFGG data were normalized with reference to the period 1961-1990, by subtracting the mean and dividing with the standard deviation.

There is a strong relation between the water flow and the ice regime parameters. The integrated curves method is used for the analysis of low flow and ice cover duration cycle variations.

In accordance with the AFDD distributions within Latvian territory the temporal changes in the data series of the ice regime phenomenon were calculated for two regions: "marine" with the AFDD from –200°F-days to –500°F-days and "continental" with the AFDD from –500°F-days to –1000°F-days.

The trend analysis of the freeze-up data series shows 9-12 days/89 years delay an average and almost no differences between "marine" and "continental" regions.

In the trend results of the ice break-up data series this difference is significant. An advance of the break-up is 19 days/89 years in the "marine" region and 29 days/89 years in the "continental" region. Ice cover duration for the 89-year period became shorter by 46 and 37 days accordingly.

Spatial distribution of the timing of the freeze-up and break-up timing and the ice cover duration as well displays meridional character. Local factors such as the river basin, morphology and water runoff exert influence on the ice regime.

The dot analysis of the winter seasonal (DJF) air temperature data series and ice cover duration shows more rapid changes in last three decades than previously.

The trend results of the 0°C isotherm data series that was created for Riga Station using the 31-days running mean is 5 days/80 years delay in autumn and 19 days/80 years advance in spring. However for the last three decades the 0°C isotherm in spring advanced by 9 days and by 1 day delayed in winter.

Information about ice and slush jams under ice cover was analysed for the period 1977-2008. Evidently the warmer winter season leads to later solid ice cover formation and as a result increases in the slush jam events. At the same time the slush jam duration is decreasing. The ice jams analysis shows a significant decrease of ice jam frequency that is caused by decreasing ice thickness and increasing winter low flow due to the climatic changes.

The volume of the water runoff under ice cover strongly depends on the groundwater contribution to river flow. If it is small and the ice cover period lasts a relatively long time the water runoff deficit becomes critical. The winter water availability can be a limiting factor for a number of aquatic populations (Prowse, 2000).

According to the integrated curve parameters the ice cover duration and the winter low flow are inversely proportional. From 1980 the ice cover data series shows a decreasing trend and the low flow data series an increasing trend. The winter low flow data series has a very significant positive trend for the period 1925-2008. The decreasing ice cover duration leads to an increase in the winter low flow; the data series has very significant trend for the period 1925-2008, the slope of the trend is 2,0 l/sec*km$^2$ per 84 years.

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# VARIABILITY OF RUNOFF REGIONAL SERIES IN THE BALTIC COUNTRIES

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Precipitation, air temperature and river discharge are the most important hydro-climatological variables for planning of human activity. At the same time all these parameters are characterized by very high variability in space and time. The Baltic Sea drainage basin is one of the regions where variations of climatic and hydrological parameters are well investigated (Lindström et al., 2006). There are many atusiwa going on river runoff changes and variability in the Northern Europe including the Baltic States (Hisdal et al., 2007; Reihan et al., 2007). However due to recent changes in land-use and water use patterns the regionalization of main meteorological and hydrological parameters for the all Baltic States is still absent.

Although the territory of Baltic countries (Lithuania, Latvia, Estonia) is not large (175000 km$^2$), climatic differences are quite considerable. The amount of precipitation varies from 850 mm per year in the uplands of Latvia to 560 mm per year in the central Lithuania (Reihan et al., 2007). The hydrological regime of the Baltic rivers depends not only on climatic factors (temperature and precipitation), but also on geomorphology, geology, land use type and soil structure. Depending on the hydrological regime, rivers in the Baltic region could be grouped into 3 major types – marine, transitional and continental. The main source of feeding of marine type rivers is precipitation. The snowmelt water rate is almost equal to the groundwater for continental type rivers. Regionalization of territory of the Baltic countries is needed for description of precipitation, temperature and river runoff patterns.

The main task of this study is to investigate variability of long-term regional data series of temperature, precipitation and runoff in the Baltic States. Comparison of the all regional series was done for period of last years (1991-2007) and past years (1931-1960) with data of reference period (1961-1990). Analysis of cyclic variations of the regional runoff time series was done for all Baltic countries.

The objects of research are long-term regional series of temperature, precipitation and runoff compiled for 10 hydrological regions: Western, Central and Southeastern Lithuania; Western, Central, Southeastern and

Northeastern Latvia; Western, Northern and Eastern Estonia. Long-term series of temperature (49 stations), precipitation (72 stations) and runoff (64 stations) were used for composition of regional series in the Baltic countries. Regional series were developed on monthly, seasonal and annual bases.

Precipitation and runoff were normalized by division with mean values of reference period of 1961-1990, whereas temperature was normalized by subtraction with the mean and division of the standard deviation. The regional series are estimated as the average of the standardized individual series.

Changes of regional series are determined comparing reference period with periods of 1991-2007 and 1931-1960. There are no big differences of annual and seasonal air temperatures comparing the series of past years (1931-1960) with reference period. The increase of annual and seasonal temperature was determined in all regions of the Baltic countries for period of last years (1991-2007) comparing with data of reference period. Temperature anomaly above the reference level depends from geographical position of regions. Annual temperature increased to 0.8 ºC in north of Baltic countries (Estonia) and to 1.1 ºC in Lithuania.

The anomaly of regional runoff series depends from type of climate (marine or continental) and sources of river feeding. The annual runoff was insignificantly higher in 1991-2006 comparing with the reference period in all regions except Western and Northern Estonia. There was increasing of winter season runoff in last years (20 – 60 % comparing with reference period) for all regional series. Decreasing of spring season runoff (10 – 20 %) was fixed in the Western regions of all Baltic countries (marine climate zone) but there were no changes of spring season runoff in the continental part of countries (Southeastern Lithuania and Latvia, Eastern Estonia).

The cyclic variations in the regional runoff time series are typical for all Baltic countries. Using periodogram method we determinated most reliable period of cycles. There was described three cycles in the long-time regional runoff series. Durations of the cycles of rivers' runoff are similar for all regional series only with the exception when dry and wet periods can differ in 1-3 years in different regions. The average period of the cycles is 27 years, including the average wet period of 13 years and the dry period of 14 years. The mostly wet period of the rivers runoff was in 1977-1991 and the driest period was in 1963-1977 for all regions. The last period (1997-2007) of cyclical variation of the river runoff would be the dry period. Through the river runoff of all regional series were smaller only by 2-4 % comparing to multi-year average. The reason of this small decreasing could be increasing of temperature and positive changes of precipitation in 1997-2007.

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# RECENT REDUCTION OF SEA ICE IN THE ARCTIC AND DECREASE OF MAXIMAL ICE THICKNESS ON LAKE BAIKAL

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We compare published data on sea-ice area in the Arctic and the characteristics of the ice regime on Lake Baikal, their actual state and trends towards 2100. In the Lake Baikal area, warming rates are more than two times higher than the global average and approximately 30% higher than in the Arctic (Kuimova and Sherstyankin, 2008). Average annual air temperatures greatly influence conditions for ice formation in the areas considered, and increased warming rates cause an intensive reduction of sea-ice area and average ice thickness in the Arctic. At Lake Baikal, the freeze-up period has shortened and the maximal ice thickness has decreased by 15-24 cm according to observations at different sites over the period 1950-2009.

Reduction of sea-ice thickness in the Arctic accelerated in the 1970s. A considerable decrease of Arctic ice thickness is observed in different areas (Chukotsky Cape, Beaufort Sea, Canadian Depression, North Pole, Nansen Depression, East Arctic), and the ratio of ice thickness in 1993–1997 to 1958–1976 was on average 0.58 (Rothrock et al., 1999).

On Lake Baikal, the ratio of maximal ice thicknesses in 2005 compared with 1950 at different lake sites (Listvyanka settl., Tankhoy settl. (near Babushkin Town) – Southern Baikal; Bol'shoy Ushkaniy Island and Nizhneangarsk Town – Central and Northern Baikal) varied from 0.75 to 0.84, its average value was 0.81. Extrapolated linear trends for periods from 1950 till 2008 and from 1970 till 2008 show values of maximal ice thickness in 2100 equal to 53 and 31 cm with a slope of 26 and 47 cm for 100 years, respectively, and the ice will remain on Lake Baikal as a seasonal phenomenon.

As far as it is known, the present situation in the Arctic is variable. E.g., according to satellite images, the Northwest passage in the Arctic Ocean was open in August 2007 but in 2008, due to complicated sea-ice conditions, Russian border guards had to performan aircraft survey instead of a naval one. On Lake Baikal, simultaneously with the Arctic change, maximal ice thickness also increased in 2008 compared to 2007 by 28 cm on average. This change was within interannual variations. According to linear trends, $T_{air}$ on Lake Baikal in 2008 reached ca. 1.5°C, while the warmest Eemian Period (125 ky BP), according to our estimates, it was equal to 2°C, and for present-day conditions, it will probably reach the same values or even exceed them.

It is interesting that numerous researchers, evaluating climatic scenarios of warming, especially those induced by humans, support an opposite point of view. We will mention only a forecast predicting a rather deep minimum of solar activity by $2040 \pm 10$ comparable to the Maunder minimum (1645-1715), resulting from a quasi- 200-year cycle (Abdusamatov, 2006).

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# RESEARCH OBJECTIVES AND ADVANCES IN DEVELOPING ADAPTATION STRATEGIES IN THE CZECH REPUBLIC

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The Czech Republic has been involved in studies of possible impacts of climate change on water cycle and lately on water resources since the early nineties of the last century. The first estimates of the possible climate change impacts were derived from the results of the CR participation in the US Country Studies Programme (1995-1996) and subsequently this problem has been addressed in a number of national and international projects (FRIEND, ASTHyDA, WATCH).

Further research needs were initiated by the implementation of Directive 2000/60/EC of the European Parliament and the Council establishing a framework for Community action in the field of water policy and by the fact that the consequences of climate warming have already been reflected in serious water scarcity problems in some of the basins in the Czech Republic.

The new projects addressing these problems have been sponsored mainly by Ministry of Agriculture, which focused its research needs on assessing availability of water resources to meet the water demands in current conditions and those affected by climate change, and Ministry of the Environment, whose research intentions included the development of models for assessing impacts of climate change on water cycle components and water resources, the development of climate change scenarios for the Czech Republic and a number of other topics, such as climate change impacts on stream water temperature or on occurrence and severity of drought.

Most of these projects have been carried out by Department of Hydrology of T.G.M. Water Research Institute, p.r.i. (Prague) and specific results have been presented in proceedings or publications from a number of international events (e.g. Novický et al., 2009a, 2009b, 2010). The presentation reviews the ongoing research projects and summarises their objectives and preliminary results.

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# URBAN HYDROLOGICAL CLIMATE CHANGE IMPACT ASSESSMENT: SOME SWEDISH EXPERIENCES

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Changes in the climate can potentially greatly impact urban hydrological processes and thus the functionality of e.g. sewer networks and waste-water treatment plants (WWTP). The main issue is likely the anticipated changes in the precipitation pattern towards larger amounts during winter and possibly higher short-term intensities during summer. Also an increased temperature may have an impact, e.g. by changing the character of snow-melt processes in northern latitudes as well as causing an increased evapotranspiration that may partly offset an increased precipitation.

To assess and quantify the impacts is a difficult task for different reasons. One is the small-scale nature of urban hydrological processes that requires a very high resolution in both time (minutes) and space (single km$^2$) in analysis and modelling. Regional climate models, that are the main tools for estimating future changes, however generally operate on temporal scales of ½-1 hr and spatial scales of 25-50 km$^2$. Further, the model results are associated with uncertainties and systematical errors that have to be treated before applications in hydrological modelling (e.g. Yang et al., 2010). Another difficulty is related to the fact that cities are not static but in constant, and often rapid, development. These changes, such as population increase and densification, are potentially at least as significant as climate changes.

During the last few years SMHI has been involved in a number of research projects focusing on urban hydrological climate change impact assessment. The main tasks has been to (*i*) analyse climate model projections at their highest possible resolutions in time and space and (*ii*) develop methods for generating urban hydrological model inputs that reproduce the changes found in the projections. In collaboration with external partners, such input has been tailor-made for urban model set-ups in different Swedish cities, e.g. Stockholm, Arvika and Kalmar. The work has involved both long-term continuous data as well as short-term design rainfalls (e.g. Olsson et al., 2009). The subsequent hydrological modelling has focused on issues such as surface flooding, WWTP inflows and sewer overflows.

In this presentation, the methodologies used in analysis and input data generation will be described and illustrated by examples from the cities investigated. Key results in terms of urban hydrological impacts will be reviewed and future prospects discussed.

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# RIVER RUNOFF PATTERNS UNDER CHANGING CLIMATE CONDITIONS IN LATVIA

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Contemporary it is not only very important to evaluate the existing water resources, but also to forecast the changes in the future. Water resource availability is related to the energy and water consumption sectors, agriculture, forestry, physical planning and human safety, either the future of various ecosystems in the particular region. That is why different projects and programmes are developed in many countries. The aim of this study is to carry out a simulation of hydrological processes in different river basins and to forecast climate change impacts on river runoff patterns in Latvia.

This paper addresses: (1) the results of the hydrological IHMS-HBV model calibration and validation for four different river basins in Latvia, and (2) the analysis of changes in hydro-meteorological data series in projection of future climate.

The hydrological model IHMS-HBV is developed in Swedish Meteorological and Hydrological Institute (Bergström, 1976). As input data for the model daily measurements of air temperature ($^{o}$C), precipitation (mm) and monthly average evaporation (mm) at twelve meteorological stations and daily river discharge ($m^3/s$) of four hydrological stations, were applied. The IHMS-HBV model was calibrated and validated for the following different river basins: the Salaca (drainage area A=3220 $km^2$), the Bērze (A=904 $km^2$), the Iecava (A=566 $km^2$), and the Vienziemīte (A=5.92 $km^2$). The calibration period was selected from 1961 to 1990 and validation period – next ten years from 1991 to 2000.

The results of the model calibration showed a good coincidence between the observed and simulated daily discharges. The Nach-Sutcliffe efficiency $R^2$ varies from 0.82 to 0.70. The best coincidence was obtained for the River Bērze, and the lower – for the River Salaca. We obtained lower statistical criteria for the model validation period comparing with calibration period. The Nach-Sutcliffe efficiency $R^2$ varies from 0.76 to 0.69.

For the simulation of river runoff according to past and future climate conditions we have used climate data series (daily mean air temperature, precipitation and vapour pressure deficit) provided by another study (Seņņikovs and Bethers, 2009) of the national research programme KALME. In this study the run of 21 regional climate models within the framework of the European Commission research project PRUDENCE, (Jacob et al., 2007) was analysed. The regional climate model RCAO run by the Swedish

Meteorological and Hydrological Institute (driving boundary conditions from the global climate model HadAM3H) was selected as it is most suitable for the area of our interests, i.e. Latvian conditions. The calculations were further statistically downscaled using the histogram equalisation method for the bias correction in the moving time-frame. The calculated data series denoted the following: CTL represents the control period 1961-1990 and characterises past climate conditions, while A2 and B2 represent the period of future scenarios 2071-2100 and forecast future climate conditions. All data series were extrapolated from the grid cross points to the meteorological station involved in our study.

