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Status and Perspectives of Hydrology in Small Basins

IHP – International Hydrological Programme of UNESCO
HWRP – Hydrology and Water Resources Programme of WMO

Status and Perspectives of Hydrology in Small Basins

Results and recommendations of the International Workshop in Goslar-Hahnenklee, Germany, 2009 and Inventory of Small Hydrological Research Basins

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Deutsches IHP/HWRP National Committee

BfG – Federal Institute of Hydrology, Koblenz

HWRP – Hydrology and Water Resources Programme of WMO

United Nations Educational, Scientific and Cultural Organization · International Hydrological Programme

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Foreword

Supporting research in small hydrological basins has been a focal area for the German IHP/HWRP National Committee. As from the beginning of the hydrological decade (IHD) of UNESCO in 1965, the German IHP National Committee has devoted itself to establishing and promoting small hydrological research basins.

On the basis of the results of the first stage (1975 – 1980) of the IHP of UNESCO, focusing on the "development of investigations on representative and experimental basins", and as a contribution to the second stage 1981 – 86, a compilation of the hydrological research basins in the Federal Republic of Germany was developed and published as IHP/OHP-Berichte 1983. In 1985, the volume "Recommendations for the Evaluation of Measurement Results from Small Research Basins" was presented as part of this series. In 1986, the latter was one of the first reports published in English. Also in the former GDR small hydrological test basins were operated. After the reunification of the two German states and the merger of the two National Committees in 1990, the topic has been followed up. In 1995, a report with recommendations on the establishment and operation of small hydrological research basins was issued, while an updated compilation of hydrological research basins in Germany was published in 2003.

All of these activities were supported by the national IHP/HWRP working group "FRIEND/ERB".

The present report continues the efforts of the German IHP/HWRP National Committee to support small hydrological research basins. This time, however, it does go beyond national boundaries and highlights research activities in small hydrological basins by means of generic examples.

The focus is on discussing the advantages of data collection and knowledge enhancement as a result of the long-term operation of small hydrological research basins. Even in the beginnings of IHD, the investigation of hydrological and hydrogeological processes has had top priority. Today, it is obvious that not all of the processes we observe have yet been fully understood. Investigations on matter transport are a new aspect in the field of small research basins. Land use changes as a result of global change impact on small basins, can be investigated and understood. The long-term operation of such basins has clearly revealed the importance of observations for the estimation of climate change as a part of global change.

This booklet is intended to inspire researchers from different fields to perform own research activities in small hydrological research basins. Moreover, it offers suggestions on integrated and transdisciplinary research. Decision-makers from research and administration are provided with arguments for continuing the operation of existing basins and establishing new ones.

Dr. Johannes Cullmann
Director of the German IHP/HWRP Secretariat

Contents

1. Introduction

The International Workshop on Status and Perspectives of Hydrology in Small Basins was held on the occasion of 60 years of hydrological measurements in the four small Bramke research basins in the Upper Harz Mountains, Germany. They were established in 1948, under extremely difficult financial and logistic conditions, by deeply committed researchers from the forestry administration and the Research Centre (today: Federal Institute) of Hydrology who concentrated in succession on questions of forest hydrology. This era was succeeded by the implementation of miscellaneous projects of various universities, institutes and agencies during the following decades.

The workshop was convened jointly by the Department of Hydrology and Landscape Ecology at the Technical University Braunschweig (TUBS) and the German National Committee for the IHP of UNESCO and the HWRP of WMO in cooperation with the European EURO FRIEND Project 5, the Mediterranean MED FRIEND, the Euromediterranean Network of Experimental and Representative Basins (ERB), and organised jointly with UNESCO/IHP, WMO and IAHS.

A limited number of 70 researchers from 24 countries attended the workshop. They were actively involved by presenting papers or posters and by participating in discussions in working groups.

These resulted in answers and contributions to questions concerning the necessity of the current and future operation and research in small hydrological basins. The four established working groups approached the discussion on the status and perspectives of hydrology in small basins considering different main aspects:

1. Which achievements are expected from research in small basins in the coming decades?
2. Which contribution to the monitoring and understanding of changes in physical processes, water fluxes, water balance and global warming effects is expected?
3. What may be the scientific contribution to the PUB initiative and what can be expected vice versa?
4. Do we need research results from small basins for the further development of mathematical hydrological models?

The working group results were presented and discussed in the plenum during the final session of the workshop and were then compiled in the Braunschweig Declaration on the need for a global network of long-term small hydrological research basins.

Figure 1 *Workshop convenors and organisers*

The oral and poster presentations that were held during the workshop have been published in the IAHS Red Book series, volume 336 (2010).

For the workshop a poster template, intended for a special poster exhibition on small basins represented at the workshop, was developed. In total 38 research basins were displayed using the same poster template format. Yet another poster was supplemented after the workshop. These posters were used to start a digital inventory of small hydrological research basins that is now available online at www.euro-friend.de.

This technical report releases the Braunschweig Declaration, summarizes the main results of the working groups and provides a hard copy of the Inventory of Small Hydrological Research Basins including European Representative Basins (ERB), representing the status at the end of 2009.

Sybille Schumann and Ulrich Schröder

2. Braunschweig Declaration on the need for a global network of long-term small hydrological research basins

I. Introduction

Since UNESCO launched the International Hydrological Decade (1965 – 1974) many hydrological research basins have been established and have since then been in the focus of studies on hydrological processes at a basin scale. Only in well-defined small basins, where there are high-quality measurements, is it possible to investigate the complexities of combined physical, chemical and biological processes. Small hydrological research basins provide inter-disciplinary observatories. Realizing the relevance of environmental changes (e.g. climate and land-use changes), the value of long-term measurements in small research basins has become more important, for instance to cope with issues of non-stationarity in hydrological processes. Knowledge gained from studies in small hydrological basins can be used for decision-making with respect to managing ecosystem services and water resources systems.

This declaration is based on the findings of the International Workshop on Status and Perspectives of Hydrology in Small Basins held in Goslar-Hahnenklee, Germany, 30 March to 2 April 2009.

The Workshop participants acknowledged the continuing support from UNESCO-FRIEND, ERB, WMO and IAHS for good knowledge-exchange frameworks in favour of scientific hydrology. At the same time, they perceived the need to strengthen the existing networks of small hydrological research basins.

A strengthened network of hydrological research basins would help to facilitate the synthesis of research required to meet future challenges in water resources management in a changing environment.

II. Benefits of a strengthened network of hydrological research basins

Workshop participants discussed a wide range of benefits from a strengthened network. A few examples are given below. For further details see this publication.

Monitoring the real world
Advances have been made using mathematical models and scenarios of future land-use and climate change. However, there is a growing awareness of the fundamental need for long-term monitoring of the environment related to land-use, climate change and climate variability. Networks of small research basins provide essential outdoor laboratories for monitoring actual changes in environmental variables unlike to predicted changes, and for validation of models and scenarios of future environmental change.

Uncertainty
New insights gained from studies across networked gauged basins, and advanced approaches for dealing with modelling errors, can be applied for dealing with uncertainties throughout the observation-conceptualisation-modelling sequence. This will help with prediction in ungauged basins, for example, where additional sources of uncertainty exist. Dealing with modelling uncertainties across networked basins will lead to better techniques to assist with integrated water resources management.

Eco-hydrology
Networks of small basins provide good opportunities for monitoring ecological changes driven by different hydrological and/or climate changes. Comparative studies of processes in urban/industrial and remote/

Figure 2 *Vauz basin, Italy*

pristine catchments supply important information for water and land-use management under environmental change. Furthermore, a better understanding of ecological changes thus gained will provide key insights for improving pollution control.

Cross-cutting themes

Networks of small basins are important tools in several types of study, e.g. (i) validation of modelling at larger spatial scales, (ii) assessing socio-economic aspects of the hydrological cycle and (iii) detection of trends and changes in runoff regimes and ecosystem responses due to anthropogenic activities and climate variability. A number of disciplines benefit from long-term research in small basins, e.g. engineering, climatology, forestry, biology, geochemistry, ecology and soil science.

Modelling

The initial development and subsequent improvement of a model requires high-quality data. When hydrometric and other measurements are made with high spatial and temporal resolution, small research basins deliver the high-quality data required for detailed model development. A network of small research basins is important for improving process representation for a range of different hydrological settings and landscape features. A network also helps field researchers to identify from modelling the important physical processes that contribute to runoff formation in different environments.

III. Recommendations

Recognizing the value of existing networks of small hydrological research basins, the Workshop recommended:

1. Strengthening of existing networks in a cooperative endeavour to ensure long-term observations in a wide range of hydrological and environmental settings;
2. Creation of a global institutional framework for better recognition and support of networked small research basins;
3. Use of the global network as a set of representative and reference basins, providing long-term Observatories;
4. Use of the networked Observatories for active interdisciplinary process and modelling studies, as well as for education and training;
5. Adoption and support of the global network at the international level; and
6. Support for existing and, where appropriate, new hydrological research basins at the national level in order to contribute to the global network.

3. Working Group Results

Opportunities of and challenges to research in small hydrological research basins were developed in four working groups. The following issues were dealt with:

- Which achievements are expected from research in small basins in the coming decades?
- Which contribution to the monitoring and understanding of changes in physical processes, water fluxes, water balance and global warming effects is expected?
- What may be the scientific contribution to the PUB initiative and what can be expected vice versa?
- Do we need research results from small basins for the further development of mathematical hydrological models?

3.1 Which achievements are expected from research in small basins in the coming decades?

3.1.1 Summary

Research in small basins is expected to contribute to studies of land use and climate change, interdisciplinary studies, studies of uncertainties and the development of new measuring techniques, besides further hydrological process understanding. It was found that networks of small basins are important tools in several types of studies, e.g. large scale modelling validation, the assessment of socio-economical aspects of the hydrological cycle, the detection of trends and changes in runoff regimes and ecosystem(s) responses due to anthropogenic activities and climate variability. It was also stressed that a number of disciplines rely on hydrological knowledge gained in small basins, e.g. geochemists, ecologists, pedologists, biologists.

3.1.2 Keynote

A keynote entitled "How can experimental hydrology create generalisable hypotheses from equivocal insights gained from small basin studies" was given by Laurant Pfister and Stefan Uhlenbrook. It is published by Pfister et al. in Herrmann et al. (2010).

3.1.3 Working Group Results

The discussions among the members of the working group were initiated by individual comments and opinions on the achievements that can be expected in the near future. Two aspects were highlighted in the beginning: (1) The ideas and thoughts of the community of experimental hydrologists in terms of small basin studies should be focused on (professional point of view) and (2) how to communicate which core messages to the outside of the community (message to non-specialists, i.e. politicians, funding agencies, etc.). Within the community, there is a consensus on the need for synthesizing the knowledge gained in the numerous small basins studies. Outside of the community we need to stress the importance of operating small catchments as natural laboratories for the development of hydrology as a natural science, preparation of new generations of experts, testing hypotheses, etc. Hydrological knowledge provides an essential input to other disciplines for solving specific problems (nitrate leaching, geomorphology).

Aspired key research activities in small basin studies: While future achievements will eventually profit from new technological developments, they will also have to be streamlined and organised within the small basin research community through the definition of precise research needs.

Box 3.1 Participants of the working group

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Piet Helbig, Germany
Andreas Herrmann, Germany
Tobias Hohenbrink, Germany
Ladislav Holko (Working Group leader), Slovakia
Irene Lehner, Switzerland
Jérôme Latron, Spain
David Morche, Germany
Pavol Miklanek, Slovakia
Jirka Pavlásek, Czech Republic
Daniele Penna, Italy
Laurant Pfister (Working Group leader), Luxembourg
Ulrich Schröder, Germany
Sybille Schumann (Working Group leader), Germany
Miroslav Tesař, Czech Republic
Daniel Viville, France
Markus Weiler, Germany
Sebastian Wrede, Luxembourg
Sergey Zhuravin, Russia

Figure 3 *Jalovecký creek basin, Slovakia*

The synthesis of present knowledge is a prerequisite for defining future research priorities as well as rendering extra-community communication far more efficient. The identification and quantification of individual processes, going in line with the understanding of feed-back mechanisms and interactions with factors and issues related to other disciplines, call for integrated approaches in our research basins (with respect to evapotranspiration, discharge generation, role of soils). The identification of controlling and organizing factors acting on the streamflow generating processes (thresholds, switching points, etc.) will have to rely on knowledge exchange strategies and intercomparison methods, most of which still have to be defined (defining meeting points, experimental hydro-wiki, classification schemes).
The insights gained from our studies need to be more systematically attached to quality evaluation via the identification and quantification of the uncertainties throughout the entire observation-conceptualization-modelling sequence of small basin research.