Compared to the control period, the major differences in meteorological parameters in the studied river basins were observed according to A2 scenario, where the annual mean air temperature will increase by 4 °C and precipitation by 12 %. The analysis of the extreme values shows that the annual minimum temperature is forecasted to increase at a rate above the annual maximum temperature, on average by 5 °C according to A2 and by 4 °C according to B2, respectively. At the same time, the duration of growing season, when the daily mean temperature exceeds 5 °C, will increase from 35 to 40 days according to A2 scenario and from 31 to 35 days according to B2 scenario.

The long-term seasonal analysis showed the following results: the mean air temperature will increase in all seasons, but the most considerable increase is forecasted for the winter and autumn seasons by 4.1-4.9 °C according to A2 and 3.0-3.4 °C according to B2. Similar significant changes in seasonal patterns can be forecasted for the mean maximum and minimum air temperature for both scenarios, although the maximum temperature is going to increase at a higher rate during winter and minimum temperature – during autumn season. Increase in precipitation is observed in winter season by 7-9% according to A2 and by 4-5% according to B2, while the decrease – over the second half of the year, especially in autumn by 4-5% according to A2 and by 2-4% according to B2. We define heavy rainfall as precipitation in excess of 10 mm per day. The number of days with heavy rainfall will increase from 32 to 107 according to A2 scenario and from 20 to 84 according to B2 scenario.

Simulation results showed that according to A2 scenario, total river runoff could decrease by 11–20 %, and according to the B2 scenario by 9–11 %. Analysis of the river runoff by seasons shows an increase in the runoff by 13.0–25.6 % according to A2 and 3.3–9.8 % according to B2 scenario in winter. However, a decrease is observed in the spring season (6.2–13 % according to A2 and 5.3–8.5 % according to B2 scenario) and the autumn season (3.0–10.3 % and 3.1–7.9 % respectively). The considerable runoff decrease is observed in the basin of the river Bērze. A small decrease of runoff 0.6–3.4 % according to A2 and 0.1–2.8 % according to B2 scenario might be expected in summer. A low decrease of runoff is expected by both scenarios in the Vienziemīte river basin.

In the study period from 1961 to 1990, it was typical that the major portion 35–42 % of the total annual river runoff occurs in the spring season, and then it is followed by 20–30 % in winter, 20–21 % in autumn and 14–19 % in summer. The analysis of the simulation results from 2071 to 2100 shows that in the case of future climate scenario A2 the major portion of the total annual river runoff 41–50 % will be generated in winter, and then it will be followed by 26–29 % in spring, 12–17 % in autumn and 12–15 % in summer. Also in the case of the scenario B2, the major portion of the total annual river runoff will be generated in winter 32–39 %, then it will be followed by 30–35 % in spring, 16–18 % in autumn and 13–20 % in summer.

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# TEMPORAL VARIATION OF SPRING FLOOD IN RIVERS OF THE BALTIC STATES

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Under current climate change conditions, extreme flood events become an increasingly threating hazard in terms of risk and damage potential. Therefore, forecasting and managing floods is the key issue of protection systems. However, forecasts still include some level of uncertainty. The uncertainty maybe controlled and managed if good hydrological data and statistical analysis is used for prediction of lood hazards for a long time period. Fortunately, Baltic states have a long time series hydrological data that make it possible to estimate flood frequency and their tendency for the last 80 years. Snow melting and ice jams result in the rise of water level in the upstream. Spring flood is a very significant hydrological phase of rivers in Baltic states. Last several years were marked by floods wave with multipple peaks that created additional difficulties in managing floods.

In this research, the timing of spring flood in rivers of the Baltic States is statistically analysed. The Mann-Kendall test and the nonparametric Sen's method (Helsel and Hirsch, 2002) for the magnitude of the trend were used to detect trends in time series for different periods. To estimate frequency of floods, Gumbel distribution was used. The main parameters such as flood duration and frequency, runoff volume, runoff peak, and its time of spring flood are evaluated for all the Baltic countries. The assessment of spring flood parameters was done for three different periods (1923–2007, 1941–2007 and 1961–2007). Maximum spring water discharges with the date of its observation from 69 hydrometric measurement stations were used for this analysis. There are three common hydrological regions in all Baltic states based on the annual runoff distribution: marine, transitional and continental. The regions in this research were more appropriate to spring floods regionalisation, it allows to estimate floods for ungauged catchments using an index flood method. Lakes, forests and soil type and of the basins have the biggest impact on the volume and duration of floods. These elements regulate the runoff, decreasing the maximum discharges and flood height and prolonging runoff duration. Despite of significant differences in area covered by the wetlands in all Baltic countries (from 8% in Lithuania to 40% in Estonia) this factor impact on the flood parameters is minor.

The spring flood maximum discharge has decreased and its fluctuation from year to year has decreased as well. Trends were negative significant and weakly significant only for the 1923-2007 and 1941-2007 periods. The period of 1961-2007 had the same negative tendency, but trends were not significant. It could indicate that spring flood maximum discharges are becoming more stable with a more uniform shape of hydrograph within a year. There were no maximum discharges over 1% probability observed during the last 70 years and over 5% – during the last 50 years.

Dates of spring flood peaks were moved to earlier times in a year. However, for the periods 1941-2007 and 1961-2007 spring flood changes were insignificant with a more stable distribution. The tendencies of maximum discharge timing are similar in all Baltic states (Meilutytė-Barauskienė and Kovalenkovienė, 2007; Klavins et al., 2002). Everywhere trends are definitely negative, i. e.maximum discharges are observed earlier and earlier (because of warmer winters). Spring flood duration is decreased. The contribution fraction of spring season runoff to the annual runoff has decreased by 3% –5% on the average (up to 10% in some regions). There is no significant trends found in spring flood volume, however the tendency was negative. All these changes could be caused by increasing ambient temperature and precipitation in the last decades.

On the one hand, decrease in spring runoff is good for the designing and construction of road bridges and culverts whose cost will decrease. A more evenly distributed river flow throughout a year will lead to a profitable situation for the hydropower industry; it is also good for water level regulation against floods and droughts. However, on the other hand, the earlier and shortened spring and the longer low flow period after spring may deteriorate water quality and have a negative impact on aquatic habitats. Thus, all these changes should be taken into account for an optimal management of water resources to prevent possible risks and to ensure the sustainability of water ecosystems.

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# PREDICTING THE INFLUENCE OF CLIMATE CHANGE ON POWER PRODUCTION IN UPPER GLOMMA RIVER BASIN

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Kuråsfossen hydropower plant is situated by the Aursunden reservoir in the upper Glomma basin and is operated by Glommen's and Laagen's Water Managements Association. The average annual production is about 61 GWh/year. The modelling tool Mike11 has been used for simulating the operation of the Kuråsfossen hydropower plant and the Aursunden reservoir in the upper Glomma basin. By use of logical operators, the operating rules have been represented in the simulation model. The logical operators are used for selecting the different runoff regimes according to the given regulations for the reservoir stated in the licence.

The regulations state the highest regulated water level depending on the season, flood discharge handling, environmental flow requirements, and winter discharge before and after establishment of a stable ice cover and change rate of runoff during the winter season among others.

The simulation model established in Mike11 is verified by use of observed in-flow to the reservoir. The model shows good agreement between the simulated and observed runoff from the reservoir and corresponding power production.

The HBV hydrological simulation model has been calibrated for simulating the inflow to the Aursunden reservoir. A delta change approach has been used for predicting the future climate for the 2021-2050 and 2071-2100, with 1971-2000 as the control period.

The simulated inflow has been routed trough the reservoir and the power production calculated based on the existing operating rules for present and future climate. The production figures and flood loss is presented for the present and the future climate. Suggestions for changes in operating rules for a better adaption to the future climate are presented.

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# LONG-TERM CHANGES OF LOW FLOW IN LATVIAN RIVERS

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Lately climate change impacts on rivers' hydrological regime have been extensively studied world-wide. At the turn of the century observations indicatean increase of air temperature and precipitation during the cold period of the year, a decrease in days with snow cover and ice occurrence and an increase in droughts during the summer and autumn. Therefore, changes in weather patterns – air temperature, precipitation, etc. – have affected the river hydrological regime and water resource availability, especially in the low flow period.

In Latvia, rivers are characterised by a typical hydrograph: two main discharge peaks – during the spring snowmelt and in late autumn during the intensive rainfall, and low river discharge – in winter and summer. In comparison with the warm period higher discharges are observed during the cold period of the year. It is typical that the major part of the total annual river runoff is generated in the spring season, then followed by winter, autumn and summer. Despite the fact that Latvia is a comparatively small country, climatic and hydrological conditions can be differing in different parts of the country. In warm winters, low river discharges are not observed in the Western district. For this district, a comparatively shorter ice cover period is observed and spring floods begin earlier. There is a greater impact on the river discharge regime from meteorological processes occurring over the North Atlantic and the Baltic Sea than for other districts in Latvia, particularly comparing the to Eastern part. This tendency changes from West to East. The aim of the study was to determine the long-term changes of the low flow patterns for the cold and warm periods of the year in Latvian rivers.

Data series of daily discharge from 1951 to 2008 registered by twenty eight hydrological stations were used in this study. The low flow periods were defined as a series of the 30-day minimum discharge in a cold period ($Q_{30cold}$, December – February) as well as warm period ($Q_{30warm}$, June – October). The high flow period was characterized by maximal discharge of the year ($Q_{max}$) which was mostly observed in the spring flood period (March – April) and sometimes occurred also in other seasons of the year. The ratios between annual low flow discharge or maximal discharge of the year and annual mean discharge ($Q_{30cold}/Q_{annual\ mean}$, $Q_{30warm}/Q_{annual\ mean}$ and $Q_{max}/Q_{annual\ mean}$) were calculated. The coefficient $d$ of uneven runoff distribution is used to expressthe distribution of river runoff per year. This coefficient is calculated as a deficit to average annual discharge that corresponds to the run-off surplus over the average annual discharge. *d* is termed as a deficit volume and it is indicated a part of river runoff where river discharges have exceeded the average annual discharge. The non-parametrical Mann-Kendall test was used for the data series analysis. The Mann-Kendall test was applied separately to each variable at each site, at a significance level of $p \leq 0.05$. The trend was considered as statistically significant at the 5% level, if the test statistic was higher than 2 or less than –2. In order to interpret the obtained results we used a classification of hydrological districts where the territory of Latvia is divided into four districts: Western, Central, Northern and Eastern.

Regarding low flow periods from 1951 to 2008, the Mann-Kendall test showed statistically significant increasing trends for 30-day minimum discharge ($Q_{30cold}$) of the cold period in 89% of studied hydrological stations. Significant decreasing/increasing trends of the 30-day minimum discharge ($Q_{30warm}$) in the warm period were found only in 6 hydrological stations. A decreasing trend was found for the maximum discharge of the year ($Q_{max}$) in 18 out of 28 hydrological stations.

Similar results were acquired to analyze ratio between annual low flow discharge ($Q_{30cold}$ or $Q_{30warm}$) and annual mean discharge ($Q_{annual\ mean}$) among the three study periods. The ratio $Q_{30cold}$ /$Q_{annual\ mean}$ increased for all studied rivers in the period 1988-2008 comparing with the study period 1951-1987. Ratio was higher for the Western part (about 0.85) and lower – for the Central district (about 0.67). The ratio $Q_{30max}$ /$Q_{annual\ mean}$ decreased also for all studied rivers in the period 1988-2008. The higher difference of this ratio between the studied period of 1988-2008 (ratio 6.5) and 1951-1987 (ratio 10.45) was acquired for the rivers of the Central part, then followed by rivers of the Northern, Eastern and Western parts. The calculated ratio $Q_{30warm}$ /$Q_{annual\ mean}$ did not show any essential changes between studied periods of 1988-2008 and 1951-1987.

The coefficient of uneven runoff distribution *d* expresses the distribution of river runoff per year. Analysis of the Mann-Kendall test showed statistically significant decreasing trends of *d* in 20 out of 28 hydrological stations. Changes in the coefficient *d* were mainly observed in the Central and Northern parts of Latvia.

It can be concluded that from 1951 to 2008 the main long-term changes in low flow are observed for the cold period of the year due to decreased spring runoff and increased winter runoff, particularly in the last twenty years. These changes are mainly determined by the climate changes occurring at the turn of century. The analysis of acquired results shows regional differences in low flow patterns in cold and warm periods.

# UNCERTAINTY OF TEMPERATURE AND PRECIPITATION PROJECTIONS FOR THE FUTURE CLIMATE OF LATVIA

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The aim of this study is to give the projections of the future climate adapted to territory of Latvia. We employed regional climate model (RCM) temperature and precipitation daily time series from the PRUDENCE and ENSEMBLES projects. All of the data sets were bias corrected to the observations of temperature and precipitation for the period of contemporary climate (1961-1990). The bias correction uses histogram equalization method described in (Sennikovs and Bethers, 2009). Observation data from 118 stations from Latvia, Lithuania, Estonia, Belarus, and Russia were used. 21 RCM data sets from PRUDENCE project and 13 data sets from ENSEMBLES project were employed.

The applied bias correction method allows modifying the statistical properties of daily time-series of any RCM for the reference period to match the statistical properties of the observation time-series. The impact of the bias correction method on the projections of the future climate was analyzed. The bias correction does not change the expected increase of the mean monthly temperature and precipitation.

We constructed the monthly averaged projections of the temperature and precipitation for the future climate scenarios A2, B2 and A1B for the territory of Latvia for the time-period 2071-2100. Most probable projections and uncertainty of projections was estimated using inter-model statistics. Data from ENSEMBLES project allowed also estimation of time development of climate projections under scenario A1B for the time period 1961-2100.

The most probable increase of monthly average temperature under scenario A2 from the PRUDENCE project is by 3.2 to 4.9 degrees, increase is larger during the winter period comparing to the summer period. The uncertainty of temperature projections is about 1 to 1.5 degrees. The most probable change of precipitation is up to +60% in winter and about 0 to +10% in summer. The range of predictions is +30% to +90% in winter and –20% to +80% in summer. The temperature projections under scenario A1B from the ENSEMBLES project is by 2.6 to 4.9 degrees with uncertainty up to 2 degrees. The precipitation projections for this scenario are +5% to +70% in winter and –20% to +40% during the summer. The increase in temperature is predicted to be faster for the time period 2030-2100 compared to 1961-2030, while for precipitation it is vice versa.

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Regional climate model data have been provided through the PRUDENCE data archive, funded by the EU through contract EVK2-CT2001-00132. The ENSEMBLES data used in this work was funded by the EU FP6 Integrated Project ENSEMBLES (Contract number 505539) whose support is gratefully acknowledged.

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# THE CLIMATE AND ENERGY SYSTEMS (CES) PROJECT: A SUMMARY OF MAIN RESULTS

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Adaptation to climate change will be a challenge in coming decades. Already, past emission will lead to unavoidable climate change and impacts become more pronounced as the scope of climate change increases. In all sectors of the economy, vulnerability to climate change must be assessed and strategies adopted to deal with the impacts.

The renewable energy sector tends to be affected by uncertainty due to temporal variability in the resource. Strategies to deal with this uncertainty are typically based on analysis of historical data. For this sector a key issue regarding climate change is therefore that the past may no longer be a reliable guide to the future. Some renewable energy resources will likely increase their productivity while others may not. In either case changes in the seasonal and geographical patterns of production and demand will need to be managed, and likewise, disturbances and costs due to possible changes in extremes such as floods, droughts, or storms need to be dealt with. Furthermore, since the electricity from the different resources is exchangeable, climate change impacts in this sector must be examined for all resources, i.e., a project examining the impact of climate change on the energy sector has to take the energy system into account as well as the different resources.

For the Nordic energy sector these impact studies are done under the auspices of the Climate and Energy Systems (CES) project. This project runs from 2007–2010 and grew out of the the Climate and Energy (CE) research project which ran from 2003–2006, with both projects funded by Nordic Energy Research foundation, the Nordic energy sector, as well as by internal funding by the participants.

The main objective of the CE project was to make a comprehensive assessment of the impact of climate change on renewable energy resources in the Nordic area including hydropower, wind power, bio-fuels and solar energy. To this end scenarios describing climate change for the period 2070–2100 were developed and the implications for renewable resources were examined through systems simulations (Fenger et al., 2007).

The renewable energy sector in the Nordic Countries is quite diverse, and the results of the CE project differed between resources and countries. For hydropower and bio-fuels the impacts on the resource were significant, but less so for wind power and solar energy. In all cases technological and market development are to be expected and in some cases these would be larger than the climate induced changes. On the other hand, in some cases a resource exhibited large climate induced changes overwhelming other factors. A case in point is the hydropower in Iceland, where melting of glaciers could increase the potential production capacity of some rivers by 50%. In all cases the results also showed a strong dependence on the evolution of the energy system. (Fenger et. al 2007).

The goal of the Climate and Energy Systems project is to look at climate impacts closer in time and assess the development of the Nordic and Baltic electricity system for the next 20–30 years. It addresses how the conditions for production of renewable energy in the Nordic and Baltic areas might change due to global warming. It focusses on the potential production and the future safety of the production systems as well as uncertainties. The key objectives are summarized as: 1) Understanding of the natural variability and predictability of climate and renewable energy systems at different scales in space and time; 2) Assessing the risks due to changes in probabilities and nature of extreme events; 3) Assessing risks and opportunities due to changes in production of renewable energy; 4) Developing guiding principles for decisions making in the renewable energy sector under climate variability and change; 5) Development of adaptation strategies and finally 6) A structured dialog with stakeholders.

The project is organized as a matrix structure with four working groups (WG) on renewable energy resources, i.e. Hydropower–hydrological models, Hydropower–glaciers/snow/ice, Biofuels and Wind power groups. Another five WG have been created to work on the interdisciplinary level and cross-cut the renewable energy resource groups; Climate Scenarios, Statistical Analysis, Risk Assessment, Energy System Analysis and Information Management. The four renewable energy groups face same questions on how the resource will be impacted by climate change. This is analysed by using climate scenarios, and depending on the energy source, different types of models will be used for both production and safety analyses.

The year 2010 is the final year of the CES project and since its beginning in 2007 an international team of about 100 scientist and students has annually contributed to the projects's research themes. The results of the project have already been introduced in numerous peer-reviewed papers and reports within the international and national science communities (see publication list at http://en.vedur.is/ces/publications/) and the main results of the project will be introduced at a final conference in Oslo during the summer of 2010 (http://www.nve.no/CES2010).

In this presentation we will summarize the key results from the various working groups, as well as to discuss the future of the successful scientific co-operation that has been established within the CES project and its earlier counterparts.

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# NATIONAL SCALE ASSESSMENT OF CLIMATE CHANGE IMPACTS ON FLOODING IN FINLAND

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Climate change has a multifaceted impact on river discharges: on the one hand it poses a risk of increased flooding, whereas decreasing trends may be expected in regions where precipitation decreases or where snow accumulation decreases. Efforts have been made to assess these changes on a continental scale to produce a general overview, but the reliability of such large-scale evaluations on the national scale is unknown. Two recent continental scale flood hazard evaluations by Lehner et al. (2006) and Dankers et al. (2007) in Europe yield contradictory results on the changes in floods in many parts of Europe, including Finland.

The Floods Directive (European commission, 2007) instructs the EU member states to perform preliminary flood risk assessments, flood hazard and flood risk mapping and flood risk management planning by 2011–2015. The directive advises that the impacts of climate change on the occurrence of floods should be taken into account when assessing the flood risks. It also poses new demands for general evaluations of changes of flood discharges, flood inundation areas and possible flood hazard due to climate change in different parts of Europe.

The overall picture of the changes in flood hazard in Finland with consistent methods and scenarios has been missing, since the European scale assessments are contradictory, do not cover smaller watersheds and may be unreliable in some areas due to limitations in continental scale modelling. In this assessment on a national scale, more detailed hydrological models and several climate scenarios were used. Changes in flooding caused by climate change for the periods 2010–2039 and 2070–2099 were evaluated at 67 sites in Finland using a conceptual hydrological model and 20 climate scenarios from both global and regional climate models with the delta change approach. Floods with a 100-year return period were estimated with frequency analysis using the Gumbel distribution. At four study sites depicting different watershed types and hydrology, the inundation areas of the 100-year floods were simulated with a 2D hydraulic model. Climate change effects were outlined regionally as well as in different types of catchments (e.g. size, location, lake percentage).

The results demonstrate that the impacts of climate change are not uniform within Finland due to regional differences in climatic conditions and watershed properties. In snowmelt-flood dominated areas, annual floods decreased or remained unchanged due to decreasing snow accumulation. On the other hand, increased precipitation resulted in growing floods in major central lakes and their outflow rivers. Lakes and lake routes are an important and typical characteristic of Finnish watersheds, and should not be ignored in any hydrological estimation in this area.

The changes in flood inundation did not linearly follow the changes in 100-year discharges, due to varying characteristics of river channels and floodplains. Inundation on a flat floodplain showed a larger change than the flood discharges, whereas rivers with greater variations in floodplain topography experienced smaller changes in inundations even when greater changes in discharges occurred. Sea level affected flooding substantially at two coastal study sites.

These results can be utilized in preliminary flood risk evaluation required by EU Floods Directive, when lowest building elevation, flood risk areas and flood adaptation options are planned, and to evaluate the need for further and more detailed case studies. The results highlight the importance of comprehensive climatological and hydrological knowledge and the use of several climate scenarios in estimation of climate change impacts on flooding. Generalizations based on only a few case studies, or large-scale flood assessments using only a few climate scenarios should be avoided in countries with variable hydrological conditions.

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# INFLUENCE OF THE CLIMATE WARMING ON RAINFALL FLOODS OF THE RIVERS OF THE WESTERN DVINA BASIN WITHIN BELARUS

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Noticeable changes of hydrological regime of the rivers are observed in last decades, caused by the consequences of global climate warming, occurring against anthropogenic influences. These changes have also transformed rainfall floods runoff.

The purpose of the present research is the long-term examination of fluctuations and a quantitative estimation of change of the rainfall floods water maximum discharges on the rivers of Western Dvina basin. At that long-term records of the maximum water discharges supervision of rainfall floods of the rivers of Western Dvina basins within Belarus were considered for the period from the beginning of instrumental observations to year 2005.

Hydrological regime of the Western Dvina river is featured by high spring high water, low summer-autumnal and winter low water, periodically interrupted by high waters, which can be formed during all seasons of the year. Approximately 50 % of the Western Dvina annual runoff is formed during a spring high water. Rainfall floods provide 20 %; on a subsurface runoff it is about 30 %. However such distribution is an average and can essentially fluctuate in years. The overland runoffs are increasing during rainfall floods. So, average value of the maximum overland runoff of rainfall floods of the 5 % probability on the rivers of the Western Dvina basin equals to 40–45 $l/(s{\cdot}km^2)$.

The analysis of observations over the maximum water discharges of rainfall floods from the long-term period was carried out to reveal the regularities of rainfall floods runoff fluctuations. The longest observations period for rainfall floods runoff is available on the Western Dvina river – Vitebsk city (since 1877). The observations duration is much less on inflows. Supervision is carried out on some of them from the end of 1920th years, while on others – from the middle of 1940th. The largest values of the maximum discharges of water of rainfall floods are noticed on the Western Dvina river – Vitebsk in first decades of XX century (1908, 1917) with 1 % probability thus less than the exceedance probability. The amplitude of fluctuations of the maximum discharges of water has considerably decreased starting from 60th years of XX century, and values of discharges are essentially less, than in a first half of XX century.

From inflows of Western Dvina the longest observation series for the water regime is available on Polota, Nacha, Ulla, and Drissa rivers, the supervision duration there is about 80 years. The highest rainfall floods on inflows are noticed in 1952, 1962, 1978, 1987, and 1994 years. There is also a decrease of the maximum discharges of water of rainfall floods in a second half of XX century in comparison with a first half; the period from the middle of 1960th to the middle of 1970th should be especially noted.

Rainfall flood is a local phenomenon, and its size depends on a combination of many factors. Therefore on small rivers the greatest rainfall floods often are marked in different years. Besides, the intensive deposits causing rainfall floods on the rivers, are seldom covering the whole reservoir.

The basin of Western Dvina is characterized by rather high density of a river network, substantial inclines, prevalence of aquitard loamy soils, etc. Thereof during rains there is a fast water running off on slopes at small losses of water on seepage. So rainfall floods are developing quickly enough, the maximum is kept not for a long time, followed by fast recession. Hydrographers of rainfall floods are characterised by a considerable steepness as on lifting so on recession. Their height can reach 1–1,7 m and more (to 4–7) upon the level of dry weather period. In a northwest part of Western Dvina basin where the rivers Polota, Nacha, Drissa are forming their drain, the drain has considerable over adjustment due to raised lakes, marshiness and wood. Here rainfall floods are more long and spread, than on other rivers.

For a quantitative estimation of changes of maximum rainfall floods runoff the period of supervision is divided into 2 intervals: the first one from the beginning of supervision to the year 1985 (the beginning of climate warming), the second one from 1986 to 2005. Average values of the maximum discharges of rainfall floods water had been defined for each of the periods. If duration of observation was less than 15 years at least for one of the periods, these rivers were not considered.

After culling there were 20 rivers-alignments for which change values of maximum rainfall floods runoff were determined, have been presented in the form of the change factor of a runoff: $k_i=(Q_{av2}–Q_{av1})/Q_0$, where $Q_{av1}$ and $Q_{av2}$ are average values of the maximum discharges of water of rainfall floods for the periods until 1985 and 1986–2005, accordingly, $Q_0$ is maximum rainfall floods runoff average value for all period of the instrumental observation. Change factors of a runoff have been mapped with use of coordinates of the centres of gravity of reservoirs of the investigated rivers.

It is revealed, that on the rivers of Western Dvina basin within Belarus some transformation rainfall floods runoff took place in 1986–2005 in comparison with the period until 1985, with speed varied on territories. As a whole for a Western Dvina basin there is decrease of the maximum discharges of rainfall floods water in time of the climate warming. And on left-bank inflows of Western Dvina there are largest decrease within 25–35 and more percent. On right-bank inflows transformation value of maximum rainfall floods runoff is substantially lower (5–15 %). And on the Nishcha and Drissa rivers the increase within 10–15 % is noticed. This situation is caused first of all by natural factors, and less by anthropogenic ones.

Thus, on the rivers of Western Dvina basin within Belarus the value decrease of the maximum discharges of water of rainfall floods is noticed in climate warming in comparison with the period until year 1985.

## Session 5

# HYDROLOGICAL INFORMATION SYSTEM AND DEVELOPMENTS IN MODELLING

# MODELLING SOIL FROST AND WATER BALANCE IN NORWAY

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The need mapping and management of water resources has been the driving force behind the frequent use of hydrological models in Norway. Although the observations network in Norway is relatively dense, the need for determination of water budgets at different spatial and temporal scales across large regions has required use of hydrological models. Simulations of soil frost and hydrological conditions are performed with the physically based COUP-model (Jansson and Karlberg, 2004) and the conceptual HBV-model (Bergström, 1995). The results are used for producing maps of the state of the hydrological system. Physically based and conceptual models describe the relationship between meteorological inputs or other boundary conditions and the hydrological system using process-based model equations derived from principles of thermodynamics and fluid mechanics, or from simplified, but plausible conceptual representations of the processes of interest.

A spatially distributed version of the HBV-model (Beldring et al., 2003) was used. The model performs water balance calculations for square grid cell landscape elements. Each grid cell may be divided into a maximum of four sub-grid hydrological response units, a lake area, a glacier area and two land use zones with different vegetations and soils. Every grid cell has unique characteristics, input data are distributed, and water balance computations are performed separately for every model element. Model simulations are performed with daily time step, using precipitation and air temperature data as input. The model has components for accumulation, subgrid scale distribution and ablation of snow, interception storage, subgrid scale distribution of soil moisture storage, evapotranspiration, groundwater storage and runoff response, lake evaporation and glacier mass balance. Potential evapotranspiration is a function of air temperature, however, the effects of seasonally varying vegetation characteristics are considered. An algorithm for calculation of soil frost depth based on results from Vehviläinen and Motovilov (1989) has been introduced. Groundwater levels are simulated using a storage coefficient and depth to an impermeable base. The HBV model was calibrated using information about precipitation, air temperature and hydrological processes for 141 basins in Norway with reliable observations. The parameter values were transferred to other basins based on a classification of the properties of the land surface, assuming that model elements with identical landscape characteristics have similar hydrological behaviour, and should consequently be assigned the same parameter values.

The COUP-model (Jansson and Karlberg, 2004) simulates one-dimensional water and heat dynamics in a layered soil column covered by vegetation by solving numerically the relevant differential equations. The main equations include the laws of conservation of mass and energy together with flow equations for water (Darcy's law) and heat (Fourier's law). Parameters of the COUP-model have been determined at a few selected sites in the Soil Water Monitoring Network in Norway. Hourly measurements of groundwater level together with soil temperature and soil water conditions at different depth are performed at totally 18 stations from around year 2000. Periodically manual observations of soil frost depth have been performed for earlier time periods. Meteorological driving variables for the COUP-model are daily values of air temperature, relative humidity, wind speed, precipitation and cloudiness from the nearest meteorological station operated by the Norwegian Meteorological Institute. To evaluate the possibility for using the COUP-model as a tool in forecasting drought, flood and landslides a first attempt using the same soil characteristics for different climatic regions has been performed.

Maps of soil frost and water balance conditions for Norway are produced by the HBV-model, while point estimates are shown for the COUP-model. Although the COUP-model uses detailed process descriptions at the point scale, modelling of land surface hydrology, especially runoff, at larger spatial scales should be performed by models which represent the significant and systematic variations in the properties of the land surface. Comparing observed data and results from the HBV and COUP models confirm that model simulations are realistic. Groundwater levels and soil water storage are relatively well described by both models. The differences between the simulation results from the two models can be attributed to differences in simulated actual evapotranspiration and winter drainage.