Communication process and progress of the small basin research community:
Ultimately, optimizing the extra-community communication process (with people and organizations outside the small research basins community) will certainly gain a lot from a systematic introduction of the uncertainties related to newly gained insights in streamflow generation processes and related issues. There are still important knowledge gaps related to water sources, flowpaths and residence times, which are nonetheless issues of highest importance to questions related to water management. Communication must clearly be based on what we know and what we don't know on both the processes taking place in our research basins and on the extent to which these insights can be transferred beyond spatial and temporal scales. This communication must clearly convey to basically any kind of community (students, politicians, stakeholders, etc.) that long-term monitoring programmes are vital for understanding the functioning and reactivity of our hydrological systems under continuously changing conditions. The communication process actually can rely on existing frameworks, such as the ERB (initially launched under the auspices of the EU-Council) and FRIEND networks, which had initially been implemented for the exchange of data, information and knowledge. Nonetheless, importance and relevance of experimental research basins has to be communicated to the European Union agencies, with a view to implementing integrated transdisciplinary research basins offering working opportunities to researchers from other disciplines.

Noteworthiness of small basins for hydrological research:

- small basins are basic units to study the water balance components, (e.g. topographical control of runoff generation, fog interception, canopy and litter rainfall interception, etc.),
- details of short and long-term variabilities of hydrological processes, etc., can best be studied in small basins
- certain processes can indeed only be studied in small basins (e.g. streamflow generation processes)
- physiographical and climatic homogeneity as a prerequisite for detailed studies of the hydrological cycle is only available in small basins,
- small basins are field laboratories/observatories under defined/known and natural/real-world conditions.
- with respect to the regionalization, that has practical implications for water management issues, small basins serve as a basis for upscaling.
- Education and training of researchers and members of operational services in small basins is a prerequisite for integrated and sustainable catchment management.

Networks of small basins as important tools:

Networks of small basins can serve as primary tools in:

- solving large-scale hydrological problems where standard monitoring hydro-meteorological networks cannot be used, i.e. in very large basins (Russia, Africa, South America, etc.),
- validating large-scale modelling,
- assessing socio-economical aspects of the hydrological cycle (water scarcity, tourism, etc.),
- detecting trends and changes in runoff regimes and ecosystem(s) responses due to anthropogenic activities and climate variability (renewable energy sources, etc.)

Figure 4 *Soil core sampling*

A number of disciplines rely on hydrological knowledge gained in small basins:

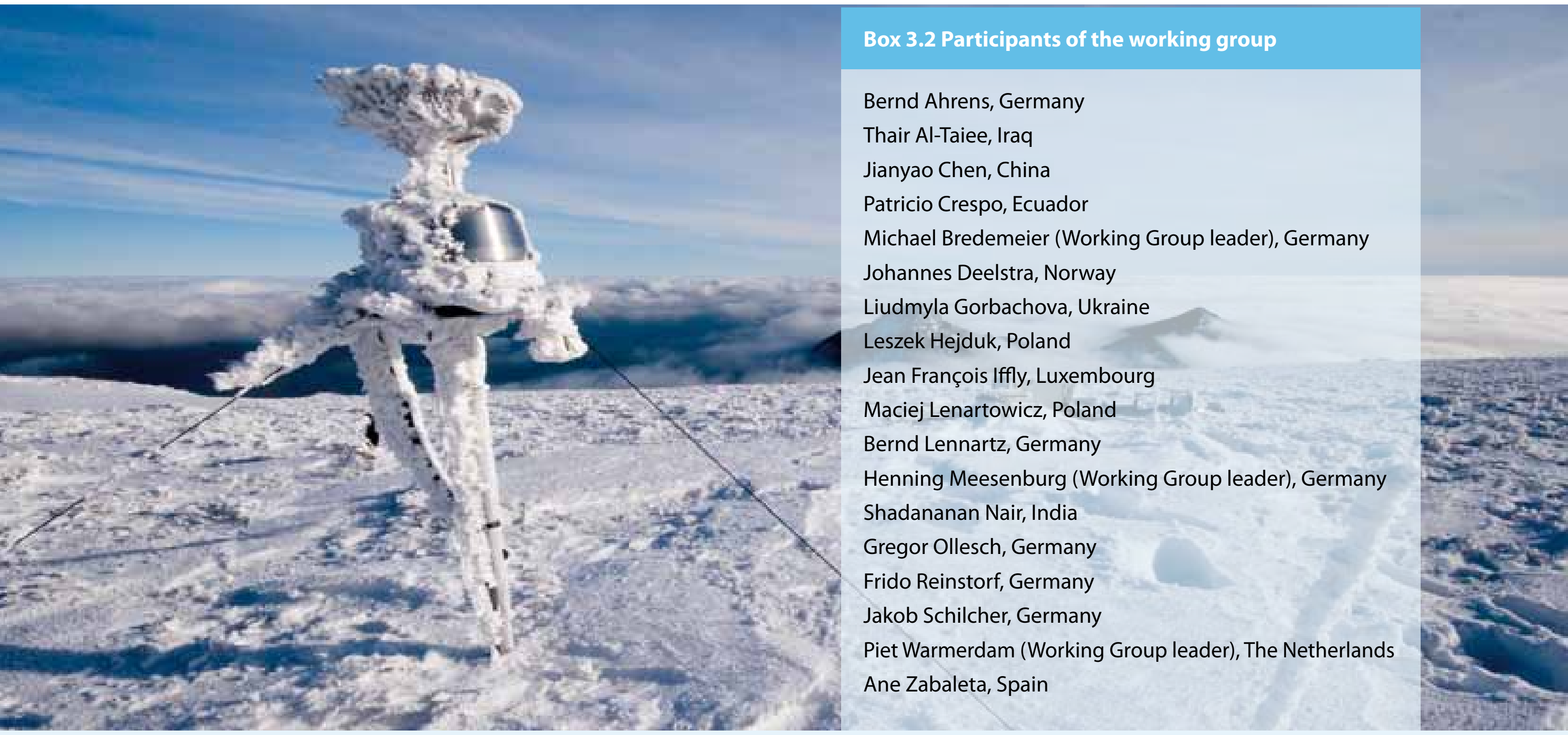
- geochemistry, ecologists, hydrologists, climatology, pedology, forestry, sociology, economics, geomorphology, geology, hydro-engineers, biologists, integrated water management, etc.

Figure 5 *GPS survey*

3.2 Which contribution to the monitoring and understanding of changes in physical processes, water fluxes, water balance and global warming effects is expected?

3.2.1 Summary

Research work in small hydrological basins is expected to contribute more specifically to the knowledge on matter transport under natural conditions and possible transport changes and transport process changes in a changing environment. An improved understanding of overall processes is expected to generate i.a. better guidelines and tools for watershed management.
The comparison of processes in urban/industrial and remote/pristine catchments is expected to provide important information for water and land use management under climate change and land use change as drivers.They also provide key insights for improving pollution control.



Box 3.2 Participants of the working group

Bernd Ahrens, Germany
Thair Al-Taiee, Iraq
Jianyao Chen, China
Patricio Crespo, Ecuador
Michael Bredemeier (Working Group leader), Germany
Johannes Deelstra, Norway
Liudmyla Gorbachova, Ukraine
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Bernd Lennartz, Germany
Henning Meesenburg (Working Group leader), Germany
Shadananan Nair, India
Gregor Ollesch, Germany
Frido Reinstorf, Germany
Jakob Schilcher, Germany
Piet Warmerdam (Working Group leader), The Netherlands
Ane Zabaleta, Spain

***Figure 6** Meteorological station at 1900 m a.m.s.l., Jalovecký creek basin, Slovakia*

3.2.2 Keynote

A keynote entitled “Climate change impacts at the river basin scale” was given by Zbigniew Kundzewicz and Fred Hattermann. It is published in Herrmann and Schumann (2009).

3.2.3 Working Group Results

Small Basins are a basis for an integrated, inter-disciplinary research that allows the study of complex interdependencies of hydrological sub-processes and systems. Small basins here are defined as basins that are relevant for process studies. Discussions focused on particular questions posed to the working group.

Can small basins serve as ‘tools’ for water management problems?

- Water management problems usually arise at smaller scales, but small basins are indispensable for process studies, model development and under-standing, which feed into management knowledge
- Inter- and transdisciplinary approaches are needed to include small basin information into the management decision-making process
- Small basins provide an indispensable scientific basis for decision-making processes, but operating with a time lag and via integration of many single results
- Studies of interactions among discharge regime, water balance components and water consumption (needs, exploitation) and their socio-economic impacts are very important, such as land use effects and trade-offs between biomass production and discharge / water bodies recharge.
- Small basins are interrelated with environmental legislation such as Water Framework Directive, because research on small basins provides the scientific basis for legislation, while legislation defines the ecological problems to be solved.
- A whole range of ecosystem services may be addressed when small basin studies are used as decision support for management issues.

Which findings can be expected by interlinking water-, energy- and balance-of-matter studies?

- A system-oriented integrating interdisciplinary approach is long and well established in catchment-based research.
- Integrating studies of energy, water, and matter fluxes is indispensable for the development of system understanding

- Monitoring of the biogeochemical cycles is important and has long been in the focus of small basin- based investigations. Now it is applied in climate change research.

Which additional findings can be expected from operating small basins with respect to the analysis of climate change and its impacts?

- Climate change gives new directions and strong impulses to hydrological research. Over time, new topical framework conditions and paradigms are generated.
- Changes in extremes are probably more important than changes in averages. Observed temporal dynamics can yield important information on this subject.
- Observing signal transfer in nested hierarchical catchments gives important insights. Integration over scales and application of state-of-the-art tools are part of this endeavour.
- Identification of impacts (drivers, pressures) other than climate change is important. Delineation of different impacts can help to quantify the climatic signal (importance of "undisturbed" or pristine basins)
- Catchments are all unique, which makes comparison among various basins very difficult, and this would also apply to any comparison of pristine/ anthropogenically influenced catchments.
- Even with the uniqueness of small basins, it should be possible to find general patterns in their response to changes in boundary conditions. However, the unique behaviour of each basin can improve system understanding.
- Support for more active and informed land use planning, water resources management, and linking to socio-economical decision making

***Figure** 7 Water samples*

Beside the particular questions posed to the working group, the value of monitoring for research in small basins and vice versa and the methodological framework for small-basin studies was discussed in detail. The value of small basins is already being emphasised by WMO, which calls for the establishment of pristine basins and reference basins.

Hydrological and biogeochemical monitoring in small basins as a basis for the study of hydrological and ecological patterns and dynamics, of water and matter balance processes and biogeochemical cycles

- Long-term aspect is not only particularly relevant for catchment-based research, but small basins also offer an ideal basis for long-term studies
- Some long-term changes can be easily measured and monitored, some are more abstract and challenging, such as "change in systems dynamics". However, the latter is equally important.
- Small basins offer an ideal study platform for inter (trans-) disciplinary research projects.
- Small-basin studies should serve as reference basins for the calibration and validation of inferences on the large basin scale (regionalisation). The establishment of networks of pristine and anthropogenically modified small basins is an important challenge for this issue.
- Small catchments at least offer a good relation between input of resources and output of information.

Development, testing and validation of new measuring technologies and models under well-defined conditions

- Small basins are usually the places where new measurement and analysis techniques are developed and tested.
- Due to their relative homogeneity and well defined boundary condition, small basins are important test sites for the development and validation or falsification of hydrological models. Data collection and model building should go hand in hand, as an interactive and iterative process.
- Models can (and should) guide experimental / monitoring design.
- Small basins may also serve as a scientific basis for the development of guidelines, manuals and legislation directives.
- Small basins offers ideal opportunities for educational purposes.

3.3 What may be the scientific contribution to the PUB initiative and what can be expected vice versa?

3.3.1 Summary

Small basins can contribute to the development of transfer functions from gauged to ungauged basins due to their high temporal and spatial resolution of data. They contribute i.a. to the learning about how small scale processes aggregate to larger scale processes. Networks of small basins could contribute to a better understanding in the assignment of processes to other hydrological scales.

3.3.2 Keynote

A keynote entitled "Catchment-scale rainfall-streamflow modelling: utility versus process understanding" was given by Ian Littlewood, UK. It is published in Herrmann et al. (2010).

3.3.3 Working Group Results

This summary records the main points discussed by the Working Group under several prescribed sub-headings, then addresses the main question posed to the Group.

Which processes can only be studied in small basins, and how?

- Processes that are influenced by biological processes, e.g. soil and land-use related processes

Figure 8 *Huewelerbach basin, Luxembourg*

- Quasi-controlled experiments in the environment, e.g. paired basin studies to understand/quantify land-use impacts on hydrology and water resources
- Systematic evaluation of ecosystem services (forestry, agriculture, water supply, etc.)
- Learning how small-scale processes aggregate to larger-scale processes
- Streamflow generation processes, flow pathways, solute transport

What contributions can be made from monitoring and studies in small basins to assist in the development of regionalisation tools?
Regionalisation here means methods and techniques for transferring information about a specific hydrological variable from places where there are measurements of that variable to places where there are no measurements of that variable.

- Accurate / well-understood data to help construct regionalisation schemes
- Separating the effects on hydrological behaviour of individual processes and interactions between processes
- Fine temporal resolution data
- Observation of specialized or unconventional data sets (including soft data)

What benefits can be expected from a network of small basins in terms of solving large-scale hydrological problems?

- Development of conceptual catchment models producing "the right answers for the right reasons" can only be achieved through an in-depth understanding of multiple facets of catchment response as a result of studying and comparing the behaviour of small basins.
- Development of procedures (with limitations described) in order to contribute to good practice, e.g. preparing guidance manuals
- Improvement of numerical model structure and performance, based on observations at a range of spatial scales and under different hydroclimatic and land-use conditions
- Impacts of environmental changes (land-use, climate)
- Manipulation experiments including assessment of different land management options, evaluation of sustainable practices, etc.
- Nested basins are particularly useful for understanding scaling issues (temporal and spatial)

Box 3.3 Participants of the working group

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João de Lima, Portugal
Ian Littlewood (Working Group leader), United Kingdom
Hilary McMillan (Working Group leader), New Zealand
Niculae Iulian Teodorescu, Romania
Tobias Törnros, Germany/Sweden
Stefan Uhlenbrook (Working Group leader), The Netherlands

Figure 9 *Eriophorum vaginatum*

Which disciplines could profit from networks of small basins?

- All environmental / social sciences disciplines
- Networks of small research basins provide unique opportunities for curiosity-driven/fundamental and engineering hydrology research

How does experience in small basins contribute to integrated water management?

- This is where science, engineering and environmental managers meet
- Dialogue between research in small basins and environmental management usefully spans a modelling spectrum where major objectives range from process understanding to utility, leading to rational environmental management (rather than a hand-waving approach)
- Pathways and residence times for pollutants
- Focus for stakeholder participation

Which are the benefits from education and training of researchers and practitioners in small basins?

- Real-world case studies
- Hands-on experience
- Providing information about processes to modellers and environmental managers

Research in small study basins: What are the contributions to the PUB initiative (and vice versa)? A Paradox? Instrumented small basins needed for Predictions in Ungauged Basins

It seems at first contradictory to emphasise the need for well-instrumented small basins as a contribution to the PUB initiative. However, on closer study, it becomes apparent that many of the PUB Themes rely absolutely on small instrumented basins. For example, PUB Theme 1: Basin inter-comparison and classification underscores the need for networks of well-understood basins. Theme 2: Conceptualization of process heterogeneity specifically references multi-scale catchment monitoring. Theme 4: Development and use of new data collection approaches and Theme 5: New hydrological theory both relate to fundamental new research for which small experimental basins are a natural home.

It becomes clear that only by developing a knowledge-base of catchment response that is both deep (detailed understanding of catchment processes and interactions) and broad (in terms of catchment biome, and spatial and temporal scales), can we hope to advance our predictions and models sufficiently to have confidence in their use in ungauged basins.

Figure 10 *Rain gauge at settlement Jizerka in eastern Jizera Mountains, Czech Republic*

Figure 11 *Badlands, Araguás basin, Spain*

Figure 12 *Measuring throughfall and stem flow, Bramke basin, Germany*

The research experiences of the participants in this working group contributed to this conclusion, with examples as follows. McMillan et al. (2010) demonstrated how data collected in small basins can be directly used to improve our ability to formulate perceptual and conceptual hydrological models. Uhlenbrook et al. (2010) followed this to show how even in poorly gauged catchments in Sub-Saharan Africa, the ability to formulate conceptual models is a crucial prerequisite for successfully modelling runoff generation. Törnros and Menzel (2010) demonstrated how hydrological modelling expertise gained in gauged basins is the first step towards knowledge in a data-scarce basin. The members of the working group therefore perceived a network of small basins as an essential resource for the PUB initiative.

The reduction of predictive uncertainty in ungauged basins is a common goal across all the PUB technical themes. While focussing on the ungauged situation (e.g. no streamflow measurements) PUB depends crucially on the analysis of (a) other hydrometeorological measurements (e.g. rainfall) at or near the ungauged site and (b) measurements of streamflow, etc. for other basins. Much of PUB is concerned with deriving and/or improving methods of transferring the information contained in such measurements to ungauged (flow) locations.

Existing and potential links between PUB and networks of small research basins are, of course, many and varied. As an example, consider the impact of data time-step on calibrated rainfall-streamflow model parameters, especially for relatively highly responsive basins. It has been demonstrated for a small, well-instrumented research basin that the parameters of a given model structure can be substantially different when calibrated using daily or hourly data respectively (Littlewood and Croke, 2008); one of the model parameters differed by about 400 %.

This modelling artefact, which is common to all discrete-time rainfall-streamflow models, can be a partial cause of the typically large uncertainty in regionalisation schemes employed to estimate hydrographs at ungauged sites – but to date it has been largely neglected.

Littlewood (2010) draws further attention to the data time-step modelling issue in the context of PUB. The problem, which will now be described in a little more detail, is that published rainfall-streamflow regionalisation schemes to date have calibrated the parameters of a given model structure using daily hydrometric data for all of the catchments in the selected set of gauged basins. Such work has made no allowances for the fact that a daily time-step may have been inadequate for quantifying the relatively quick flow response component of streamflow for some of those gauged basins. In order to reduce the typically large uncertainty in a statistical relationship between a given model parameter and physical catchment descriptors, it will be necessary to normalise that parameter so it is essentially independent of the data time-step used for its calibration. Adopting this procedure for each model parameter should lead to better streamflow modelling at ungauged sites.

So far, work on the model parameter normalisation issue (Littlewood and Croke, 2008) has been restricted to just one rainfall-streamflow model structure (IHACRES) and one catchment (the Wye at Cefn Brwyn, UK). For this combination, an empirical method of model parameter normalisation has been presented. Other researchers have therefore been invited to (a) calibrate other model structures using exactly the same data for the Wye at Cefn Brwyn, (b) make available to the research community similar high-quality datasets from small research basins for data time-step analysis using a range of model structures and (c) investigate methods of model parameter normalisation. The PUB Top-Down Modelling Working Group (TDWG) has established a framework to facilitate this work, under the title TRUMPER (Temporal Resolution impacts on Uncertainty in Model Parameter Estimation and Regionalisation – see "Projects" at http://tdwg.catchment.org/projects.html).

TRUMPER highlights the need for fine temporal resolution data from networks of small research basins (different sizes, hydroclimatic types, land-uses, etc.), including nested sub-basins where available, and is just one of the ways that PUB and small research basins can and should interact.

Through analysis of fine temporal resolution data from many small research basins, TRUMPER should provide more accurate (i.e. normalised) model parameters. This will lead to a better appreciation of (a) what calibrated model parameters mean in terms of the processes they represent conceptually and (b) the limitations to process understanding using such models. TRUMPER will, inevitably, raise research questions for the future. A dialogue concerning PUB/TDWG/TRUMPER has been established with ERB and FRIEND-5.

Figure 13 *Climatic station, Rietholzbach basin, Switzerland*

Figure 14 *Freshwater tidelands, Aper Tief basin, Germany*

Figure 15 *Gauging site, Jalovecký creek basin, Slovakia*

3.4 Do we need research results from small basins for the further development of mathematical hydrological models?

3.4.1 Summary

It was stressed that it is indispensable to bring modellers and field researchers together, and that small basins act as an important platform in this respect (research, training and education). It has been ascertained that small basin studies are very important in improving model process representations in models and, in particular, in rejecting approaches that do not adequately represent processes. Processes that are implemented in models can be evaluated and validated in small basins, while the value of measured parameter values in models can also be assessed. Field researchers can also profit from modellers, e.g. in the design of experiments for testing process representations and predictions of future change in different environments. Models may also reveal requirements for new types of field observations.

3.4.2 Keynote

A keynote entitled "Do we need research results from small basins for the further development of mathematical hydrological models?" was given by Keith Beven, UK. It is published in Herrmann et al. (2010).

Figure 16 *Rivulet, Płachty Stare and Czarna Zagożdżonka basin, Poland*

3.4.3 Working Group Results

Value of small basins

1. Small basins act as an important platform for bringing modellers and field experimentalists together (research, training and education).
2. Small basin studies are very important in improving model process representations in models, and getting the right answers for the right reasons in predicting strong nonlinearities and hysteresis in basin responses with wetting and, in particular, rejecting approaches that do not adequately represent processes.
3. Adequate testing of model process representations requires a network of small basins that span a range of different hydrotopes/landscape features.
   a. There should be a catalogue of meta-data about each basin, including information on data quality and uncertainties.
   b. There should be some common standards for data collection and uncertainty assessment (for instance ISO standards on discharge determinations).
   c. The data collected should include some patterns of internal responses where possible.
4. The value of different types of data in testing model process representations (flux, tracer, remote sensing, point measurements, new measurement techniques) might vary for different types of response and needs further research to maximise benefits of investments in small basin research.
5. Interaction between modellers and experimentalists may reveal requirements for new types of field observations.
6. We should refer to the National Academy report (Integrating Multiscale Observations of U.S. Waters, 2008).

Role of Small Basins in Testing Model Representations

7. Testing model representations requires high quality input and output data as a minimum.
8. Testing will be more rigorous when comparisons are made across several basins and when internal responses are included.
9. There are commensurability issues in model testing in both space and time. Comparing point values of internal states (e.g. soil moisture or water table levels) can be less important than showing (qualitatively?) dynamics if an internal response is modelled.

Box 3.4 Participants of the working group

Keith Beven (working group leader), United Kingdom
Helge Bormann, Germany
Luca Brocca, Italy
Johannes Cullmann, Germany
Francesc Gallart (working group leader), Spain
Hubert Holzmann, Austria
Thomas Krauße, Germany
Noemi Lana-Renault, Spain
Osvaldo Salazar, Sweden
Martin Sanda, Czech Republic
Britta Schmalz (working group leader), Germany
Olga Semenova, Russia

Figure 17 *Polytrichum commune*

10. However, how to define what is a “satisfactory” or “adequate” model representation, to get the right results for the right reasons, requires further research.

Role of Small Basins in Moving to Larger Scales

11. Larger scales are collections of hillslopes and small basins, but with a wider range of diversity.
12. Small basins are important sources of information about the nature of responses for different hydrotopes/landscape features.
13. Transfer of model parameters from small to larger scales may not be simple because heterogeneities and scale issues can result in parameter values that are scale-dependent, but values from small basins should be an important source for prior (if uncertain) estimates that might be later refined in a learning process.
14. However, there may be some hydrotopes/ landscape features with different types of hydrological responses (e.g. some agricultural systems, riparian forests and wetlands, regional aquifer systems) that are important in larger scale responses but which are not adequately represented by available small basins that might require new experiments.
15. Testing of model structures over a range of scales and hydrotopes will mean that only successful models should survive but fit will not be perfect (because of input error and simplification) so uncertainty in such evaluations should be considered in evaluation.

Role of Small Basins in Integrated Water Management

16. Management requires information not only about flows but also about quality, particularly non-point pollution.
17. Small basin process studies are important in providing information about pathways and residence times.
18. Long term records from small basins are crucial in assessing change. Monitoring should be continued into the future.
19. Results of predictions of change should be stored for future evaluation.