The normal climate in Norway includes a continental climate in the inner and northern part of the country and a more maritime climate along the coast. The winter climate at the continental sites can be described as cold, low precipitation and the precipitation falls as snow. The maritime climatic shows higher air temperature, high amount of precipitation during the winter period and the precipitation usually comes as rain. This leads to two different groundwater regimes. The continental climate leads to a steadily decreasing groundwater level during the winter period, while the maritime climate leads to high groundwater level (close to the surface) during the winter period. The reason for the "winter drought" (low groundwater level, restrictions on water use) at the western coast the winter 2009/2010 was that the winter climate had a strong continental character. A dry autumn together with an early start of a cold, dry winter, close to the coldest resulted in driest winter in 100 years along the western coast. Preliminary results of forecasting the "winter drought" at the western coast of Norway during the winter of 2010 with both models will be used as an example of the two models structures.

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# ENHANCED PRECIPITATION ANALYSIS IN ALPINE CATCHMENTS BY COMBINING A METEOROLOGICAL ANALYSIS AND NOWCASTING SYSTEM WITH A HYDROLOGICAL MODEL

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The quality of real-time flood forecasting systems in small Alpine catchments is highly dependent on the quality of precipitation input. Both the precipitation analysis (for updating the system states of the hydrological model) and the precipitation forecasts are important in this respect. In Alpine catchments, a significant part of the uncertainty in the precipitation input is due to its large spatial variability caused by terrain effects. Moreover, the heterogeneous topography strongly contributes to the small-scale spatial variability of precipitation.

In the presented study coupled runoff simulations between the INCA analysis and nowcasting system, and a conceptual distributed runoff model are performed in high spatial and temporal resolution. The long-term objective of this investigation is to improve the understanding and quality of precipitation fields as well as the forecast ability by feeding hydrological information back to INCA.

The nowcasting system INCA (Integrated Nowcasting through Comprehensive Analysis) algorithmically combines station observations and remote sensing data (radar, satellite) in order to provide meteorological analysis and nowcasting fields at high temporal (15 min) and spatial (1 km) resolution (Haiden et al., 2010). In addition to point measurements from raingauges and radar data, a newly developed, intensity-dependent parameterization of the elevation-gradient of precipitation is used in this system (Haiden and Pistotnik, 2009). The need for a parameterization of elevation effects arises from the fact that in spite of the generally high raingauge density in Central Europe, their area-height distribution is such that medium and upper elevations are generally under-represented by measurements.

In the continuous hydrological model, the runoff processes are modeled through a cascade of storages. The model requires precipitation and temperature as meteorological forcings. In the presented study, for the reason of simplicity and data quality, offline-data is used. The model accounts for the processes of snow accumulation and melt, interception storage, evapotranspiration from vegetation, snow and soil, evolution of soil moisture, surface runoff, inter flow, base flow and zone routing. The spatial discretization is grid based, where upstream grid cells drain into downstream cells.

Since the continuous runoff simulation represents a closed water cycle on the Earth´s surface, the simulated runoff can be seen as the integral over the precipitation in a catchment over a certain period. By comparing the simulated and observed runoff on a long-term, seasonal and single event-basis, different elevation-dependency parameterization experiments can be performed and validated. Realizations of precipitation fields are generated in the INCA analysis system, depending on assumptions made for different height dependencies of precipitation, also taking into account flow patterns, weather situations or season. The basis for these assumptions is to some extent made by the analysis of measurements, whereas there are the mentioned limitations due to the sparse observation network.

The methodology is applied to the upper Enns and Steyr river catchments in the north-central Austrian Alps. This region is characterized by a high spatial variability of rainfall climate. The two selected catchments exhibit very different behavior in terms of geology, characteristics of runoff generation and height. Furthermore the relatively large number (>50) of high-resolution precipitation stations and discharge measurements prove to be a benefit to the investigation.

Results of the ongoing study show that the hydrological model is sufficiently sensitive for the validation of different realizations of precipitation fields, and that the tested variations of the height dependency of precipitation have a clear effect on runoff simulation. Further work aims at taking into account uncertainties in rainfall measurements, the hydrological model parameters and the implementation of a height dependency parameterization scheme which is a function of meteorological conditions.

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# ON SITE HYDROLOGICAL MODELING

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One dimensional hydraulic modeling represents a common method for improving our understanding in respect to the hydrological behaviour of a particular river or stream. In spite the fact 1D models are simpler than 2D or 3D models, it is nevertheless not straightforward to run the simulation and obtain predictions from these models due to their relatively high computational and data requirements. As a result, hydraulic models are designed for specially equipped workstations with fast CPU, large amount of memory, and network based storage capabilities. These factors are limiting hydrologist's ability to run hydrological models on site where they could compare almost in real time the outcomes models outcomes with the environmental reality. On site modeling overcomes this limitation enabling modelers to feed models Wireless Sensor Networks (WSN) acquired data and execute them while on site. This is achieved through developing a environmental simulation middleware consisting of WSN middleware, OGC compliant Web Processing Services and mobile simulation client.

The work presented in this paper is related to the HYDROSYS project (www.hydrosysonline.eu), and is linked to its Nordic scenario or Kylmaoja stream in the south of Finland. The goal of the project is to provide end-users with advanced on-site and on-line spatial analysis tools for the purpose of environmental modeling. In this sense we have integrated a 1D hydraulic model based on 1D de Saint-Venant equation solved using Verwey's variant of the Preissmann discretization scheme exposed as an OGC WPS with Global Sensor Network middleware and a mobile simulation client. This allows end users to carry out environmental simulation on-site almost in real time using smart clients.

The setup has a big potential for environmental management and decision support and could be highly exploited by environmental managers and specialists.

# MODELLING RIVER BATHYMETRY AND SUBSTRATE FROM AERIAL PHOTOGRAPHY

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Knowledge of underwater terrain is an essential component of many hydrological and environmental applications such as flood modelling and habitat mapping. The accuracy of the geometry of the river bed has great influence on the result of hydraulic models. Remote sensing allows to model bathymetry at spatial scales that are impossible to achieve with traditional methods. It is possible to map large stretches of river based on aerial photography at relatively low cost compared to lidar or sonar. Developing the full potential of passive remote sensing for modelling water depth in fluvial environments remains a challenge.

We are testing a range of optical bathymetric models on a section of the river Tana (Tenojoki, in Finnish) in Lapland. Clear water is a major requirement for the use of optically based models, a condition often fulfilled in high altitude and high latitude rivers.

Spectrally based bathymetric models operate on the principle of isolating the depth signal from the reflectance values of the water surface. This is achieved by either removing the influence of the river substrate using a deep water correction method or by calculating the rate of attenuation of light in the water column. We were so far able to achieve an accuracy of 28 cm by applying a deep water correction algorithm to 0,5 m resolution RGB imagery. The method is currently being refined and combined with other methods for depth extraction from image brightness values.

In addition to creating subaqueous digital terrain models, maps of river bed substrate types are also being produced. Whereas bathymetric methods focus on isolating the depth signal, substrate mapping aims at removing the influence of the water column on the reflectance of the river bed in order to allow the distinction of different substrate types at varying depths. This information is useful for creating habitat models of fluvial environments.

# EVAPOTRANSPIRATION IN HIGH ALPINE CATCHMENTS – AN IMPORTANT PART OF THE WATER BALANCE?

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The objective of this study is to analyse the spatial variability of evapotranspiration rates in alpine catchments and its influence on runoff volumes. It is often stated that potential evapotranspiration rates rapidly decline with increasing sea-level, leading to relatively low values in high alpine catchments. Nevertheless important driving forces for evapotranspiration, solar radiation and wind, increase with higher elevation. This inconsistency is examined.

It is widely accepted that the Alps are the "water tower" or "water castle" of Europe. Many large rivers with significance for water resources management in lowlands, including the Danube, Rhine or Po, have their sources in the Alps. High precipitation sums, together with low winter temperatures inducing snow accumulation in the headwaters lead to high runoff-rates in spring and summer, with the Alps contributing up to 80 % of the total water amount in downstream regions.

In high alpine catchments evapotranspiration plays an important role as it can reduce runoff by approximately 30 %. Possible impacts of climate change on climatological parameters may lead to even higher evapotranspiration rates, giving this part of the water balance equation even more significance. An accurate measurement of the spatial and temporal distribution of evapotranspiration is admittedly almost impossible and afflicted by high uncertainty. This is even more the case for high alpine regions. The indirect estimation through mathematical models is, at least at the moment, the only feasible approach. The application of the worldwide accepted estimation methods for potential evapotranspiration is, however, often limited due to the demanding meteorological parameters needed.

In the presented study we use meteorological data from the INCA analysis system for the calculation of the distributed potential evapotranspiration. The INCA system (Integrated Nowcasting through Comprehensive Analysis) algorithmically combines station observations and remote sensing data (radar, satellite) in order to provide meteorological analysis and nowcasting fields of several parameters at high temporal (15 – 60 min) and spatial (1 km) resolution. For a detailed spatially distributed assessment of evapotranspiration rates the input-data must be available as continuous fields, which is guaranteed by using the INCA data. Potential evapotranspiration is calculated with the ASCE-Penman-Monteith method on a 60 min basis, utilizing the fields of temperature, humidity, wind and solar radiation generated by the INCA system. For the water balance study a continuous hydrological model, also estimating the actual evapotranspiration, is used to model the influence of evapotranspiration on runoff, using the temperature and precipitation fields, also from the INCA system, as driving forces. Actual evapotranspiration is calculated as a function of potential evapotranspiration, soil moisture, vegetation cover and snow sublimation. Apart from this the conceptual hydrological model also accounts for the processes of snow accumulation and melt, interception storage, evolution of soil moisture, surface runoff, inter flow, base flow and zone routing.

The methodology is applied to sub-catchments of the upper Enns and Steyr river basins in the north-central Austrian Alps. The overall modelled area has a size of 1235 km$^2$, with a mean catchment size of 40 km$^2$. The elevation ranges from 420 m to 2880 m a.s.l. The selected catchments are characterised by high variability in vegetation cover, geology and exposition of valleys and slopes.

The results of the ASCE-Penman-Monteith calculation show surprisingly high potential evapotranspiration rates in high alpine areas in winter, spring and fall, which can be explained by the relatively high solar radiation values in these heights and its evaporative power. As expected, high spatial and temporal variability of modelled evapotranspiration rates with clear effects of exposition and elevation is assessed. The actual evapotranspiration rates calculated by the hydrological model are obviously lower than the potential rates, especially due to limiting snow sublimation in months with snow cover and, to a lesser extent, missing moisture in soil and vegetation layers in summer, leading to a less pronounced effect of evapotranspiration on the water balance.

# TWO DIMENSIONAL FLOW MODELING USING RIC-NAYS A CASE STUDY OF PING RIVER

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RIC-Nays is a free software for flow and morphology of river developed by Foundation of Hokkaido River Disaster Prevention Research Center which can be used for hydraulic modeling. It comprises calculation of flow, sediment and bed deformation, and bank erosion. The software mainly composes of three modules; RIC-NaysPre for grid file generating, 2d-solver for solving 2-dimensional flow using finite differential method and RIC-Nays2D for visualized result presenting in both tabular and graphic modes. All modules are programmed by using graphic user interface (GUI). Some manual and references are available for user/modeler comprises Quick Start Guide, Tutorial, User's Manual for RIC-NaysPre, 2D Solver User's Manual and RIC-Nays2D User's Manual. There are also, equations of two-dimensional flow and bed deformation in general co-ordinate system which comprise basic equation of 2D flow in co-orthogonal coordinate, bed shear stress, velocity components at channel bottom, streamline curvature. The computation procedure was well described by Shimizu (2006) as shown below;

The continuity equation of liquid flow:

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y} = 0 \tag{1}$$

The momentum equations in the x and y directions:

$$\frac{\partial (hu)}{\partial t}+\frac{\partial (hu^2)}{\partial x}+\frac{\partial (huv)}{\partial y} = -hg\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho}+D_x \tag{2}$$

$$\frac{\partial (hu)}{\partial t}+\frac{\partial (hu^2)}{\partial x}+\frac{\partial (huv)}{\partial y} = -hg\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho}+D_x \tag{3}$$

All of the equations then are solved by using Finite Difference Method (FDM) and Cubic Interpolation Pseudo particle (CIP) Methodology. Commercial software for flow modeling can be replaced by RIC-Nays at no cost. As shown in its tutorial document (Foundation of Hokkaido, 2008), RIC-Nays has been used to model flow of the Chao Phraya river in Thailand. In this paper, flow in the Ping River was modeled by using the first feature of RIC-Nays, calculation of flow.

The Ping River is the biggest among the four tributaries of the Chao Phraya river, the principle river in Thailand which flows 250 kilometres from the central region to the Gulf of Thailand. A study area is a 16-kilometer-long reach of the Ping river starting from the Lower Ping dam to Sam Ngao district in Tak province.

Lower Ping dam was built as a regulation dam for impounding the released water and pumping back into the reservoir of Bhumibol dam which is located five kilometers upstream. Storage of Lower Ping dam is released to downstream regularly on daily basis, once a day. Unsteady flow from spillway operation of Lower Ping dam was modeled by using two dimensional flows to analyze hydraulic characteristic of the open charnel flow from a few kilometers downstream of the dam to Ban Mae Pha Yuap village which is located 12 kilomerters downstream.

Purpose of this model is to obtain accurate result from hydraulic analysis by using 2-dimensional flow model in order to solve the existing erosion along the left and right sides of river bank which affected intrastructure in the area.

Input Data was collected from field investigation including 11 cross sections using leveling, theodolite and echo sounding method, flow hydrograph from spillway gate operation starts from 0 to 800 cubic meter per second, roughness characteristic of river channel. Stage of maximum flow along the river bank was also collected using leveling for model calibration. Model of Ping River channel was divided into 10 segments along its cross-section and 114 segments perpendicular to its longitudinal profile, therefore up to 1,140 grid points was generated to obtain a reliable result. The model was calibrated by using data from field investigation during normal operation of the dam.

Flow characteristic as a model results was obtained in many forms such as flow velocity, velocity vector, water surface contour, contour of water depth, stream line at any specific time, profile of water surface at any segment. Output of the model was also shown in form of tables, figures, time series and geo-referencing using Google Earth's overlay to produce visualized images as well as a continuous snapshot and animation of moving flow. At last the output from RIC-Nays was also input to Geo Slope application to analyze river bank stability.

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# THE APPLICATION OF THE CONCEPTUAL IHMS-HBV MODEL FOR SIMULATION OF HIDROLOGICAL PROCESSES: THE CASE OF RIVER GAUJA WATERSHED

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Mathematical methods which also include hydrological modelling are widely used in hydrology nowadays. In the situation when the network of data collecting stations is being narrowed hydrological models can be used as useful tools to expand existing or generate completely new data series of the river stream flow. It must be kept in mind that modelling can not substitute monitoring, for monitoring represents the collection of actual data whereas modelling comprises theoretically calculated data series. Nevertheless this kind of simulation of hydrological processes can be a worthy solution to generate hydrological data in ungauged. The network of stations of the hydrological observations has been significantly narrowed since 1994 in Latvia.