3.5 References

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4. Inventory of Small Hydrological Research Basins

The inventory of small hydrological research basins including European Representative Basins (ERB) is thought as a starting point for a constantly growing digital inventory. The online version of this inventory is published at www.euro-friend.de.

To add further small hydrological research basins to the inventory, it is possible for researchers or basin operators to (1) download the Poster Template that has been developed, (2) complete it duly and then (3) to submit it via e-mail to the German IHP/HWRP Secretariat. In succession it will be published on the web site.

The inventory will give researchers a chance to inform about their research laboratories and to invite interested colleagues to participate in interdisciplinary research in these basins.

Figure 18 *Snowmelt Bridge creek, Vauz basin, Italy*

Austria	
Löhnersbach basin	(1)
China	
Zhuhai Campus basin	(2)
Czech republic	
Anensky brook basin	(3)
Otava basin (ERB)	(4)
Mokruvka basin	(5)
Uhlířská basin	(6)
France	
Strengbach basin (ERB)	(7)
Germany	
Aper Tief basin	(8)
Bohlmicke basin	(9)
Bramke basin (ERB)	(10)
Brugga basin	(11)
Elsterbach basin	(12)
Kielstau basin	(13)
Krofdorf basin	(14)
Obere Brachtpe basin	(15)
Schäfertal basin	(16)
Zarnow basin	(17)

● *ERB basins*

Iraq

Fayda and Al-Baqaq basins (18)

Italy

Vallaccia basin (19)
Vauz basin (20)

Luxembourg

Huewelerbach basin (ERB) (21)

Mongolia

Kharaa river basin (22)

New Zealand

Mahurangi River basin (23)

Norway

Skuterud basin (24)

Poland

Small ungauged basins, Carpathian Mts (25)
Łazy basin (26)
Pożary basin (27)
Płachty basin (28)

Rumania

Sebes River Basin (29)

Russia

Devitsa basin (30)
Kontaktovy basin (31)

Slovakia

Bela river basin (32)
The Jalovecký creek basin (ERB) (33)

Spain

Aixola basin, Basque Country (34)
Araguás basin (35)
Arnás basin (36)
San Salvador basin (37)
Vallcebre research basins (ERB) (38)

Switzerland

Rietholzbach basin (39)

Ukraine

Butenya basin (ERB) (40)

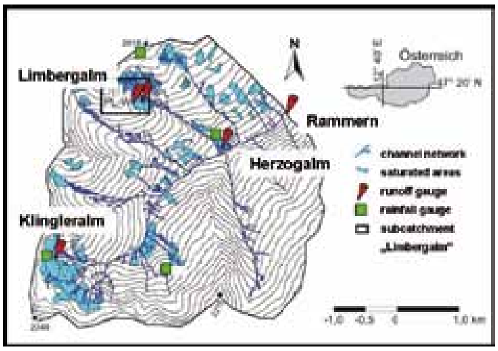
Rammern

Löhnersbach, Austria

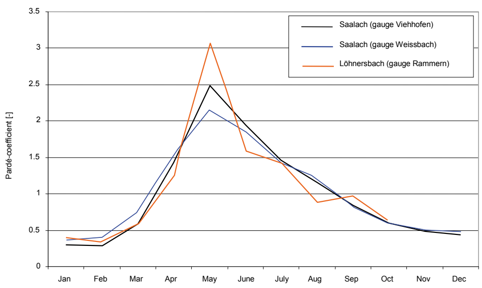
Basin characteristics

River Basin / River Basin (according EU-WFD)	Danube
Operation (from… to…)	since 1990
Gauge coordinates / Gauge datum:	47° 21.513, 12° 40.045
Catchment area:	16 km²
Elevation range:	1100 to 2200 m a.s.l.
Basin type: (alpine, mountainous, lowland)	alpine
Climatic parameters: (mean precipitation, temperature and others)	P: 1500 mm/a; T: ø 5°C
Land use:	spruce forest, alpine pasture
Soils:	Cambisol, Podzol, Gleysol
Geology:	northern greywacke zone (shale and sandstone)
Hydrogeology: (Type of aquifers, hydraulic conductivity)	unconfined aquifer; hydraulic conductivity 10^{-4} m/s
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Qmin: 0,03 m³/s; Qmax: 6,3 m³/s; Qmean: 0,56 m³/s

Map of the research basin



Mean hydrograph / Pardé flow regime



Pardé flow regime for gauge Rammern, Viehhofen and Weissbach.
Gauge Rammern is part of catchment Viehhofen.

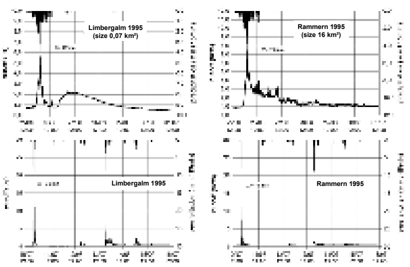
Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

two typical event types at different scales

bimodal →

and

unimodal →



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
precipitation	1992 - 2005	5 min (April to Oct.)	4
temperature	1992 – 2005	5 min (April to Oct.)	1
temp. precip., snow, wind, air hum.	since 1931	5 min	2
discharge (Rammern)	since 1990	5 min	1
discharge	1992 - 2005	5 min	4
spring (discharge, elect. cond., temp., turbidity)	since 1999	1 h	1

Applied models

1. HQSim: developed by Kleindienst (1996) and applied by Kirnbauer et al. (2009)
2. TAC[D]: Uhlenbrook (1999) and Johst et al. (2008)
3. Potsdam Model: developed of and applied by Zillgens et al. (2005)
4. BROOK: Federer & Lash (1978) and Kirnbauer et al. (1994)

Main scientific results

Experimental process studies:
Hydrological investigations in the upper Saalach region covered catchment sizes from 0,07 km² (Limbergalm, and other saturation areas of similar size), 16 km² (Rammern/Löhnersbach) and 150 km² (Viehhofen/Saalach). The studies that concentrated on processes to be observed on saturation areas in the Löhnersbach catchment gives evidence that the runoff coefficient on such areas is high but not unity and that it shows considerable dynamics: It increases with event precipitation and with increasing antecedent soil moisture as indexed by baseflow prior to the events. The quick runoff response to precipitation events is mainly generated on such areas by saturation overland flow but also by quick subsurface flow generated upstream in the duff layers below alpine roses and other shrub vegetation. Tracer and hydrochemical investigations substantiated these findings. At the microcatchment Limbergalm (0,07 km²) two characteristic event types could be distinguished: A unimodal flashy type resulting from short and high intensity rainfall events. Lower rainfall intensities but greater cumulative precipitation and/or high initial baseflow trigger a bimodal type of hydrograph consisting of a quick, flashy first runoff reaction and a second, smooth hydrograph due to subsurface stormflow. These two event types can be observed across all scales of the study area and can be seen as indicator of the catchment behaviour. If the bimodal type can be observed on the microscale on all greater scales runoff is dominated by subsurface stormflow, high runoff coefficients and slow recession of the falling limb of the hydrograph.

Runoff modelling:
Based on these field investigations the model structure was derived for the micro catchment: Surface and quick subsurface processes are modelled raster based with the diffusion analogy approach. Slow subsurface processes are modelled with the linear reservoir approach applied to hydrotopes delineated on GIS-base by combining geological and vegetation information. This model structure was the basis for modelling at the small catchment scale (16 km²). Model parameters were calibrated with data from two years. The model validation followed two ways: a) an on-site validation with runoff data from the catchment outlet and b) a multi-site validation for the tributaries (alpine torrents of about 1,2 to 2,5 km²) to the main brook of the small catchment. The simulated hydrographs of these tributaries were compared to daily discharge measurements with the salt dilution method and showed satisfactory agreement. This seems to indicate that the model describes the main features of the process.

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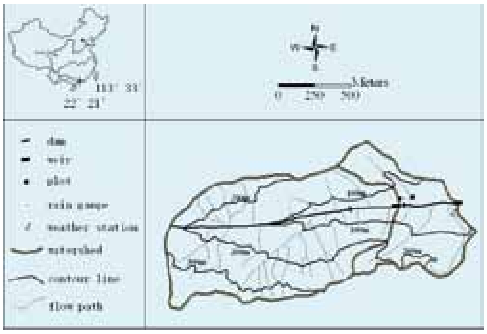
http://www.hydrologie.at/
phone: +43 1 58801 22320 fax: +43 1 58801 22399

Zhuhai Campus Basin, Sun Yatsen University, China

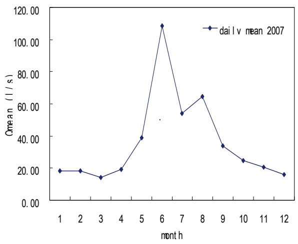
Basin characteristics

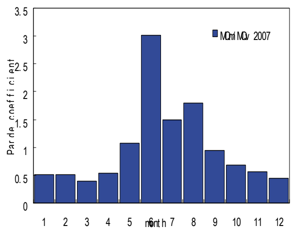
River Basin / River Basin (according EU-WFD)	Your text here.
Operation (from… to…)	Since 2005, still in operation
Gauge coordinates / Gauge datum:	22°21′; 113°33′
Catchment area:	1.13km²
Elevation range:	20 – 412m
Basin type: (alpine, mountainous, lowland)	Hilly area
Climatic parameters: (mean precipitation, temperature and others)	1800-2000mm (annual precipitation), 1100mm/a (pan evaporation)
Land use:	Brushwood
Soils:	laterite
Geology:	granite
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Your text here.
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	8.7l/s, 710.08l/s, 35.6l/s (2007)

Map of the research basin



Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

1. Two reservoirs inside the basin, not operated since 2000, when the campus was built up.
2. The basin is next to the sea, and the tide fluctuation is also measured every 30 min.
3. The depth of soil layer is well related to the vegetation, slope and etc. The depth is generally 2-3 m in the place where the slope is gentle with pine tree, while it is less than 1 m in the place with shrub or outcrop

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	Oct 2006 - cont	30min	2
precipitaion	Nov 2006 - cont	Impuls/0.1mm	3
evaporation	April 2006 - cont	daily	2
Temperature, Air pressure,Humidity,Radiation	Oct 2006 - cont	30min	1
Groundwater/Tide	Oct 2006 - cont	30min	17/1
Soil moisture, potential	Oct.2006-	30 min	3

Applied models

1. Baseflow separation models (Kalinin, digital filter, Smoothed minima, and etc)
2. FEFLOW

Main scientific results regarding base flow

1. Data series of 12h for 29 events at the upper weir were constructed for recession analysis by matching strip method. The master recession curve (MRC) was drawn. Recession constant for interflow K (i) and base flow K (b) was estimated to be 0.9622 and 0.9733, and recession index to be 0.03853 and 0.02706 respectively with an average of 0.0328.
2. Base flow analysis in the upper reach was operated by using smoothed minima, digital filter, Kalinin, and empirical methods, which have been proposed to separate base flow from the hydrograph. BFI was calculated to be a range of 0.43-0.86 for the year of 2007, while it shows a maximum of 0.96 in the dry season from November to March, and a minimum of 0.29 in the rainy season from April to October.
3. The average of D and ^{18}O value from the precipitation samples is -13.78‰ and -2.35‰, while it is -32.88‰ and -4.92‰ respectively for the river water. The average of the D and 18O value from the groundwater samples of recharge area is -41.30‰ and -5.97‰, indicating that groundwater is the main component of the stream flow. According to water and isotopic balance, the average ratio of groundwater contribution to the total flow during the period of February to May was estimated to be 73.7% in the upper reach and 68% in the lower reach.
4. Compared BFI in the upper reach during the period of February to May by different base flow separation methods, and that calculated by the 3rd digital filter method is the most close to the isotope analysis, which is 0.73.

Key references for the basin

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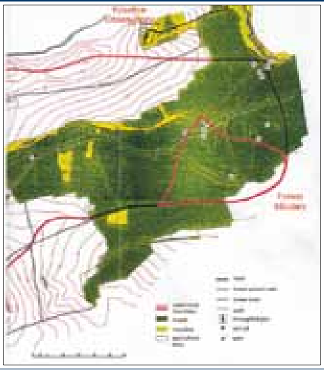
Forest tributary

Anensky brook basin, Czech republic

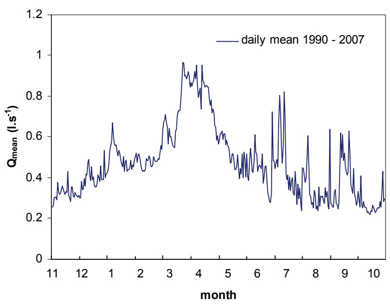
Basin characteristics

River Basin:	Zelivka / Sazava / Vltava / Elbe river basin
Operation (from… to…)	Since 1984, still in operation.
Gauge coordinates / Gauge datum:	15°05´E; 49°34´ N / 490 m a.m.s.l.
Catchment area:	0.285 km^2
Elevation range:	480 – 530 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	Upland, forest
Climatic parameters: (mean precipitation, temperature and others)	621 mm (1961-1990), 7.1°C (1961-1990)
Land use:	90% forested (spruce), 10% agricultural
Soils:	Dystric cambisol
Geology:	Biotitic and silimanitic-biotitic paragneiss
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Fractured rock aquifer with porous aquifer overlay
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Q_{mean} 0.5 l.s^{-1}

Map of the research basin



Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1984 – cont.	1 week (1984-1988) 1 day (1989-1998) 5 min (since 1999)	1
Hydrogeochemical analyses	1984 – cont.	1 month (since 1984)	1
Precipitation amount	1984 – cont.	1. at Observatory: Daily (1984-2001) Hourly (since 2002) 2. at Throughfall plot in forest: Monthly (since 1990)	2
Precipitation quality	1984 – cont.	WET-ONLY Daily BULK Weekly THROUGHFALL Monthly	2
Meteorological parametres (temperature,wind velocity and direction, air pressure, humidity, solar and UV-B radiation, etc.)	1980 – cont.	Hourly	1

Applied models

1. MAGIC

Main scientific results

The results of long-term hydrogeochemical monitoring in the monitoring catchment show that:

- The reduction of sulphur emission in the Czech Republic has resulted in decreasing of background sulphur deposition. The greatest difference is observed in throughfall. A distinct reduction of sulphates occurs in the basin. Sulphur input has been decreasing continuously from 20–30 kg.ha^{-1}.year^{-1} in the first half of the nineties to 5–10 kg.ha^{-1}.year^{-1} after 2000. Distinct reduction of sulphur input by almost constant output caused basic changes in sulphur balance in the catchment. In the beginning of 1990s retention predominated very rapidly, but since 2000 leaching was found.
- There is not considerable trend observed in the deposition of nitrogen. The nitrogen budget provides evidence of large consumption of this element by vegetation. Nitrogen runoff displays a characteristic annual course, with its maximum in the spring months when the vegetation is still unable to consume this element and water runoff is high, the minimum occur in the summer and autumn.
- The output of basic cations exceeds their input. The sources of these cations currently include ion exchange process in the soils, with the primary weathering of minerals accounting probably for their smaller part. Their output increases in last years while acidity of precipitation is decreasing. The quality of soils is getting worse by this process.

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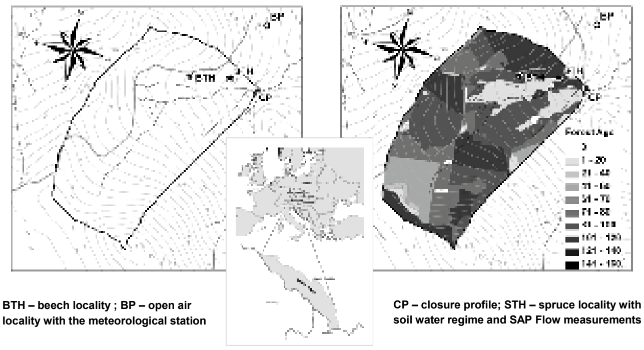
Liz experimental catchment

Otava river basin, Czech Republic

Basin characteristics

River Basin / River Basin (according EU-WFD)	Otava river basin / Vltava river basin
Operation (from… to…)	Since 1976, still in operation
Gauge coordinates / Gauge datum:	13°40´56´´E; 49°03´57´´N / 828 m a.s.l.
Catchment area:	0,99 km^2
Elevation range:	828 – 1074 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	861 mm (1976-2008), 6,3 °C (1976-2008)
Land use:	100 % Afforestation (acid spruce beech type of forest)
Soils:	Oligotrophic forest Eutric Cambisol
Geology:	Proterozoic biotite paragneisses and migmatites locally overlain by Holocene deluvial-fluvial loams and deposits
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Fractured rock aquifer with a shallow near-surface aquifer confined to morphological elevations
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	1,03 l/s; 207,5 l/s; 10,67 l/s (1976-2008)

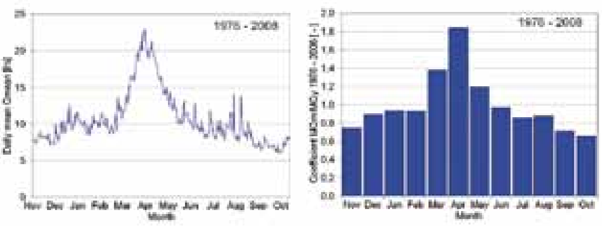
Map of the research basin



BTH – beech locality ; BP – open air locality with the meteorological station

CP – closure profile; STH – spruce locality with soil water regime and SAP Flow measurements

Mean hydrograph / Pardé flow regime

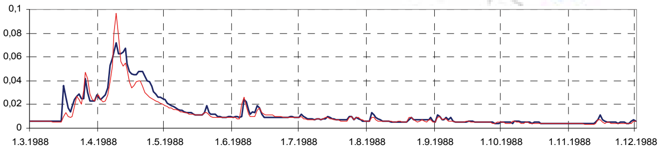


Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Sacramento soil moisture accounting model (SAC-SM

Model scheme and six runoff components generated by the model (DIR - direct runoff, from those parts of the basin which become impervious after saturation; IMP - the runoff from the part of basin is permanently impervious; SUR - surface runoff; INT – interflow; S supplementary baseflow (i.e. essentially the seasonal component o baseflows); PRM - primary baseflow, i.e. long term part of baseflow)

Example of the SAC – SMA Model application



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	Nov 1975 – cont.	1h 10 min (since 1993)	1
Precipitation	1975 – cont. 2000 – cont.	Daily Impuls/0,1 mm	2
Air temperature, humidity	1976 – cont.	1h / 10 min.	1
Groundwater level	1976 – cont. 2005 – cont.	Weekly 10 min.	6 4
Sap Flow	2005 – cont.	10 min.	6
Environmental isotope ^{18}O	2007 – cont.	Weekly	2

Applied models

1. SAC – SMA Model
2. RETU Model
3. BROOK ´90 Model
4. Micrometeorological Deposition Model

Main scientific results

1. The soil water movement and retention play the leading role in the runoff formation in Liz catchment.
2. Occult precipitation represents an important factor affecting water and mass balance in the headwater region in the Czech Republic. In the Sumava Mts. fogwater showed high acidity and NH_4^+, SO_4^{2-} and NO_3^- were the dominant species in fog-water.
3. Simulation of phytomass productivity based on the optimum temperature for plant growth in a cold climate was studied:

- The optimum temperature of 25 °C for plant growth in the present day conditions in the cold climate areas lowers both risks of reduction or cessation of plant growth.
- In the case of lower optimum temperatures for plant growth, higher consumption of water for transpiration could result in a depletion of water sources, increases in plant temperature owing to a drop in transpiration, and finally a reduction or cessation of plant growth as a consequence of the high temperature of the plant.
- In the case of higher optimum temperatures for plant growth, the heat from solar radiation is not sufficient for heating up the plants to this temperature, resulting in a reduction or cessation of plant growth as a consequence of the low temperature of the plant.
- We can conclude that monitoring of the hydrological regime in mountain localities in the Czech Republic and simulation of the phytomass productivity showed that the optimum temperature for plant growth is 25 °C, and that plants growing at this optimum temperature produce the biggest volume of phytomass in the long-term.

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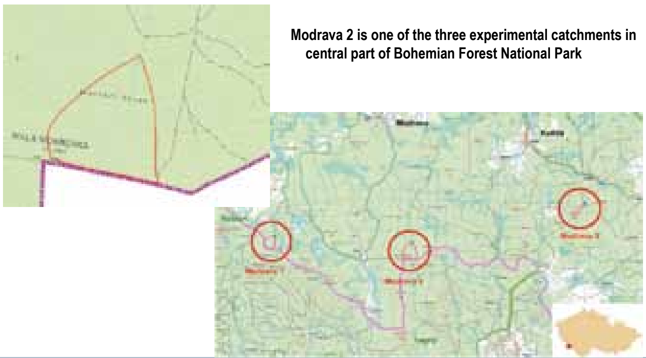
Modrava 2

Mokruvka catchment, Czech Republic

Basin characteristics

River Basin / River Basin (according EU-WFD)	Upper Vltava basin / Elbe river basin
Operation (from… to…)	from August 1998, still in operation
Gauge coordinates / Gauge datum:	48°58'N, 13°30'E / 1197 m a.m.s.l.
Catchment area:	0.17 km^2
Elevation range:	1197 – 1330 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	mountainous
Climatic parameters: (mean precipitation, temperature and others)	1750 mm (2007-2008), 5,0 °C (2007-2008)
Land use:	Open young Norway spruce forest
Soils:	Podzols
Geology:	Granite, paragneiss
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Shallow aquifer, K = 10^{-5} m.s^{-1}
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0.0 l.s^{-1}, 2.7 l.s^{-1}, 300 l.s^{-1}

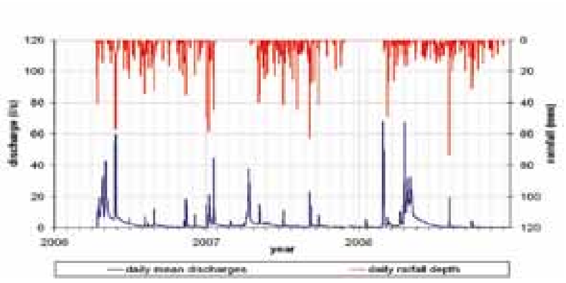
Map of the research basin



Modrava 2 is one of the three experimental catchments in central part of Bohemian Forest National Park

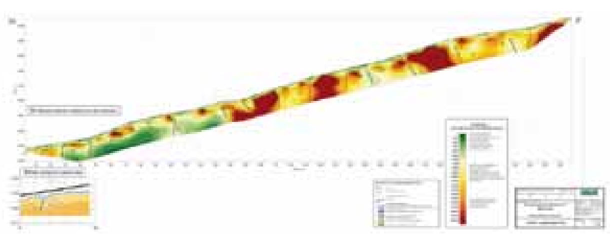
Mean hydrograph / Pardé flow regime

Daily mean discharges and rainfall from period 04/2006 – 12/2008



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Results from geophysical survey of left slope of Modrava 2 catchment



Instrumentation and data

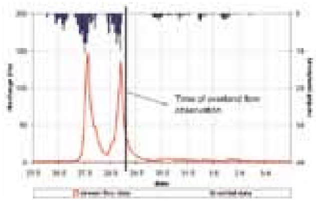
Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1998 – cont.	2 (4) min	1
Precipitation	1998 – cont. 2002 - 2008 2008 – cont.	2 min 20 min 15 min	2
Air temperature	1998 – cont. 2002 – 2008 2008 – cont.	1 hour 20 min 15 min	2
Water conductivity	1998 – cont.	3 (1) hout	1
Soil moisture and temperature	2002 – cont.	20 min	1

Applied models

1. Linear models
2. HEC – HMS
3. Unit hydrograph model
4. Day degree (snowmelt)

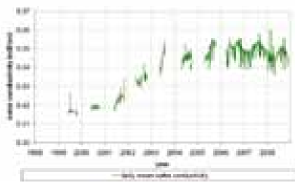
Main scientific results

1. Overland flow was observed on catchment during the rainstorm of high intensity. High peak discharges formed overland flow together with interflow.



2. The vegetation cover has a negligible role on generation of high volume runoff. These results were concluded from soil tension monitoring on Modrava 1 and 2 catchments during catastrophic floods in 2002. Maximum retention capacity of soil in both catchments was rather low in comparison with rainfall amount.

3. Water conductivity showed the reaction of catchment on fast changes in forest ecosystems due to Bark beetle calamity. Main growth of water conductivity was observed five years after harvesting of original forest.