In this research conceptual IHMS-HBV model is applied to simulate hydrological processes within the Gauja watershed. The river is located in north eastern part of Latvia and its basin covers nearly 8900 km$^2$. IHMS-HBV model is created by Sten Bergström and was first applied to assist the hydropower stations in Sweden (IHMS manual, 2006). The structure of the model can be described as very simple. A handful of input data are necessary for the model to simulate the hydrological processes. A total of 33 various parameters are used to calibrate the model for River Gauja.

In this research the River Gauja basin is divided in three sub-basins where three different stations of the hydrological observations Gauja-Sigulda, Gauja-Valmiera and Gauja-Tilderi are used as outflow points of the river. Firstly, the research executes the calibration of the IHMS-HBV model by analysing multiple combinations of meteorological input data of the model for each formed sub-basin and aims to reach the highest possible correlation between observed and modelled river discharge to compare the calculated correlations of the created combinations. Four different combinations were simulated for each hydrological station. Statistical criterion $R^2$ is used a measure of the correlation (Nash and Sutcliffe, 1970). Secondly, the values of IHMS-HBV model parameters generated in the process of calibration are used to model the stream flow of Amata, Tirza and Vaidava which are tributaries of the River

Gauja. This will aid to evaluate the use of these parameters for simulating hydrological processes in other sub-basins of the Gauja watershed.

The research looks at the whole basin of the River Gauja, except a lower part from station of the hydrological observations Gauja-Sigulda to the mouth of the river. The main reason is the lack of observed daily discharge data. Besides the IHMS-HBV model does not include parameters that represent fluctuations of water level caused by wind near the mouth.

The necessary meteorological and hydrological input data for the model were obtained from the Latvian Environment, Geology and Meteorology Centre. These input data are: average daily temperature of air (obtained from five stations of the meteorological observations), the sum of daily precipitation (obtained from eight stations of the precipitation observations), and the values of potential monthly evaporation.

A ten year period from January 1st, 1980 till December 31st, 1989 is used to calibrate the IHMS-HBV. The validation of the model was made for the following five year period from January 1st, 1990 till December 31st, 1994. The results of calibration showed a good coincidence between the observed and simulated daily discharges. The Nash-Sutcliffe efficiency $R^2$ for different meteorological station combinations for Gauja –Sigulda 0.83 to 0.87, for Gauja – Valmiera 0.75 to 0.86 and for Gauja – Tilderi 0.80 to 0.86. The validation of model showed different results. The Nash-Sutcliffe efficiency $R^2$ varies for Gauja –Sigulda 0.78 to 0.81, for Gauja – Valmiera 0.77 to 0.86 and for Gauja – Tilderi 0.70 to 0.79.

Obtained model parameters with best Nach-Sutcliffe efficiency $R^2$ from Gauja – Sigulda, Gauja – Valmiera and Gauja Tilderi were used to simulate stream flow of Amata, Tirza and Vaidava. Simulation showed unequal results. Good coincidence between the observed and simulated daily discharges for Tirza (the statistical efficiency $R^2$ varies from 0.71 to 0.80) was obtained. Not so good results showed Vaidava and Amata simulations. The statistical efficiency $R^2$ varies from 0.51 to 0.64 for Vaidava and 0.49 to 0.63 for Amata.

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# S-HYPE – A HIGH RESOLUTION MODEL FOR WATER AND NUTRIENTS COVERING SWEDEN

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The European Water Framework Directive (WFD) requires compilation of information about ecological status, pressures and management programmes for all European waterbodies. Sweden is a country rich in surface water, with more than 100 000 lakes >0.01 km$^2$ and 118 major rivers discharging to the surrounding seas. So far, the five water authorities in Sweden have defined 17 313 waterbodies, but this number is expected to increase to around 25 000 during 2010. However, the national monitoring programme is rather sparse, e.g. it only includes 300 hydrological gauges and some 900 sites where grab samples of nutrient concentrations are taken a few times per month. This provides little information for each waterbody, and therefore, the Swedish Meteorological and Hydrological Institute (SMHI) got the request to deliver high-resolution model data to water authorities, to support their WFD work.

Since the early 70's operational flood forecasts in Sweden has been based on the HBV model (Bergström, 1995). However, the environmental sector has other needs, which is why a new model concept, called Hydrological Predictions for the Environment (HYPE) was developed. At present, the major environmental concern linked to water status in Sweden is eutrophication. This is also the major concern for the surrounding Baltic Sea. Therefore, modelling of nitrogen (N) and phosphorus (P) concentrations were emphasized during the development of the HYPE model (Lindström et al., 2010).

The overall aim of this study was to evaluate a national model application of the HYPE model for Sweden. The model application is called S-HYPE, and uses only readily available data. The spatial resolution is in line with what is required by the WFD, with special focus on the majority of the subbasins which are ungauged. To reduce uncertainties in ungauged areas, a stepwise calibration procedure was introduced using the fact that model coefficients are linked to physiographical variables and model processes rather than to specific sites. The hypothesis is that this national model will give valuable information also for ungauged basins within the modelled domain, even though only readily available databases and data from a few sites are used for calibration.

The country of Sweden (~450 000 km$^2$) was thus divided into 17 313 subbasins (on average 28 km$^2$). The model set-up was based on readily available national databases. For physiographical data, emissions, and agricultural practices, fixed values for representative years were used as input. Daily input of precipitation and temperature was used as the dynamic forcing of the model. Model evaluation was based on 90% independent time-series from several hundred monitoring sites, using the statistical criteria such as the Nash and Sutcliffe Efficiency (NSE), correlation, relative errors and absolute values of relative errors. The results show that the spatial variation was explained by 92 % for specific water discharge, and 88 % and 59% for total nitrogen and total phosphorus concentrations in surface water, respectively (Strömqvist et al., manuscript). Temporal day to day variations were modelled with satisfactory results for water discharge and the seasonal variation of nitrogen concentrations was also generally well captured by the model. However, resolving the temporal variation phosphorus still remains a challenge. For water discharge in 76 large, partly regulated basins the median NSE was 0.52, and the corresponding number for 20 unregulated river basins was 0.84. In small basins, the NSE was still typically above 0.6.

Major achievements compared to previous similar experiments were assigned to the stepwise calibration process and the use of the model concept where coefficients are linked to physiographical variables rather than to specific sites. Calibration was made on a multi-basin level for the whole domain assuming that differences in physiographical characteristics and forcing data was sufficient to account for spatial variability, while model coefficients were kept constant. This idea to identify key parameters and making use of different calibration criteria for different parameters seems very promising for predictions of water and nutrients in ungauged basins. The results indicate that the model produces valuable results for water managers, for both gauged and ungauged waterbodies.

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# PREPARATION OF INFORMATION DATABASE NECESSARY FOR MATHEMATICAL MODELS OF WATER ECOSYSTEMS' DESIGN. DIFFICULTIES AND UNSOLVED PROBLEMS

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Hydrological information database is an integral part of hydrobiologic and hydrochemical information system. Core of all such systems should be represented by libraries of mathematical models of various levels of hierarchy and designations linked with specifically structured databases and knowledge bases. Despite significant successes in building such systems, there are lots of principal difficulties and unsolved problems as well.

A vast amount of poorly systematized and sometimes contradicting facts have been and are still being accumulated in ecological studies. At the same time, there is a sharp discrepancy between the degree to which ecosystem's structure is examined and the mechanisms of its functioning. Different structural levels of water ecosystems have been examined extremely unevenly at present. However, the necessity to study the object fully and evenly on different levels of its organization is of great importance for systematic studies and mathematical modeling.

Up until now preparation of informational database needed to design mathematical models of ecosystems is not considered as an important, independent task which not only needs special studies to be carried out but also involvement of highly-qualified experts familiar with the studied object. As a result, many expeditionary hydrobiological and hydrochemical studies are frequently episodic and usually unsystematic, at least from the point of view of utilization of obtained data in mathematical models. Not only this decreases the quality of primary data but also distorts the real pattern of mechanisms of multiple processes in water ecosystems. Results of expeditionary evaluations should provide full series of observations of all major parameters of ecosystem's state, have low uncertainty and be taken with frequency corresponding to spatial-temporal dynamics of ecosystem. This is especially important for next-generation models which would be widely using methods of remote observations and data acquisition procedures. All this would require coordinated observation programs, uniform sampling and laboratory methods of studies.

However, we should not think that by merely increasing volume and quality of collected information it would be easy to solve principal problems of mathematical modeling and forecasting. This was well demonstrated in the practice of designing of numerical methods of weather forecasting. Biological prognosis has a lot in common with meteorological and hydrological prognoses. They are all based on nonlinear system equations with a big number of freedom degrees and they often do not comply with conservation laws due to presence of many errors (noise) in observation data.

A lot of methods and ideas taken in the first stages of mathematical modeling from physics, chemistry, theory of differential equations, methods of linear and dynamic programming are still being commonly used in mathematical modeling. Nevertheless they are poorly suited or absolutely inapplicable for quantitative description of ecological processes and phenomena as it is often unclear what should be measured and how. Impossibility for sharp differentiation of reasons and causes in complex systems makes it difficult to find functional links in them which may be described by equations. Biological features are found to be much more complex than physical ones and therefore hardly evaluated and subsequently parameterized.

As an example of preparation of information database necessary and water ecosystems' design we would present a spatially irregular imitation model of the Neva Bay, Gulf of Finland ecosystem. It was built using data of systematic hydrological, hydrochemical and hydrobiological observations performed on a constant grid of sites for several years.

The imitational model of the Neva Bay ecosystem contains the following developed and programmatically realized general blocks: (I) hydrodynamic – needed to calculate the nonstationary, vertically averaged structure of currents in the waterbody; (II) hydrothermodynamic – for calculation of the photoperiod, components of the thermal balance and temperature regime of the waterbody; (III) hydrooptical – for calculation of optical characteristics of the water column; (IV) block needed for description of processes of nitrogen and phosphorus compounds' transformation in the waterbody and dynamics of dissolved oxygen; (V) block needed to calculate the time of cycle and flow of matter between the selected (aggregated) model parameters of the ecosystem; (VI) block needed for the evaluation of imitational model's parameters. All calculations in the model are carried out only in the basis of standard meteorological, hydrological, hydrochemical and hydrobiological information. Block (IV) of the imitational model considers 17 variables of state: concentrations of dissolved fractions of organic nitrogen and phosphorus, inorganic phosphorus, ammonium, nitrite, nitrate nitrogen, nitrogen and phosphorus contained in the detritus, concentration of dissolved oxygen, biomasses of hydrobionts (heterotrophic bacteria, phytoplankton, protists and zooplankton) in nitrogen and phosphorus units.

The task of modeling of spatially irregular water ecosystem's dynamics is divided into two main stages. Model's calculation begins with numerical integration of thermohydrodynamic system equations in time step $\tau$. As a result of modeling of the hydrological complex values of current speed, flows of shortwave solar radiation, photoperiod values averaged by depth and vertically averaged water temperature are determined. Then, a system of equations of turbulent diffusion and compounds' transformation is integrated on the same time interval. Solving this task allows finding values of biotic ecosystem components' concentrations to the end of the set time increment. Building of computational algorithms is based upon utilization of various schemes of splitting equations on physical processes and spatial coordinates (Podgornyj, 2000; 2003). Calculations have started from the moment of clearing of the Neva Bay from ice and continued until October the 31st.

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## Session 6

# EXTREMES AND UNCERTAINTIES

# UNCERTAINTIES IN FLOOD HAZARD MAPPING AND ESTIMATION OF BUILDING DAMAGES FOR A RIVER FLOOD

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Floods may cause a variety of damage to people, infrastructure, cultural heritage, ecological systems, industrial production, including the competitive strength of the affected economy. Damages are usually categorised as direct or indirect and tangible or intangible, whether or not they result from a direct connection with flood water and if the damages may be easily expressed in monetary terms. Flood characteristics, such as water stage, discharge, flow velocity, the area of inundation and seasonality affect the amount and types of damage. In the context of building damages, the relevance of different flood actions varies. Before flooding events occur, it would be beneficial to carry out accurate and up-to-date flood damage assessments for cost-benefit analyses of flood prevention measures and to inform the relevant stakeholders. Cost-benefit analyses are used to justify flood prevention measures, such as building of dykes.

In general, uncertainty may arise from a lack of knowledge and/or the natural variability of a system or process. In flood risk mapping studies, uncertainties arising from several sources have received only brief mention, from the lack of recent information and site-specificity of the stage-damage curves used, to limitations of the applied methodology due to simplifying hypotheses. In addition, ambiguity has resulted from a shortage of hydrological datasets, as well as the requisite knowledge of the characteristics and locations of the buildings. It should be noted that also some factors causing over- or underestimates in expected flood damages. Overestimation may arise from flood proofing measures and other responses due to flood warnings. Conversely, underestimation results from the omittance or miscalculation of damages to industrial sectors and historical buildings, from pollution in flood water and biases in the expected probabilities of extreme events.

In our review of recent flood risk mapping approaches in Europe, we noted that sources of uncertainty were rarely questioned. We demonstrated potential sources of uncertainty in flood risk mapping of buildings using a case study of a spring flood in 2005, in Kittilä, Finland. One- and two-dimensional hydraulic models of the flood corresponded well with the actual inundation. The initial modelling result of the inundated buildings differed considerably from reality, but this could be improved through modelling performed with more diverse building elevation data. The accuracy of the DTM is a key determinant in the accuracy of flood hazard modelling. An exposure analysis of buildings is often utilised by an overlay analysis of map layers representing both the flood and buildings. However, we indicated that the analysis be partly hindered by the characteristics and inaccuracies of the building datasets used and the modelled flood. In flood damage modelling, the average damages calculated from the database were used, as empirical damage data was too general for a detailed flood damage assessment. Damage modelling with empirical and synthetic damage data could be made more reliable through better archiving of actual flood damages and by making more diverse damage estimates of standard buildings.

# TRENDS OF CHANGES OF EXTREME CLIMATE EVENTS IN LATVIA

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Climate change is not only characterized by changes in the mean values, but also by changes in variability of climate indicators and extremes. Just few examples illustrate the threats and significance associated with extreme climate events: extreme heat events – heat wave; extreme precipitations, floods. As it has been stated in several studies just increase of extreme climate events can cause major threat to society and individuals. Often extreme climate events has been identified using internationally agreed, predefined indices that is day count exceeding a fixed threshold, percentile threshold, extreme event duration. In several studies significant increasing trend in Europe of many extreme indexes has been found over the later part of the 20th century. So far studies of the climate change in Latvia and other Baltic countries have been mostly carried out based on trends of changes of mean values.

In this study long-term variability of extreme climate event indicators in Latvia were investigated. To assess trends of changes of extreme climate events, indexes, such as number of extremely hot days, frost days or number of days with heavy precipitations (altogether 17 indexes) were used and compared with indexes characterizing climate. Trend analysis of long term changes of extreme climate events demonstrate significant increase of meteorological events associated with increased summer temperature (for example, number of summer days and tropical nights) and decrease of events associated with extreme temperature events in winter time (number of ice days and frost days). In case of Rīga a definite role may play urban heat island impacts, as far as the trends of many extreme event indices are more expressed than in surrounding areas. Due to climate change and decreasing length of cold days, growing season length is increasing. Also heavy precipitation intensity is increasing.