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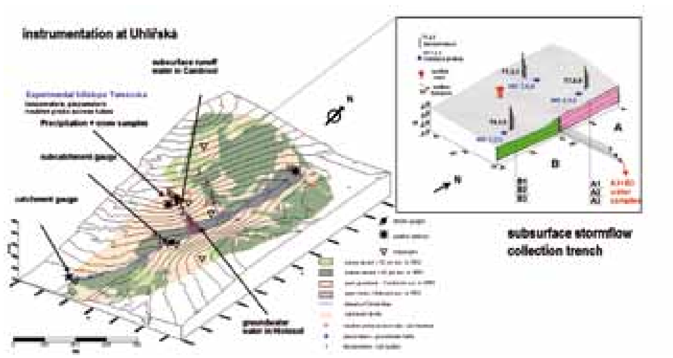
Uhlířská
Czech Republic

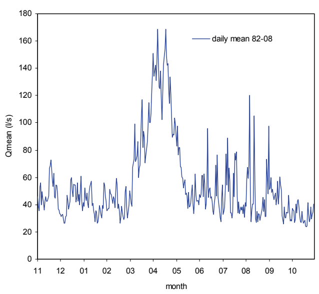
Basin characteristics

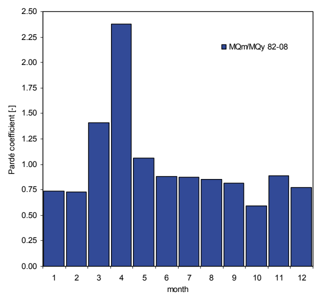
River Basin / River Basin (according EU-WFD)	Černá Nisa rive basin / Nisa river basin
Operation (from… to…)	Since 1982, still in operation
Gauge coordinates / Gauge datum:	15°09'E, 50°49'N, 776.17 m a.m.s.l.
Catchment area:	1.87 km²
Elevation range:	776 – 886 mm a.m.s.l.
Basin type: (alpine, mountainous, lowland)	mountainous
Climatic parameters: (mean precipitation, temperature and others)	1400 mm (1931-60 derived), 4.6°C (1961-1997)
Land use:	95% Norwegian spruce, 5% grassland, single beech trees
Soils:	Dystric and Podzolic Cambisols, Histosols, Gleysols
Geology:	granite, deluviofluvial sediments, glacial tills
Hydrogeology: (Type of aquifers, hydraulic conductivity)	fractured bedrock, sedimentary shallow aquifer
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Q_{mean}=55 l/s (1982-2008), Q_{max}=3824 l/s (7.8.06 7:45), Q_{min}=7 l/s

Map of the research basin



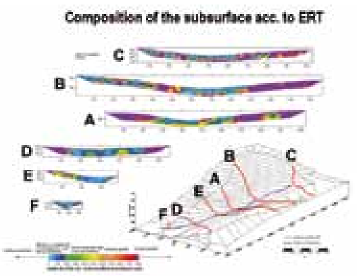
Mean hydrograph / Pardé flow regime





Czech Hydrometeorological Institute and River Labe authority data

Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Streamflow	1982 – cont. *subcatchment 2007 – cont	1h 10 min (since 1996, *2007)	2
Precipitation	1961 – cont (nearby Bedřichov) 1982 – cont. (seasonal) 1996 – cont. (seasonal)	Daily (since 2004 impulse) Hourly Impulse/ 0,1 mm	1 continuos – Bedřichov 7 (seasonal)
Air temp., Humidity & Radiation, Wind speed	1982 – cont. 1996 – cont	1h 10 min	1 2
Groundwater level	1997 – 2002 1999 – cont.	monthly hourly	15 2
Soil Suction Soil Moisture	1997- 2002 / 1998 – cont 1997 – cont / 2006 – cont	biweekly / 10 min quarterly / 10 min	120 / 21 20 / 11
Env. isotopes ^{18}O, ^{3}H, ^{2}H hydrochemistry + Al, Fe pH, redox, ORP, nitrates, chlorides	2006 – cont 1996 – cont, *2004 - cont 2004 - cont	event, daily, monthly monthly, *event 10 min	16 1 1

Applied models

Concept model	SWMS_2D, S1D, S2D, S1D_Dual – Richard's eq+ADE based models	
Modflow+MT3D	Topmodel	Magic

Main scientific results

1. Overland flow is limited occasionally to saturated areas. Direct runoff ranges 0-25 % of total event precipitation at the drainage ditches and temporal streams (isotopes)
2. Evapotranspiration forms approximately 20% of the annual precipitation
3. Snow covers the catchment typically November to April. Major runoff contribution from snowmelt takes place in April and March. Winter season (Nov-Apr) forms 58% of the total runoff.
4. Soil profile of Dystric Cambisol type plays crucial role in transformation of the hydrograph interacting soil water in capillary pores and gravitational water in preferential pathways (proved by environmental isotopes)
5. Soil profile of Histosol overlying sedimentary aquifer impacts the chemical composition of the outflow. There is strong correlation of hydrochemical parameters with the magnitude of streamflow (indirect for pH, el. conductivity; direct for ORP)
6. Direct pressure transition in the saturated subsurface is the most probable mechanism of the storm rainfall to flood runoff response Due to low hydraulic conductivity of sedimentary materials overlaid by peat, there is partially pressured water table observed at the transition zone in between hillslopes with Cambisol and valley with Histosol due to hillslope lateral return flow
7. Groundwater recharge is approximately 36% of the rainfall, baseflow forms 46% of the streamflow. Aquifer forms the space available for approximately 2 yr of precipitation amount as estimated based on electrical resistivity tomography and modelling approach
8. The mean residence time of water in the catchment is estimated to approx. 7 months (env. isotopes). The residence time of the groundwater is estimated in the range of 1- 10 years by modelling approach

Key references for the basin

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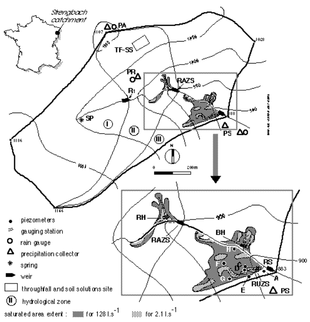
Strengbach

Strengbach basin, France

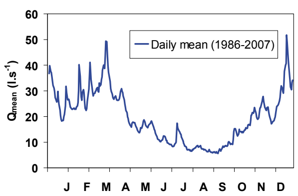
Basin characteristics

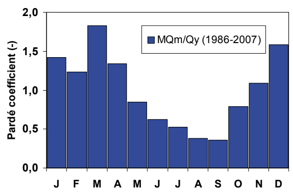
River Basin / River Basin (according EU-WFD)	Ill river basin / Rhine river basin
Operation (from... to...)	Since 1986, still in operation
Gauge coordinates / Gauge datum:	7°12'E; 48°12'N / 883 m a.m.s.l.
Catchment area:	0.8 km^2
Elevation range:	883 – 1146 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	1369 mm (1986-2007), 6°C (1986-2007)
Land use:	57% Norwegian spruce, 15% beech, 15% mixed forest
Soils:	Podzolic and brown acidic
Geology:	Leucogranite.
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Fractured rock aquifer
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	1.15 l/s, 469 l/s, 19.7 l/s (1986-2007)

Map of the research basin



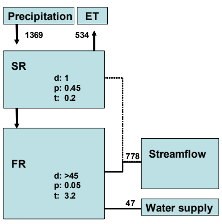
Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Mean annual water fluxes (mm) and hydraulic reservoirs features



SR: Soil water reservoir
FR: Fractured rock groundwater reservoir
Water fluxes (mm.y^{-1})
d: thickness of the reservoir (m)
p: porosity (m^3.m^{-3})
t: mean water transit time (year)

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	Sept 1986 – Sept 1988 Sept 1988 – cont.	1h 1 min	1
Precipitation	Sept 1986 – cont. Sept 1988 – cont.	Daily 10 min.	2
Air temp., humidit,	Sept 1986 – cont. Sept 1988 – cont.	1h / 10 min.	1
Glo. Radiation, Wind speed	Jan. 1989 – 2002	1h / 10 min.	1
Water table	Apr 1996 – Sept 2005 Oct 2005 – cont	Weekly, Fortnightly	4
Chemical elements	Dec 1985 – Sept 2005 Oct 2005 – cont	Weekly, Fortnightly	6
Environ. isotopes ^2H, ^{18}O	Dec 1989 – Aug 1995	Weekly	3

Applied models

1. FlowPC 2. Biljou 3. Topmodel 4. GR4

Main scientific results

Water residence time

The lumped-parameter model (FlowPC) developed by Maloszewski and Zuber (1994) was applied to the 1989–95 environmental isotopic tracer (^{18}O) data set of the catchment in order to determine the water transit time. An exponential piston version of the model applied to spring water indicates a 38,5 month mean transit time, which suggests that the volume in the aquifer, expressed in water depth, is 2,4 m. A considerable thickness (>45 m) of fractured bedrock may be involved for such a volume of water to be stored in the aquifer.

Stormflow components analysis

Complementary approaches associating chemical (trace and major elements), isotopic tracers and hydrological measurements have been performed to identify the origin of water pathways in various hydrological conditions

DOC associated to Si allow to identify the different contributing areas (upper layers of the saturated areas, deep layers of the hillslope and rainwater).

During the first stage of a long duration and less intensive rainfall event (40 mm in 20 hours), a significant part of the runoff (30±39%) comes from the small extended saturated areas located down part of the basin (overland runoff then groundwater ridging). During the second stage, the contribution of waters from the deep layers of the hillslope in the upper subcatchment becomes more significant. The final state is characterised by a balanced contribution between aquifers.

During an intensive 30 mm rainfall of a summer storm event, the infiltration in the soil via macropores provokes a sharp rising of the water table by groundwater ridging, then, an increasing extent of the water saturated area. The processes involved are saturation excess surface runoff and return flow.

Long term hydrochemical trends

The long term observation of this ecosystem indicates, for example, that the spring SO_4 concentration (also Ca and Mg) continuously decreases in reason to a reduction of the atmospheric inputs of these elements and also -as there is less H^+ in the atmosphere and therefore in the soils- to a decreasing weathering in the soils. The increasing NO_3 concentration is due to the declining spruce stand which consumes little nitrogen

Key references for the basin

1. Viville, D., Ladouche, B., Bariac, T. (2006). Isotope hydrological study of mean transit time in the granitic Strengbach catchment (Vosges Massif, France). Application of the FlowPC model with modified input function. *Hydrological Processes;* 20, (8), 1737-1751.
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4. Probst, A., Dambrine, E., Viville, D., Fritz, B. (1990). Influence of acid atmospheric inputs on surface water chemistry and mineral fluxes in a declining spruce stand within a small catchment (Vosges massif, France). *J. of Hydrology*, 116, 101-124.

Contact

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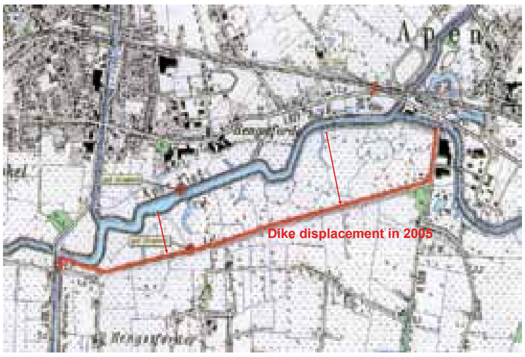
Augustfehn

Aper Tief, Germany

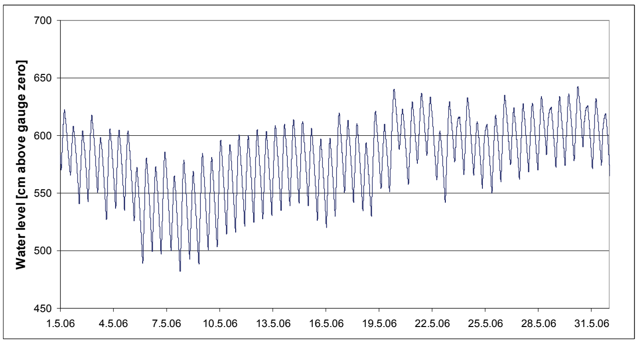
Basin characteristics

River Basin / River Basin (according EU-WFD)	Ems river basin
Operation (from… to…)	2004 – 2009
Gauge coordinates / Gauge datum:	3417020 / 5898320 / -5.02 m asl (NLWKN Aurich).
Catchment area:	75 ha
Elevation range:	0 to 4 m above sea level
Basin type: (alpine, mountainous, lowland)	Lowland, tidally influenced
Climatic parameters: (mean precipitation, temperature and others)	~780 mm/a precipitation, ~8.5°C mean temperature
Land use:	Pasture until 2004, natural succession from 2005 on
Soils:	Sandy gleysols, partly fen soils
Geology:	Quaternary sediments
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Unconfined porous aquifer
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Variable flow directions and discharges depending on tide

Map of the research basin



Exemplary hydrograph



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

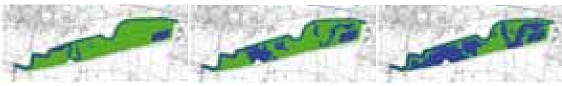
1. Tidally influenced area
2. Development of freshwater tidelands
3. Natural succession of vegetation
4. One artificial lake; artificial drainage in the surrounding area

Instrumentation and data

Measured eco-hydrological parameters	Measuring period	Temporal resolution	Number of stations
Surface water table Groundwater table Soil genesis Erosion, sedimentation processes Dynamics of tidal creeks Species composition (flora, fauna)	2004-2009 Mainly during the growing season	5min (surface water table, groundwater table) Annual (flora, fauna) Measurement campaigns (sedimentation / erosion processes)	1 (surface water) 5 (groundwater) 20 vegetation plots

Applied models

1. GIS based inundation model



Main scientific results

1. Development of a natural marsh dynamics in a freshwater system:
   - Formation of tidal flats
   - Formation of highly dynamic tidal creeks
2. Groundwater dynamics closely coupled to river dynamics
   - Tidally driven groundwater fluctuations
3. Rewetting of the area after displacement of the dike; initiation of altered soil formation processes
4. Natural succession due to abandoned land use and tidal dynamics (rewetting)
5. Rapid changes in species composition within a few years (flora and fauna)
6. Exemplary project achieving a win-win situation between nature protection and flood protection

Key references for the basin

1. Publication in preparation for "*Wasser und Abfall*" (Vieweg Verlag / GWV Fachverlage GmbH)

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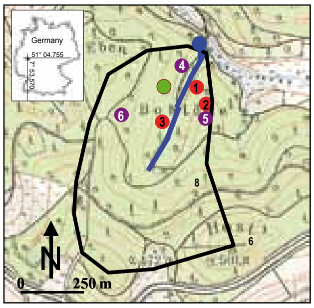
Bohlmicke

Bohläse, Germany

Basin characteristics

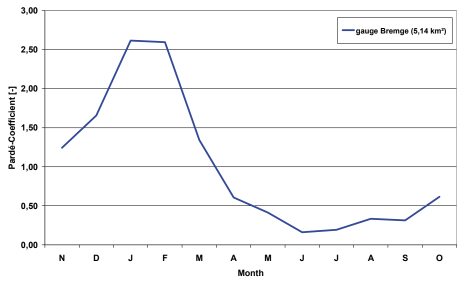
River Basin / River Basin (according EU-WFD)	Rhine
Operation (from… to…)	2000 to 2007
Gauge coordinates / Gauge datum:	N 51° 04.755, E 7° 53.570
Catchment area:	0,7 km²
Elevation range:	382 to 425 m a.s.l.
Basin type: (alpine, mountainous, lowland)	low mountain range
Climatic parameters: (mean precipitation, temperature and others)	P: 1250 mm/a; T: ø 8°C
Land use:	forest
Soils:	Cambisol, Leptosol
Geology:	grey clay shale
Hydrogeology: (Type of aquifers, hydraulic conductivity)	unconfined aquifer
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Q_{min}: 0,006 m³/s; Q_{max}: 3,16 m³/s; Q_{mean}: 0,078 m³/s

Map of the research basin



- soil hydrological measurement stations
  1) footslope I
  2) upperslope
  3) footslope II
- throughfall
  4) spruce forest (20-30 years)
  5) spruce forest (75-85 years)
  6) beech forest
- precipitation
- gauge Bohlmicke
- catchment „Bohläse“
- channel „Bohlmicke“

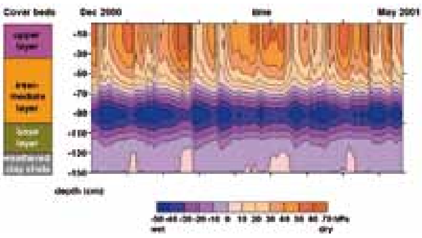
Mean hydrograph / Pardé flow regime



Pardé flow regime for gauge Bremge (2001-2003).
Catchment “Bohläse” is part of catchment “Bremge”.

Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

1. Catchment bears typical periglacial cover beds which are characteristic for low mountain ranges in middle europe.
2. Good opportunity to analyse the influence of the soil structure on the vertical and lateral soil water fluxes and on the runoff processes.



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
precipitation	2000 - 2007	weekly	1
throughfall	2000 - 2007	10 min weekly	1 2
discharge	2001 - 2007	10 min	1
soil water potential	2000 - 2007	10 min	3

Applied models

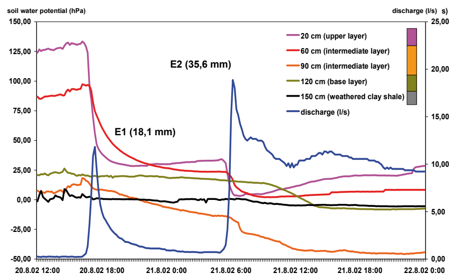
1. Any runoff model wasn`t applied yet.

Main scientific results

Based on studies at different scales, runoff processes in the catchment “Bohläse” (Sauerland, Germany) were analysed during several rainfall-runoff-events. Using hydrological tracers and hydrometric methods, the influence of periglacial cover beds was determined for runoff at the catchment scale and for soil water flux at the point scale.

The process studies show that the influence of the base layer depends on the current water content. If the water content in the base layer is low, vertical water movement is impeded. On the other hand, if the water content is high, the base layer becomes a preferential flow path for interflow. Due to the spatial variability of the soil physical properties, the base layer functions as a preferential flow path for interflow only if the bulk density is low.

The results confirm the importance of periglacial cover beds for runoff processes in low mountain regions and represent an experimental basis for hydrological regionalisation depending on the spatial distribution of periglacial cover beds.



Key references for the basin

1. Chifflard, P. (2006): Der Einfluss des Reliefs, der Hangsedimente und der Bodenvorfeuchte auf die Abflussbildung im Mittelgebirge. Experimentelle Prozess-Studien im Sauerland. – Bochumer Geographische Arbeiten 76, 162 S.
2. Chifflard, P. & Zepp, H. (2008b): Skalenübergreifende Prozess-Studien zur Abflussbildung in Gebieten mit periglazialen Deckschichten (Sauerland, Deutschland). – Grundwasser 13(1):27-41, doi: 10.1007/s00767-007-0058-1

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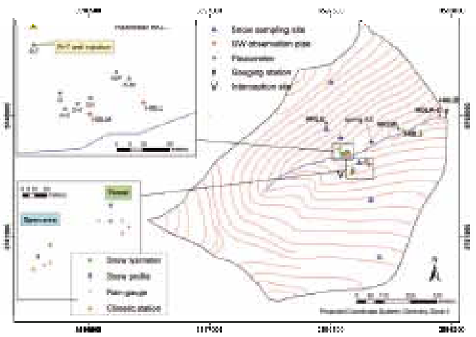
Lange Bramke

Bramke basin, Germany

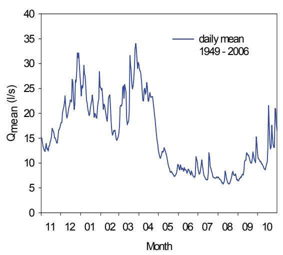
Basin characteristics

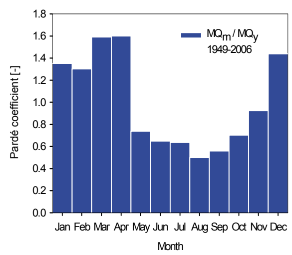
River Basin / River Basin (according EU-WFD)	Oker river basin / Weser river basin
Operation (from… to…)	Since 1948, still in operation
Gauge coordinates / Gauge datum:	10°26'E; 51°52'N / 537.76 m a.m.s.l.
Catchment area:	0.76 km²
Elevation range:	538 – 700 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	1300 mm (1949-2007), 6.3°C (1963-2007)
Land use:	90% Norwegian spruce, 10% grassland
Soils:	Podsolic brown earth, brown earth Podsol, Pseudogley
Geology:	Sandstones, shaly quartzite
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Fractured rock aquifer with a shallow porous aquifer overlay along the stream channel
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0.0 l/s, 15.68 l/s, 634 l/s (1949-2007)

Map of the research basin



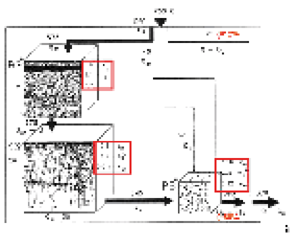
Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Mean annual water fluxes [mm WC] and hydraulic reservoir features



BS = Soil water reservoir
KS = Fractured rock groundwater reservoir
PS = Porous groundwater reservoir
Q = Water flux [mm/a]
V; Vm = Total volume; volume of mobile water [10^6 m³];
t_t = Mean transit time of tracer [a];
t_o = mean transit time of water [a]
n = Total porosity
n_{eff} = Effective porosity

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	Nov 1948 – cont.	1h 10 min (since 1992)	1
Precipitation	1948 – cont. 1987 – cont. 1992 – cont.	Daily Hourly Impuls/ 0.1mm	2
Air temp., humidity	1987 – cont.	1h / 10 min.	2
Groundwater level	1988 – cont. 1992 – cont.	Weekly, Houly	21 5
Environmental isotopes ^3H, ^2H, ^{18}O	Event based	Event dependent	Event dependent

Applied models

1. Concept model
2. Mike Basin
3. Feflow
4. IHACRES

Main scientific results

1. No overland flow exists. Direct runoff (=event water) equals to 12 %(= 80 mm/a) of total which is less than 5% of the input. Since interflow is negligible, indirect flow is 88 % (= 590 mm/a) and consists of groundwater.
2. The unsaturated zone and the fissured rock aquifer are short-cut by preferential flow paths which enable fast percolation. Groundwater recharge is extremely high (620 mm/a). The mean transit time of groundwater is 2.0 years.
3. Subsurface pressure heads and groundwater exfiltration react spontaneously on basin input. The latter controls the generation of flood hydrographs which consist dominantly of groundwater. Major cross-faults function as efficient drain channels.
4. The successive steps of the runoff formation process are probably the following:

   (i) Infiltration with saturation of top soils, quick drainage through macropores towards greater depths, and compression of the capillary fringe which may initiate pulse pressure transmission and connected aquifer reactions without mass transfer;

   (ii) Rise of piezometric table, i.e. increase of subsurface pressure head and subsequent mass displacement, which can be split into vertical seepage in the unsaturated (cf. (i)) and lateral (groundwater) flow in the saturated zone; and

   (iii) Groundwater exfiltration to stream channels as a combined effect of pressure transmission and mass transfer, with hydrograph generation as a result. To maintain the quantitative input/output balance, short-term groundwater losses are compensated without much delay, i.e. groundwater recharge is a permanent process throughout the year.

Key references for the basin

1. Herrmann, A. & Schumann, S. (2009) Untersuchung des Abflussbildungsprozesses als Kontrollmechanismus für den Gebietswasserumsatz des Oberharzer Einzugsgebiets Lange Bramke (Investigations of the runoff formation process as a mechanism for monitoring the basin turnover in the Lange Bramke catchment, Upper Harz Mountains). Hydrologie und Wasserbewirtschaftung 53(2), 64-79
2. Herrmann, A. (2008): 30 Jahre integraler Forschungsansatz zum Abflussbildungsprozess und 60 Jahre Abflussbeobachtungen im Oberharz.(30 years of integrated scientific investigation of the runoff formation process and 60 years of runoff observations in the Upper Harz Mountains). Hydrologie und Wasserbewirtschaftung, 52 (3), 132-136
3. Maloszewski, P., Herrmann A., Zuber, A. (1999) Interpretation of tracer tests performed in fractured rock of the Lange Bramke basin, Germany. Hydrogeological Journal, 7: 209-218.