Analyses of the trends in annual and seasonal precipitation show pronounced intraseasonal and inter-station variations. Overall, increasing trends are evident in precipitation series for the cold period, and monthly precipitation series for most of the stations show increasing trends from December through March. The analysis of the trends in monthly precipitation found a statistically significant decreasing trend only in September and July. Generally, most of meteorological stations exhibited equal tendencies in the given month, but similar physical geographical regions showed clearly expressed trends neither in annual nor monthly precipitation series and it could be due to fact, that spatial distribution of precipitation is very much a local phenomenon. The time series of precipitation in Riga showed an increase in the number of heavy precipitation events.

Amongst factors influencing trends of changes of extreme climate events character of large scale atmospheric circulation processes are discussed. 16 dominant atmospheric circulation patterns were identified and frequency of the recurrence influencing respective weather conditions was studied.

# SKILL ASSESSMENT OF REGIONAL CLIMATE MODELS: HYDROLOGICAL PERSPECTIVE

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Regional climate models (RCMs) provide a useful source of data for assessment of climate change for hydrology. There are numerous RCMs variating in skill in representing the contemporary climate. To assess which is the best a methodology was composed based on skill assessment of temperature, precipitation as well as standard deviation of temperature and precipitation (Sennikovs and Bethers, 2009). In this paper we would like to propose a different skill assessment to improve hydrological results from the time series. This is needed due to problems faced while performing different hydrological calculations. While performing them with the currently available regional climate models (RCM), using various well calibrated hydrological models, it was noted, that most of them have a problem representing spring floods. Due to their inability to represent the scale of the peak.

The goal of our study was to find the cause for this problem, and try to find the best available RCM for hydrological modelling. Our main focus lies on the correlation of temperature and precipitation (T/P) as the hypothesis made was that RCM inability to correctly show the T/P correlation may be the cause for the misrepresentation. To do this we chose 20 RCMs from the PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects) project and RCMs from the ENSEMBLE project for the control period 1961-1990 as well as observations for the given period. Bias-correction was used for the RCM data. Next the T/P correlation was determined for every model and compared with the observed data. Hydrological runs where made for each model to show the correlation of T/P correlation and the models ability to represent the spring floods.

Analysing the results gave us the opportunity, to correctly assess how the T/P correlation effects hydrological modelling. We detected that RCMs have a different T/P correlation than observed data mostly due to higher correlation in the winter months. It was possible to compare different RCMs and how well they cope with the spring floods, so giving the possibility to choose the most suited for hydrology in Latvia. Using this skill assessment gave us an opportunity to improve the quality of hydrological modelling using RCM data.

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# INFLUENCE OF THE HYDROGRAPH SHAPE ON THE SCOUR DEVELOPMENT WITH TIME AT ENGINEERING STRUCTURES IN RIVER FLOW

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Transport system infrastructures, namely roads, bridges, dams, and water intakes in rivers are under permanent impacts of multiple floods. To estimate their safety and stability during scour at hydraulic structure foundations, a multidisciplinary approach, which will involve the principles of hydraulics, hydrology, morphology, geology, and so on, is required.

High floods in Europe during the last decade have destroyed a lot of engineering structures because of the scoured foundations; however, the EU Floods Directive 2007/60/EC does not take into account either increased loads of floods or damage risk estimation and management for engineering structure foundations in river flow.

In spite of the importance and complexity of the phenomena, the estimation and management of flood damage risks for engineering structure foundations in rivers has not yet been studied at all.

During the past few decades, the equilibrium and temporal depths of scour have been studied by different authors. In their studies, the flow parameters at the peak of the flood with unrestricted or restricted duration were used. However, in nature, the flow loads on engineering structures have the form of hydrograph and multiple floods form scour holes.

In the present study, the effects of probability, duration, sequence, and frequency of multiple floods on the safety and stability of engineering structures in river flow are studied. In frame of this study the impact of the floods with different shapes of hydrograph on the scour process is investigated.

The differential equation of equilibrium for the bed sediment movement in clear water conditions was used and the method for computing the scour development with time was elaborated. According to the method, the relative scour depth at the hydraulic structures depends on the following dimensionless parameters: the contraction rate of the flow, kinetic parameter of the open flow, kinetic flow parameter under the bridge, Froude number of open flow, Froude number/slope ratio, relative grain size of the bed material, relative depth of flow, relative local velocity, steady or unsteady flow conditions, relative depth of scour developed during the previous time, stratified bed conditions, as well as the time, probability, duration, frequency, and sequence of the multiple floods, sediment transport conditions, shape of the structures, slope of the wall side, and the angle of the flow crossing.

The tests where made in the conditions: $Fr_m = Fr_n$ (Froude number in models is equal to the Froude number in open flow conditions), horizontal scale was 50, and the time scale was equal to 7.

The method for estimating the scour development with time (Gjunsburgs et al., 2004) was used to perform computer modelling; it allows us to determine the influence the shape of the hydrograph on the scour process near engineering structures in river flow.

Two types of hydrograph shape were studied.

For the first type of hydrograph, the time periods of the rising and recession parts have different ratios, and where equal to 1:2, 1:3, 1:4, 1:6, and 1:8, where the first and second numbers are the rising and recession times of the flood, respectively, but with the same duration of the flood. In the second type of hydrograph the ratio between rising and recession parts was the same, but the time of rising part of the hydrograph remain constant, and duration of the floods was different. The probability of the floods was the same for both types of the hydrograph.

The results for scour development with time obtained in tests and calculations by using the above-mentioned method were similar, namely the rapid development at the start of the scour process and than the gradual reduction with time.

For the first type of the hydrograph, the influence of its shape on the final depth of scour was small, but the scour process was different at the initial stage. According to the calculation results, the scour depth development is more rapid for hydrograph with a higher slope of the rising limb.

For the second type, the rising part of floods was constant, but the recession part increased with every case. The greater the recession time of the floods and the less slope of the recession limb of hydrograph, the greater the depth of scour.

It was found that the shape of the hydrograph affects the depth, width, and volume of the scour hole developed during the floods. The ratio between the rising and recession cycles of the flood impacts the scour development with time. When the depth of scour at hydraulic structures increases, the safety and stability reduces, and if the depth of scour exceeds designed value, the structure can be damaged. The results obtained in this study are presented in tables and figures and confirm our conclusions.

The European flood forecasting system (De Roo et al., 2003) can be used together with the method of scour depth estimation with time (Gjunsburgs et al., 2004); as a result, it would be possible to estimate the safety and stability of the engineering structure foundations in river flow during the maintenance period or at the design stage and to avoid environmental damages and economical losses.

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# THE PROBABILITY OF LOW-FLOW EXTREMES OF THE DAUGAVA RIVER AT DAUGAVPILS

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During this study, the long-term changes in the probability of hydrological droughts (low-flow extremes) of the Middle Daugava River were evaluated. The daily mean discharge data series of the Daugava River at Daugavpils since 1936 were analysed. Probability distribution of the maximum drought event (the relative runoff deficit and the low flow duration) was estimated for the all-year droughts, summer droughts and winter droughts of two 40-years long overlapping observation periods (1936-1977 and 1966-2007, respectively). The discharge data series were obtained from the The Global Runoff Data Centre, 56068 Koblenz, Germany (GRDC, 2008). The task was performed by applying the program *"Nizovka 2003 – Distributions of Low Flow Extremes"* elaborated by the Department of Mathematics and Institute of Hydrology, Agricultural University of Wroclaw.

According to this study, probability distribution of the Daugava's low-flow extremes changed significantly over time. During the last 30-40 years, the probability of large runoff deficit and long duration of the low-flow periods has significantly decreased. The summer and winter low-flow extremes, which were observed in the Daugava River at Daugavpils 30-40 years ago, are less probable now. Such shift could be related to the climate change, especially for the winter season due to higher air temperatures and more frequent snow melts during the last decades (Koļcova et al., 2007).

Along with the existing trends of climate change, further shortening of the winter droughts and less severe discharge deficit of the Daugava River at Daugavpils is expected. This, in turn, could have significant impact on the ecosystems of the Daugava's floodplain lakes: their water chemistry, plant and animal communities, the overgrowing by macrophyta etc. On the other hand, the observed changes in distribution of summer droughts are, probably, related to substantial changes in the land use within the Daugava's drainage basin, the degradation of melioration systems etc.

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# TIME PERIOD DEPENDENCE OF TRENDS IN FINNISH HYDROLOGICAL DATA

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This paper discusses observed changes in the hydrological regime in Finland based on the data by the Finnish Environment Institute. The aspect of this article was to focus on the effect of time period on trend slopes. It stands to reason that trend analysis is dependent on the chosen time period. Lake surface water temperature, lake ice cover and discharge trends were studied for several time periods. Hydrological variables in Finland have records at least since the early 20th century. Some of the ice break-up, freeze-up and discharge data are even available from the mid-1800s.

All data were analysed until 2008 and 2000, with several different time periods. Trends were tested statistically with a non-parametric Mann-Kendall trend test. Trend comparisons were made for time periods of 1961–2008, 1961–2000, 1971–2008, 1971–2000, 1981–2008, and 1981–2000 for all variables. In addition, if several stations had longer periods of records available, additional periods were included. For a couple of the longest time series, trends were also calculated with Mann-Kendall (Sen's slope) method year by year until 2008, in order to see changes in the trend slope and significance for the whole observation period.

For water temperature, eight stations with at least 35 years of records were included in this study. The longest surface water time series date back to 1916, while the records are considered reliable since 1924. Data included daily surface water temperature measurements, observed at 8 am during the open water period. Maximum surface temperature of the season, as well as mean monthly temperatures of June, July, and August were included in the trend study.

There are dozens of time series of lake ice break-ups and freeze-ups in Finland. In this study, three longest series were investigated. The observations started at lake Kallavesi in spring 1822/autumn 1833, at lake Näsijärvi in 1836, and at lake Oulujärvi in 1854. The date of permanent freezing of the whole area visible from the observation site was interpreted as the freezing date in this study. The break-up date was chosen as the date when ice was no longer visible from the observation site.

Ice thickness data from 23 lake stations were included in this study, all stations having records at least from early 1960s and observations are still continuing. Eight of sites have records from the 1910s. The ice thickness is measured in the wintertime every 10th, 20th and 30th of the month since the late 1970s. Before that, measurements were made every 15th and 30th of the month. Average value from three different drill holes is defined as the official record. For all winters maximum ice thicknesses were collected, and trend tests done for them.

The discharge data included daily mean discharges for thirteen different stations. Both rivers and lake outlets are included in this investigation. Discharges have been determined from water level records by the rating curve method. All the studied sites are unregulated. Trend analysis was applied to annual mean (MQ) discharges, seasonal means: winter (DJF), spring (MAM), summer (JJA), autumn (SON), annual maximum (HQ), and annual minimum (LQ) flows. Seasonal discharges were calculated from monthly means.

The level of 5% was used for critical significance. With Mann-Kendall trend test, magnitude was calculated using a non-parametric linear Sen's slope estimator. M-K trends were calculated with 'MAKESENS', Excel-program provided by the Finnish Meteorological Institute.

Analysis showed that different time periods have totally different trends in some variables. Especially lake ice thickness and river discharge have different characteristics for different time periods. Some of variables did not have much difference between the periods.

Surface water temperature trends were calculated only from the 1960s, because only a few time series were available earlier. All trends that were found for the surface water temperature were positive. There were no trends for June mean temperature for any of the time periods. Number of trends of maximum surface temperature and mean July temperature were almost the same from the 1960s and 1980s. From beginning of the 1970s only a few trends were found. The largest number of trends was discovered for the mean August temperature.

All three break-up and freeze-up time series had statistically significant changes from mid-1800s until present. Break-ups have become earlier and freeze-ups later in all statistically significant trends. For periods of 1961–2000 and 1981–2000 no trends were found for any of those three sites. For both break-up and freeze-up, the trend slope has become larger after the 1950s, although only some time periods are statistically significant.

From the mid-1910s to the 2000s both increasing and decreasing trends on maximum ice thickness were found at some sites. The largest number of positive trends was for the period 1961–2000. From the early 1980s until 2008 or 2000, statistically significant positive trends were not found, neither for the period 1971–2008. Generally, the very same observation site did not have both statistically significant increasing and decreasing trends for different time periods. There were only a couple of cases of this kind.

From the 1910s until the early 21st century, there were no overall changes in mean annual discharges, high flows, and mean summer discharges or mean autumn discharges. In 1911–2008 low flows, mean winter flows and mean spring flows had increased at about half of the observation sites with records since the early 1900s. For recent 20–30 years a number of summer and autumn trends were slightly higher than for longer periods. In recent

30 years no changes in mean winter discharges were found. From the 1980s mean annual flows and high flows had decreased in some places in central Finland. This results from wet years in the early 1980s. For longest time series (Muroleenkoski), the trend slope and its significance were calculated year by year from 1863 until the present. Trend varies from statistically significant positive to statistically significant negative during the long time period. Trend slope is above the zero line (positive) until the end of 1960s, when it dips rapidly to negative side.

This study shows that chosen time period has an effect on the trends detected. In some cases trends were similar no matter which time period was used, but in some cases trends were even opposite in the different time periods. Therefore it is important to state, which time period the trend tests are applied. In shorter time periods trend slope changes are larger year by year than in long time periods.

# HYDROLOGICAL PROJECTIONS FOR CHANGES IN FLOOD FREQUENCY UNDER A FUTURE CLIMATE IN NORWAY AND THEIR UNCERTAINTIES

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An issue which can arise in the practical application of hydrological projections in climate change impact studies for flood risk management, is how to take account of the so-called 'uncertainty' in model results. Given that, such applications often require quantitative estimates that can be implemented with a sufficient degree of confidence, the plethora of model results available from different climate models and methods and their differences can lead to a perception that their use in climate change adaptation is premature. In this paper, we present an application of ensemble methods for estimating likely changes in flooding in Norway under a future 2071-2100 climate. The approach is based on time series input data derived from multiple GCM/RCM combinations, run under three emission scenarios (A1B, A2 and B2), and downscaled to a local 1 by 1 km grid using two alternative methods (delta change and empirical adjustment). These input timeseries are used to drive hydrological models based on 25 calibrated parameter sets for each of 115 catchments throughout Norway. The approach yields several hundred scenarios for each catchment, from which cumulative probability distribution functions (cdfs) for the range of results can be constructed and used to specify the likelihood of a change of a given magnitude. The contribution of the various possible sources to the total 'sampled' uncertainty can also be assessed by comparing the summed differences between the cdfs for each of the individual cases. An example of the methodology was previously presented in Lawrence et al. (2008) as applied to peak flows ($Q_{95}$) and to the mean annual flood (Lawrence, 2010) in four Norwegian catchments. Here, the approach has been extended to consider a large number of catchments (with areas ranging from 6 to ~15500 km$^2$) distributed throughout Norway. In addition, practical application in planning for flood management in Norway requires that the 200-year return period is considered. The simulated discharge time series are therefore used to fit extreme value distributions from which likely changes in the frequency of floods of a given return period under the current climate are estimated. The fitting of an extreme value function introduces an additional contribution to the total uncertainty, which has also been considered here.

Results derived from the annual maximum flood series, from which the 200-year flood was estimated based on a fitted Generalised Extreme Value

(GEV) distribution, indicate a general regional pattern in which the magnitude of the 200-year flood is expected to increase in western and southwestern Norway and in coastal areas. In more inland areas, currently dominated by flooding during the snowmelt period, little change or a slight decrease in the magnitude of the 200-year flood is projected. These results are consistent with previous analyses of hydrological projections for changes in the, for example, 50-year flood in Norway for the period 2071-2100. Additionally, analysis of the range of results for individual catchments suggests that the projected changes for catchments currently dominated by snowmelt floods are associated with larger uncertainties than projections for catchments dominated by rainfall flooding. The catchments exhibiting the largest uncertainties in the results, however, are those which lie in a transitional zone between rainfall dominated and snowmelt dominated flooding, under the current climate. This larger uncertainty is most likely caused by a potential shift from snowmelt to rainfall dominance in the floods represented by the annual maximum flood series, due to the warmer temperatures in the 2071-2100 climate. In fact, an increase in the occurrence of rainfall-induced floods within the annual maximum flood series was found in all of the catchments currently dominated by annual snowmelt floods. In several of the smaller catchments amongst these, the largest event within the 30-year annual maximum flood series for the 2071-2100 is rainfall-induced, incurring in the autumn. The events are, however, isolated, such that the fitted GEV function largely reflects the pattern of snowmelt flooding, and thus a decrease in the frequency of today's 200-year flood is projected.

The relative contributions to the uncertainty in the projections for each catchment were analysed with reference to the SRES/GCM/RCM combinations, the HBV hydrological parameter sets for each calibrated model and the fitted parameters for the GEV distribution for the return period projections. In many cases, the magnitude of HBV parameter uncertainty is at least as large as the spread between the projections for individual RCMs. HBV parameter uncertainty, though, is particular pronounced in the transitional areas where rainfall floods are expected to occur more frequently. Uncertainty associated with the fitting of the extreme value distribution to the annual maximum series for the estimation of a 200-year flood is, however, often larger than the other sources of sampled uncertainty.

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# EXTREME HYDROLOGICAL EVENTS ON THE LOWER DANUBE AND IN THE MOUTH AREA DURING RECENT DECADES

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Late in the 20th century and early in the 21st century, a frequency of catastrophic hydrological events on the Danube River increased. The joint Russian-Ukrainian studies in the lower Danube basin (Hydrology…, 2004) revealed significant trends in many hydrometeorological quantities. In 1974–2002, the air and water temperature and atmospheric precipitation amount increased, ice conditions grew mild, and, despite water intake for economic needs, the Danube River water discharge increased. Simultaneously, in recent decades, the occurrence frequency of extreme hydrological events in the Danube basin increased; for example, significant floods occurred in 1980, 1981, 1988, 1999, and 2005. On this list are catastrophic floods in August, 2002 and March–June, 2006 (Mikhailov et al., 2004; 2008). The above-mentioned events on the Danube River and catastrophic freshets in the basins of the Elbe, Kuban, Terek, and other rivers in recent years confirm the suggestions that global climate warming, intensification of synoptic processes, and increment in the total amount of precipitation in some of the planet's regions can cause increasing frequency of extreme hydrological events.

In a frame of our investigations, we considered:

(i) Formation and transformation of the catastrophic rainfall flood along the Danube River in August, 2002. The preceding synoptic situation and the basic features of the flood movement along the Danube River were revealed. In 2002, torrential rains on the Upper and Middle Danube triggered two extreme rainfall flood waves. At some gauging stations on the Middle and Lower Danube (Bratislava, Budapest, and others), the August flood levels exceeded historical maxima and caused a catastrophic inundation. Owing to the timely release of water from the Iron Gate reservoir, the rain flood was smoothed out and turned into a flat release wave on the Lower Danube (Mikhailov et al., 2004)

(ii) Formation of the extreme spring–summer flood in March–June, 2006. A certain specific feature of the 2006 flood is as follows: large resources of snow by the beginning of the unusual early melting, its active development, heavy rains in the Danube basin, and simultaneous flood over the whole basin, including large tributaries.

In general, development of the combined melting and rain flood on the Danube River and its transformation along the river in 2006 were similar to analogous developments of this phase of the water regime in other high-water years, including those before the Iron Gate I reservoir construction. Due to low useful volume (about 3 $km^3$), this reservoir cannot regulate the immense runoff of the Danube during a large flood (not less than 100 $km^3$). At a number of gauging stations on the Lower Danube, water levels also exceeded historical maxima. On the Ukrainian reach of the Danube River, the greatest observed levels did not exceeded historical maxima. It could be explained by flood wave "smoothing out" seaward, typical to for all river mouth reaches. The rise of water levels in the mouth area was accompanied by strong storm surges and led to inundation (Mikhailov et al., 2008).

(iii) Peculiarities of the extreme low water period (drought) in August–October, 2003. A low precipitation (rain, snow), reported by the Danube River basin in 2003, and the hottest summer led to the formation of the extreme low water period in August–October, 2003, when water levels on the Lower Danube fell to the lowest marks.

In our study, we used the results of join Russian and Ukrainian investigations of the regime of the Lower Danube and its delta, and hydrological and meteorological observational data of Danube Hydrometeorological Observatory (Izmail, Ukraine). Long-term trends in changes in many hydrometeorological characteristics were revealed. During recent decades, the air and water temperature, the amount of precipitation increased. The water runoff of the Lower Danube increased in spite of water withdrawal and evaporation losses from reservoirs. The impact of above-mentioned extreme events and other changes in regime of the Danube River on the hydrological and morphological processes in the mouth area including delta and nearshore zone of the Black Sea was investigated.

In the future, global climate warming, intensification of synoptic processes, increment in the total amount of precipitation and its irregularity can result in an increase in a frequency of extreme hydrological events. Information about the extreme hydrological events taking place in the Danube Basin can be of interest of researchers because many rivers are subject to a strong effect of climatic changes and can have similar regime features.

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# RAINFALL AND CLIMATE SCENARIOS FOR DESIGN OF DRAINAGE SYSTEM

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The fact that climate change is affecting the intensity and frequency of rainfall is well accepted in the scientific community. Actual projections provided by climate models suggest that the probability of occurrence of intense rainfall will change in future climate scenarios due to increasing concentrations of greenhouse gases. Considering that the design of urban drainage systems is based on statistical analysis of past events, a change in the intensity and frequency of extreme rainfall events will most probably result in more problems for the drainage system. The design criteria must therefore be revised to take into consideration possible changes induced by climate change. This paper investigates the extreme events of rainfall data and climatic scenarios under climate change to design proper drainage system for two cities of India, National Capital Territory of Delhi and Financial hub Mumbai. This procedure integrates information about climate projections and extreme rainfall over the region under consideration in the past to find 50 year reoccurrence period. This will also integrates information about expected level of performance (or acceptable level of Risk) and expected lifetime of the infrastructure system. Analysis has revealed that the present drainage system of both these cities is far from sufficient to cope up the growing demand. There is need for revolutionizing the drainage system for sustainable development.

# THE LINK BETWEEN ATMOSPHERIC CIRCULATION AND LARGE RAINFALL FLOODS IN NORWAY

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Norway is frequently exposed to frontal systems from the Atlantic and the Norwegian Ocean causing heavy precipitation near the west coast. Long mountain ranges cause most of the precipitation to occur on the windward side of the water divide. The precipitation is much less on the lee side of the mountain ranges. Annually 5400 mm precipitation occur at the wettest location in the west, while less that 300 mm occur in some inland valleys east of the water divide. Although the transport of humid air masses from the west is a dominant circulation type; storm trajectories from southeast to southwest does also occur causing occasionally heavy precipitation in areas east of the water divide in the normally drier basins in east Norway.

Based on data on historical floods, daily rainfall data back to 1895 and classification of daily weather types, the link between rainfall-generated flood events and the weather types have been examined for different districts in Norway. A motivation for this study has been to obtain an improved background for interpreting the consequences of shifts in the atmospheric circulating for the occurrences of floods in a changing climate.

The most hazardous storm trajectory causing severe floods in southeast Norway are fronts moving from the European mainland from south/southeast i.e. meridianal weather types. The south-eastern weather type is known as Vb-tief or Vb-zug (Van Bebber, 1891) and occurs typically in July or August. The circulation is characterised by blocking anti-cyclones in the North Atlantic and over Finland to the Baltic States or Russia. The low is moving from the Mediterranean east of the Alps and towards northeast. The temperature and humidity is very high in the warm sector, while cold air masses further west caused very high rainfall from the quasi-stationary front. Many of the recent major floods such as the 1987 flood in the Oder, the 2002 flood in the Elbe and the 2005 flood in Switzerland were caused by this weather type. The most serious flood of this type occurred in east Norway in July 1789 causing enormous losses and killed around 80 people. Other weaker events have caused extensive damage in east Norway in late August of the year 1938, and in Mid-Norway in August 1940.

Air masses from southwest have caused large floods both in Britain and in Norway. These floods occur often in the summer or autumn. The source of these air-masses has occasionally been remnants of tropical cyclones, which has been absorbed by extra-tropical cyclones as they moved towards northeast. The tropical storms does not move towards northwest Europe in most years, but occasionally sequences of storms are able to penetrate even to Norway. A pronounced sequence occurred 1883-1885. More recently a pronounced clustering of events occurred in 2004-2006. Most of these events cause 100 – 200 mm rainfall at location close to the outer coast from the North Sea coast to the Lofoten district in North Norway. Tropical hurricane Faith affected most of west Norway 7.Sept 1966, and remnants of tropical hurricanes Maria and Nate caused severe flooding and land slides in the Bergen district 14.Sept. 2005. Remnants of a tropical storm caused 311 mm rainfall over 24 hours in the Bergen district. Warm and humid air masses from the central Atlantic cause also heavy rainfall even if no remnants of a tropical storm are embedded in the low. This occurred 14.Nov. 2005 in the Bergen district.

Extra-tropical cyclones cause also heavy and often long duration precipitation in the west, linked to westerly storm trajectories. A total of 480 mm rainfall was observed in four days in late November 1940, causing a severe flood in many rivers. Some of the large events in the rivers in Mid-Norway are linked to storm trajectories from northwest, because mountain ranges to the south and west prevent precipitation to penetrate from these directions. Large rainfalls event in much of west and north Norway occur, when there is a pronounced anti-cyclone situated over Britain and/or the European mainland. Rainfall floods near the coast in south and southwest occur mostly when there is a low near Britain.

Although the largest rainfall floods in southeast Norway are caused by the southerly meridional weather types, most rainfall events occur as a result of westerly weather types.

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**Session 7**

# GROUNDWATER AND SURFACE WATER INTERACTIONS

# EFFECTS OF KARST PROCESSES ON SURFACE WATER AND GROUNDWATER HYDROLOGY AT SKAISTKALNE VICINITY, LATVIA

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There are karst processes present in southern Latvia, around Skaistkalne town, where gypsum layers of Upper Devonian Salaspils Formation are dissolved forming underground fractures, channels, and caves, as well as sinkholes, when overlying glacial deposits have collapsed. Earlier studies (Narbutas et. al, 2005) have shown that there is an underground hydraulic connection between Iecava and Memele rivers about 5 km upstream Skaistkalne town.

To study the effect of karst processes on surface water and groundwater hydrology the data on water levels, river discharge, tracer test results, analysis of water chemistry data were evaluated and processed, and hydrogeological model of the area was built in order to simulate groundwater and surface water interaction in high and low water seasons.

Water level in the Iecava River at the study area is 34 m a.s.l. in average, but in the Memele River – only 28 m a.s.l.; groundwater level in Salaspils aquifer varies between 29 and 33 m a.s.l. in monitoring wells located between the both rivers. The water flow is directed southwards, to the Memele River. Sediments of Salaspils Formation outcrop at the Iecava and Memele river bottoms, facilitating surface water and groundwater interaction and surface water infiltration from the Iecava River to Salaspils aquifer. The aquifer conduits water flow from the Iecava River to the Memele River.

The fluorescine tracer was injected at the Iecava River during the tracer test. The tracer dye was observed in karst lakes between Iecava and Memele rivers, at springs in the Memele River banks and in the Memele River. The test proved hydraulic connection of the both rivers.

Field measurements of water conductivity in the Iecava and Memele rivers and monitoring wells shows that there is no groundwater discharge in the Iecava River from the karst aquifer, and the main groundwater discharge from karst aquifer occurs in the Memele River because:

1) water conductivity in the Iecava River is 600-700 $\mu$S/cm,
2) water conductivity in the Memele River varies from 780 to 1400 $\mu$S/cm,
3) water conductivity of groundwater in karst aquifer varies from 1200 to more than 2500 $\mu$S/cm.

Water in the Iecava River is bicarbonate calcium type, but groundwater in karst aquifer is sulphate calcium type. The water of the Memele River changes from bicarbonate calcium type to bicarbonate – sulphate calcium type at the area, where the main groundwater discharge takes place near Verdini settlement. Although karst aquifer is distributed all around Skaistkalne, intensive groundwater discharge and Iecava – Memele rivers hydraulic connection is observed just within limited extent near Verdini settlement.

The study shows that fracture zones and channels forming in aquifers due to the karst processes are very important water conduits within aquifer, but their location and distribution is limited by a number of factors that should be studied in future.

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# MODELLING THE WATER FLUX EXCHANGE BETWEEN NORWEGIAN AQUIFERS AND RIVERS AND CLIMATE CHANGE EFFECTS

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Building up a groundwater model to simulate the interaction between a groundwater aquifer and its hydraulically connected river is straight forward as long as the necessary input data are available. In the past, obtaining input data was an unsurpassable obstacle. One had to collect river elevation data at several locations along the river and estimate the daily groundwater recharge which requires a full set of daily meteorological data and a model for the unsaturated zone to estimate the soil water deficit. Assuming that a conventional groundwater model for the aquifer has already been developed one can thus perform water flux exchange estimations.

The necessity for such estimations has lead to the development of integrated models which combine a groundwater model (often capable of unsaturated zone simulation as well) with a river simulation model. This reduces the need for river elevation data which are effectively replaced by meteorological data and river discharge data, but of course requires a river model to be built.

The estimations obtained herein are in essence based on such a model integration approach although this integration is not automated. In other words there is no dynamic interaction between the groundwater and river models. Three models have been used. The FEFLOW groundwater model for the water flux estimations, the HBV distributed hydrological model for obtaining river discharge and groundwater recharge, and the MIKE11 model to convert river discharge into river water levels.

Water flux estimations have been carried out for two aquifers which have approximately the same areal size and are connected to rivers with different annual discharge behaviours, but none the less have experienced severe flooding. The results obtained for the period 1961-1990 (normal period) show that bank storage takes place for both aquifers during the flood period in April-May each year and that the direction of flow is influenced primarily by the river water levels and to a much lesser degree by groundwater recharge.

Once the models were set up it required only a little extra effort to simulate climate change scenarios. The HBV model has been used to simulate many different scenarios and these became readily available for groundwater simulations. A scenario with moderate $CO_2$ emissions was chosen for the period 2071-2100. The results clearly show a shift when compare to the normal water flux curves as well as anomalies during the winter period.

# GROUNDWATER LEVELS AROUND HÁLSLÓN RESERVOIR, EAST ICELAND, BEFORE AND AFTER IMPOUNDING

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Hálslón reservoir in East Iceland is contained by three dams, the largest one being a 198 m high CFRD on the southern end of the Dimmugljúfur gorge. Groundwater level from boreholes and several other parameters are used to build a groundwater model showing changes in groundwater levels following impounding of the 61 km² reservoir. The key contributors influencing the groundwater levels are the reservoir water level and the water level of the river downstream of the main dam in the Dimmugljúfur gorge.

The Kárahnjúkar Hydropower Plant is situated in East Iceland. It's 2100 Gl storage reservoir, Hálslón, is connected to the power house by a 7 m wide, 40 km long headrace tunnel. The glacial river Jökulsá á Dal, being harnessed, runs north from the Vatnajökull glacier and has carved a gorge up to 200 m deep at Kárahnjúkar. At the Kárahnjúkar dam site the river lay in a 50 m deep gorge cutting hyaloclastite formation of pillow lava, breccias and tuff, formed during a subglacial volcanic eruption and olivine basalt compound flows. Permeability values in the highly heterogeneous hyaloclastite formations range from very low to very high (Guðmundsson et al. 1999).

Several faults were observed during the research drilling, excavation and building of the dams. The faults have a general direction of NE-SW extending from Sauðárdalur valley to Kárahnjúkur and some of them converging with the gorge north of the dam site. The faults vary in width ranging from mere centimetres to several decimetres. They are usually filled with mostly well cemented rock debris (Sæmundsson et al. 2005). The bedrock below the 198 m high main dam was extensively sealed with a grouting curtain reaching down to 100 m below the plinth.

Groundwater has been monitored in the Kárahnjúkar area from 1998 so a fairly accurate picture of groundwater conditions exists. Prior to the harnessing of the river, groundwater in the southern part of the observation area, was a couple of meters below ground surface on the slopes above the river but connected to the river level down in the valley. Further away from the river where the land is flat numerous lakes show that the groundwater level is close to the surface. In the hyaloclastite ridges on the west bank groundwater is deep down due to high permeability. Around Sauðárdalur valley the groundwater level is at about 10 m depth below surface and further north, on higher ground, the depth is 20-30 m. On the east bank closer to

Kárahnjúkur, the depth of the groundwater increases as the river cuts deeper into the plateau draining the surroundings. In Kárahnjúkur the groundwater used to be at about 60 m depth as measured up in the slopes. West of the main dam site groundwater used to be 80-100 m below surface. This is mainly because of the prominent faults on the western bank of the reservoir draining the groundwater into the gorge. In the valley floor of Sauðárdalur groundwater was close to the surface in gravel fillings (usually within 2 m) and in Desjarárdalur valley the groundwater was at 5-10 m depth.

The presence of the reservoir raises the groundwater level in its vicinity. As soon as impounding started in late September 2006 groundwater rose west of the reservoir where groundwater level had been very low before. In places where groundwater level was higher than reservoir level, groundwater was not affected. The reservoir reached its maximum elevation in October 2007. No major leakage has been observed and total leakage through the main dam and its immediate surroundings amounts to about 270 l/s. In the southern part of the area groundwater was close to the surface prior to impounding and thus the change is minimal. In the middle section groundwater was close to the surface in vegetated areas but in the hyaloclastite hills, groundwater has not risen due to high permeability of the formation. In Sauðárdalur north of Sauðárdalur dam groundwater has risen by up to 1 m and some of the boreholes down the valley are artesian when the reservoir level is high. In Desjarárdalur valley east of Kárahnjúkur groundwater has risen by 10 m close to the dam and about 5 m lower down in the valley.

The greatest change in groundwater elevation has been observed on the northwest side of the reservoir. Prior to impounding groundwater was very low rising slowly from the river inland. This was due to numerous faults and fractures in the hyaloclastite formations and the underlying basalt. The faults permitted easy passage for the groundwater into the gorge draining the area northwest of the proposed reservoir. This zone of high secondary permeability seems to be up to 1 km wide. The introduction of the reservoir with its 625 m asl maximum water level raises the groundwater surface more than 100 m next to the shore northwest of the reservoir but further inland the increase is less than 20 m and in Sauðárdalur a 1 m increase in groundwater level is primarily due to controlled leakage under the Sauðárdalur dam. Permeability is high in the hyaloclastite and thus the passage of water ought to be mainly north towards Sauðárdalur. As the faults lie parallel to the reservoir shoreline they controle leakage down into the Dimmugljúfur gorge leaving a 1 to 1.5 km broad zone of affected groundwater. To the east in the Kárahnjúkar hyaloclastite, high permeability directs the seepage water freely into the gorge and in Desjarárdalur groundwater level has risen by about 5 m. Seepage and small springs are seen on the surface but the affected area is 1 to 2 km downstream from the dam.

Hálslón reservoir controls groundwater level in it's vicinity. In the southern part of the observation area the changes are in the order of few meters. To the northeast of the reservoir the change of groundwater level is in the order of 5-10 m and to the northwest of the reservoir the change is in the order of 100 m. Around the northern part of the reservoir the area of raised groundwater level does not reach far due to high permeability in the hyaloclastite formations and secondary permeability.

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# CORRELATIONS BETWEEN THE QUALITY OF SURFACE WATER (STREAM) AND GROUND WATER IN THE LITHUANIAN KARST ZONE

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Transition of substances from one component into another depends on many different factors. Concentration of the main nutrients (nitrogen and phosphorus) in the basin first of all depends on physical and chemical properties of the soil, and on the atmospheric moisture regime.

Changes and fluctuation of water balance elements enhance more intensive seasonal and yearly hydro-chemical fluctuations. Hydrological transformation system is distinct for the changes of parameters into one direction. When the accumulating and infiltrating capacity of geosystems – basins are increasing, their total moisture due to surface and subsurface abilities is also increasing. In the case of decreasing accumulating capacity, the increase in basin infiltration is observed, not in their moisture (Tilickis, 2005).

In river valleys where ground water is closely interrelated to surface water, amplitudes of water level fluctuations much depend on surface water fluctuations and distance to a water body. The most significant ground water fluctuations are observed in places where the thickness of aeration zone reaches 3-4 m (Giedraitiene and Domasevicius, 1996). In autumn, during spring rainfall or in summer, ground water inflow decrease nitrate concentration in the stream (Grimaldi et al., 2004).

The Northern Lithuanian karst zone is unique in its geological and hydrological conditions. The follow-up of karst sinkholes create suitable conditions for surface water and pollutants to get into the subsurface water.

The object of the work is to determine correlations of the change in nitrate nitrogen concentration between the karst zone of the surface water and ground water in the drained stream watershed.

The studies were carried out in moraine sandy loam and peat soils of Lithuanian active karst zone. The site is situated at the source of stream G-1 (tributary of the Apascia, area 1.63 km$^2$). The layers of gypsum-dolomite occur at 5-10 m depth from the soil surface (gypsum layers occur deeper) of the research site.

The quality of ground water was observed in two boreholes at a distance of 1.2 km from each other. The borehole 6 (depth 6 m) was arranged in a sandy loam and sandy light clay loam soil, in a drained area at a distance of 3 m from the stream watershed G-1; the borehole 2 (depth 4 m) was arranged in a peat soil, between the stream G-1 and a sinkhole.

Water quality was measured in the drainage the outlet of which is at 10 m distance from the borehole 6. The area of the drainage system is over grown with perennial grass.

Water quality of the stream was measured nearby the boreholes. Water samples were taken once per month at the same spot in all study places.

The nitrate nitrogen was established by photo-colorimetric method by analyzer "FIA star 5012 system".

The ground water level was nearer to the ground surface in the well 2 (in the research period, the average water level was 107 cm, the minimum water level was 55 cm, and the maximum water level was 158 cm) than in the well 6 (178 cm, 79 cm and 277 cm respectively). During the cold period (November – March) of the year the stream discharge was up to 5.5 times higher, and ground water level was up to 1.3 times closer to the ground surface, compared to the warm period (April – October) of the year. Higher stream water discharges occurred in cases when ground water was near the ground surface. As the correlation analysis has proved, during the cold period of the year the fluctuations of ground level determined the changes of stream discharges by 29-42%. No similar relation was observed during the warm period of the year.

The highest nitrate nitrogen ($N\text{-}NO_3$) concentration was determined in the drain water, less – in the stream water, and the least in the ground (borehole) water. In the well located near the sinkhole, the nitrate nitrogen concentration was 1.7 times higher than in the well arranged in the drained area.

As the study data has shown, changes in $N\text{-}NO_3$ concentrations contained in surface (stream) water and subsurface (drainage and ground water) are interrelated and of seasonable nature. During the cold period of the year the average $N\text{-}NO_3$ concentration contained in the surface water was higher than in the warm period of the year. In subsurface water, on the contrary, $N\text{-}NO_3$ concentration was higher in the warm period of the year. This shows different conditions for hydro-chemical processes to occur in surface and subsurface water.

When the ground water level fluctuated at a distance less than 120 cm from the ground surface, the strongest correlation (determination factor $r^2=0.75\text{-}0.85$) of the change in $N\text{-}NO_3$ concentration in the ground, drain, and stream water was identified. With the decrease of the ground water level, the change of $N\text{-}NO_3$ concentration in the water was less related to the drain and stream water quality. However, correlations between the quality of the drain and stream water have maintained strong ($r^2=0.46$). Large amounts of nitrogen are leached through drains; which determines the concentrations of this element contained in stream water.

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# THE IMPACT OF OIL SHALE MINE WATER IN THE RIVER PURTSE HYDROLOGICAL REGIME OF NORTH EAST ESTONIA

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The impact of mining on the river run-off and catchment area is still rather unexplored and has only recently been studied in Estonia. This research concerns the impact of oil shale mine water directed into the River Purtse which is classified as medium size river in Estonia (the length of river is 26-100 km). Previous research (Rätsep and Liblik, 2001) shows the average mine water content in the River Purtse run-off is 30 %. This research does not identify the amount of extra groundwater in the mine water, which raises the amount of the river run-off.

To study the changes of the River Purtse and area hydrological regime during the oil shale mining development, we analyse the mine water effect to the run-off during the high and low season. In comparison, data of the River Keila was used to illustrate the natural state river. The River Keila has been selected because, in natural conditions, the River Purtse and River Keila catchment area, hydrogeology and hydrological regime appear similar. Therefore, they are excellent study areas to research the impact of the mining activity to the run-off and catchment area.

The present paper regime shift is presented using the Gumbel method and Rodionov algorithm to study hydrological changes in the River Keila and River Purtse catchment area. Rodionov algorithm was developed in Washington University (Rodionov, 2004) and based on a sequential t-test analysis. In our analysis we have used recorded annual data of oil shale mine water, precipitation and observer rivers run-off, which were measured daily during the period 1923–2005.

The Estonian oil shale deposit is situated in the North East Estonia region. Since 1916, it's has been increased in area to approximately 430 km$^2$. The River Purtse and River Pühajõe are both located in that mining area. Altogether, in these catchment areas there have been 15 mines and opencasts. At the present time, only 4 mines are operating in the River Purtse and there are no open mines in the River Pühajõe catchment area. All together 20 % of the River Purtse and about 50 % of the River Pühajõe catchment area is on primary impact by mining area. The River Keila is locating about 150 km from oil shale mining area in west, its run-off and catchment area has never been affected by mine water or mining area.

The Rodionov algorithm illustrates the changes in the River Purtse run-off regime shift are similar to that of the River Keila. At same time model divides the amount of mine water to periods which correspond clearly with mining development periods in the River Purtse catchment area. To analyse the River Keila and River Purtse 25 % higher annual river run-off return period, the main frequency factor is precipitation rather than mine water. Therefore, mine water discharge does not affect medium river run-off annually but seasonally.

In Estonian rivers, the high water season usually occurs in March and April. Seasonal flooding starts with snow melting and arrival of spring precipitation. The natural river average flooding period in Estonia is up to 43 days. In the case of River Purtse, the average flooding period is 55 days. Furthermore, the amount of maximum run-off is lower than that in the River Keila. Another difference is the flooding season starting time. In the same climate conditions the River Purtse flooding season starts about 4-5 days later than in a natural river. This is a time when snow water is infiltrating to the mine and directed to the rivers. We can also see differences between natural and mining area rivers in low water season which occur in summer time June to July. During this time, lots of medium size river run-off can be minimal. In contrast, the River Purtse and flow is more consistent.

Results of the Rodionov algorithm analysis identifies two different hydrological periods of the River Purtse in low season. Prior to 1974 the annual low season run-off was much lower than subsequent following years. In the River Keila case study there is no regime shift during on that time. Factors responsible for regime shift are the sudden rise in mine water during the 1970s. At the present time official mine water discharge amount is much lower than in the 1970s, although the free flow from closed mines continues. Secondary is the rise in precipitation but it does not occur in the River Keila.

Present analysis shows that the impact of mine water annually to the medium size river hydrological regime is minimal. On the contrary, mine water discharge can affect the high and low water season period as well as the run-off high and low peak. Furthermore, the high season flooding period is longer but the run-off peak is not that high than in natural rivers.

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# MODELLING OF GROUNDWATER TABLE FLUCTUATIONS IN AGRICULTURAL MONITORING STATIONS

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The objective of the presented study is to investigate the overall status of the fluctuations of groundwater table and to evaluate the possibility to use modeling for simulation of groundwater table. Shallow groundwater is a major natural resource and an integral part of the hydrological cycle. Surface water and shallow groundwater interactions could be studied with regard of climate change. However, it is important to consider that climate change could have a significant impact on many aspects of the hydrological processes and groundwater table.

Water table of groundwater in unconfined aquifer is determined by a variety of factors, where the petrographic properties of the vadose and groundwater saturated zone, and the regional hydrological, hydrodynamic conditions and soil water balance are the major natural factors. In agricultural fields additional to mentioned factors, groundwater table fluctuations are also highly influenced by anthropogenic impacts influences, in particular land use, subsurface drainage.

In 2006 monitoring of groundwater table in Latvia have been started in three agricultural run-off monitoring stations (Auce, Berze, and Mellupite) using 10 observation wells.

Conceptual groundwater table model METUL by Krams and Ziverts (1993) was calibrated using measurements of the daily groundwater table fluctuations during the period 2006–2009. This model is site oriented two-dimensional mathematical model based on daily weather data. Data for groundwater level modeling are divided in two parts. Meteorological data (precipitation, air temperature, relative humidity) are using for model data input and groundwater table observation data (borehole logger data) – for model calibration process.

In previous mentioned monitoring stations groundwater table and temperature measurements of the shallow groundwater wells were carried out by data longer (Geolog Micro) with one hour frequency and average estimation for a day.

Meteorological input data from nearest meteorological stations Saldus and Dobele were used.

Water balance for model calibration is three parts: estimation of snow cover, active soil zone of moisture balance and groundwater balance together with capillary fringe.

Simulated groundwater table could be compared for both reference period (1991-2009) and future period (2071-2100). Impact of climate change is based on the assessment of groundwater table mean and annual peak values. This result suggests that future groundwater table's variations might be higher than currently expected.

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