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Brugga gauging station

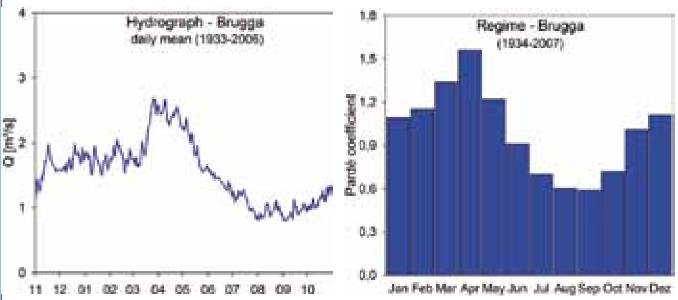
Brugga basin, Germany

Basin characteristics

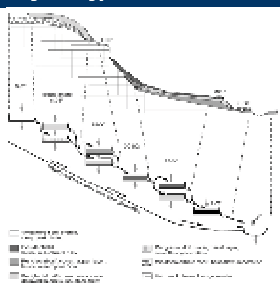
River Basin / River Basin (according EU-WFD)	Dreisam river basin / Rhine river basin
Operation (from… to…)	From 1933 to now
Gauge coordinates / Gauge datum:	E: 3421750 m N: 5311600 m Datum: 308 m.a.s.l.
Catchment area:	40,1 km²
Elevation range:	1493 m.a.s.l. (Feldberg) – 434 m.a.s.l. (Oberried)
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	P=ca. 1730 mm T=ca. 7.7°C ETP=ca. 566mm
Land use:	Forest: 75.7; grassland: 21.8; acres: 1.5; impervious: 0.9
Soils:	Brown earth, gley soil, podzol
Geology:	Gneiss, Migmatite; Quaternary overlaying strata
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Basement: connected fissures, n:0.1-2.1%, k=10^{-10}-10^{-5} ms^{-1} ; Quaternary strata: extremely variable parameters
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Qmin:0.2; Qmax: 33.6; MQ:1.55 [m³/s]

Map of the research basin

Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal Resolution	Number of Stations
Discharge	1933 – now	daily , 10 min	2
Springs	1998 - now	weekly, 10 min	2
Temperature, EC, pH	1995 – now	10 min (95-99) weekly (99-now)	1
^{18}O (Q and P), ^{2}H (P)	Q: 1998-now; P:1995-now	weekly	2 (Q + P)
Major ions	1998-now	weekly	1
Silicate	1998 – 2004	weekly	1
Precipitation	1994 – now	daily	3
Climate parameters (temperature, humidity, radiation, wind)	1994 – now	daily	3

Applied models

1. Precipitation-Runoff Modeling system (PRMS); Mehlhorn, 1998
2. Tac (tracer aided catchment model), TOPMODEL, HBV, PRMS; Uhlenbrook, 1999
3. Tac^D (tracer aided catchment model, distributed); Uhlenbrook , 2002
4. Mixing models (with two and three components); Didszun, 2004
5. Catchment water quality model (non point source model, NPSM); Eisele et al. 2001

Main scientific results

1. Tracer experiments:
   Groundwater residence time in the lower Quaternary strata and basement: 920 d; Groundwater dynamic in the lower Quaternary strata and basement: 340 d (double porous medium)
   Modeling with PRMS(tracer based conceptualization, validation and calibration):
   direct runoff: 16%; indirect runoff out of the upper Quaternary strata: 52% and out of lower Quaternary strata and basement: 32%

2. Development of a semi distributed rainfall runoff model (Tac). Tracer data can serve as multi-response data to assess and validate a model.
   Direct runoff is generated on saturated and impervious areas and on steep permeably boulder fields. It can amount 50 % of total runoff, long term portion is ca. 10%
   Two underground flow system: 1-hillslope groundwater, ca. 70% of total runoff, mean residence time of 2-3 years; 2-critaline fissured aquifer system, ca. 20% of total runoff, mean residence time of 6-9 years.
   Further development of the semi distributed model Tac to the distributed model Tac^D.

3. The hydrochemical distinguishing between upland springs, hill slope water and stream water is possible. But flowpaths in hillslopes feature a great heterogeneity. Neither depth nor position of hillslope water have systematic influence on the natural tracer concentrations.
   The spatial heterogeneities is clearly scale dependent. They are much more pronounced in small subcatchments but reduce with increasing catchment size.

4. The applied model proved to be applicable in a mesoscale catchment performing satisfactory results for the simulation of stream flow. The simulated nitrate concentrations were strongly controlled by the nitrogen input, the water movements and the nitrogen reactions in the different sub-areas. The simulation of nitrogen transport for the validation period showed only an agreement with the measured concentrations for the mean values, but the short time dynamics of the measured curve could not be fitted.

Key references for the basin

1. Mehlhorn J. (1998): Tracerhydrologische Ansätze in der Niederschlags-Abfluß-Modellierung. Freiburger Schriften zur Hydrologie, Band 8, Universität Freiburg.
2. Uhlenbrook S. (1999): Untersuchung und Modellierung der Abflußbildung in einem mesoskaligen Einzugsgebiet. Freiburger Schriften zur Hydrologie, Band 10, Universität Freiburg.
   Uhlenbrook S. et al. (2004): Hydrological process representation at the meso-scale: the potential of a distributed, conceptual catchment model. Journal of Hydrology, Vol.291, No.3-4, P 278-296
3. Didszun J. (2003): Experimentelle Untersuchungen zur Skalenabhängikeit der Abflussbildung. Freiburger Schriften zur Hydrologie, Band 19, Institut für Hydrologie der Universität Freiburg.
4. Eisele M., et al. (2001): Application of a catchment water quality model for assessment and prediction of nitrogen budgets. Phys. Chem. Earth (B) Vol. 26, No.7-8, P. 547-551

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Elsterbach

Elsterbach catchment, Germany

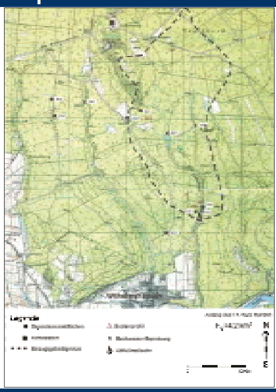
NW-FVA

HESSEN

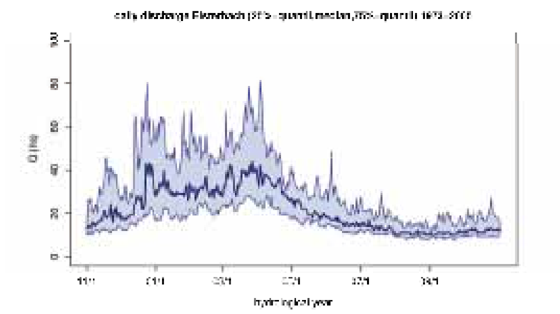
Basin characteristics

River Basin / River Basin (according EU-WFD)	Weser river basin
Operation (from… to…)	From 1972 to 2005
Gauge coordinates / Gauge datum:	10°26'E; 51°52'N / 537.76 m a.s.l.
Catchment area:	4.25 km²
Elevation range:	220 – 465 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	784 mm (1972-2004), 7.7°C (1961-1990, DWD Beberbeck)
Land use:	95% forest: Norway spruce 46%, European beech 28%, oak 7%, other tree species 19%
Soils:	Eutrophic brown earth, Parabraunerde, Pseudogley and Stagnogley
Geology:	Sandstone with quaternary overlying strata, basalt
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Northwestern part: very deep and well permeable soils northeastern part: soils hardly permeable to water
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	5.0 l/s, 3511 l/s, 33.4 l/s (1972-2005)

Map of the research basin

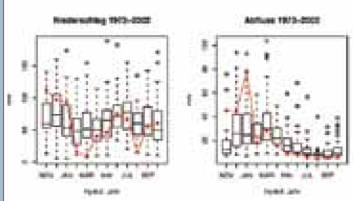


Mean hydrograph / Pardé flow regime

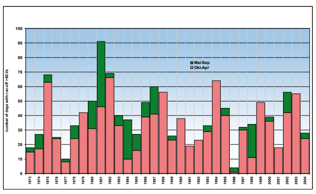


Impact of climatic changes on the runoff

Precipitation and discharge during the dry year 2003



Trend of number of days with runoff > 2 *Q_{mean}



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	Nov 1972 – Oct. 2005	1h	1
Precipitation	1972 – 2005 1972 – 2005	Daily monthly	1 6
Air temp. (DWD Beberbeck)	1961 – 1990	1h	1

Applied models

Main scientific results

1. The average runoff adds up to 246 mm which is 31 % of the yearly precipitation. The ratio runoff / precipitation varies between 18 and 50 %.
2. Runoff shows a very wide range from 1,2 l / s* km² to 826 l / s* km² and is similar to the runoff of alpine creeks.
3. Two little creeks that rise from different geological strata (basalt; sandstone) form the Elsterbach creek.
4. Important steps of runoff formation process:

   (i) The plateau of the northeastern part of the watershed is characterized by low infiltration capacity due to almost impermeable clay–layers. There is a high proportion of subsurface flow after heavy rain fall and this creek contributes above average to flood waters. During summer this creek often falls dry.

   (i) The soils in the northwestern part of the watershed are very deep and highly permeable with quick drainage through macropores towards greater depths and low saturation of topsoils.
5. The two creeks are very different concerning water chemistry. While the pH (median) of the northwestern creek is 6.7, the pH of the northeastern creek is between 4.4 and 4.6. Sulfate concentration is a much higher in the northwestern creek due to coal sources in this area. A declining trend could be observed for strong acids, particularly for sulfate, because of strongly reduced deposition rates. There is no declining trend for nitrogen concentration, which is between 0.5 and 2 mg/l during vegetation period and 8 to 10 mg/l during winter months.

Key references for the basin

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Soltfeld

Kielstau basin, Germany

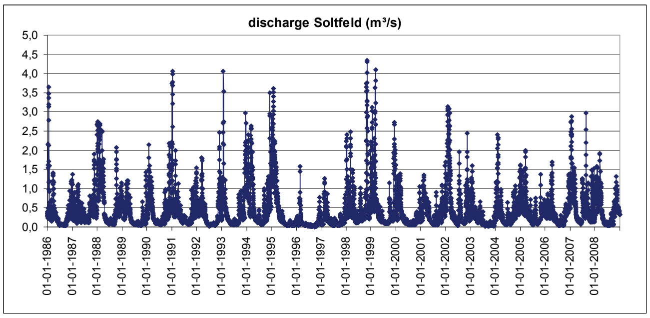
Fachabteilung Hydrologie und Wasserwirtschaft

Basin characteristics

River Basin / River Basin (according EU-WFD)	Kielstau river basin / Treene basin / Eider basin
Operation (from... to...)	Since 1985, still in operation
Gauge coordinates / Gauge datum:	GK: 3532037/6064565, 26.569 m.a.s.l.
Catchment area:	49.3 km² up to Gauge Soltfeld
Elevation range:	78 m to 27 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	lowland
Climatic parameters: (mean precipitation, temperature and others)	mean annual precipitation and temperature: 893 mm and 8.3°C, respectively (DWD, 2007)
Land use:	56% arable land, 33% grassland+fallow (DLR 1995)
Soils:	Stagnic and Haplic Luvisols, Stagnic Gleysols, Sapric Histosols
Geology:	Pleistocene-Holocene, formed by ice-ages
Hydrogeology: (Type of aquifers, hydraulic conductivity)	3 porous aquifers: I and II sands Pleistocene, III lignite sands Tertiary; separated by clay-silt layers
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	QNN 0.009, QMN 0.048, QM 0.424, QMH 2.747, QHH 4.522 [m³/s] (1987-2005)

Map of the research basin

Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

1. flat area but relatively uneven with rolling hills and numerous depressions
2. hydrology characterised by shallow groundwater, low hydraulic gradients and high interaction between groundwater and surface water
3. Kielstau flows through Lake Winderatt (surface area of 0.24 km², mean depth of 1.2 m)
4. two large tributaries: Moorau and Hennebach
5. rural catchment: only few small villages and detached farms
6. fraction of drained agricultural area in the catchment is estimated to be 38% (Fohrer et al., 2007)
7. six municipal wastewater treatment plants (in total: 6378 population equivalents)
8. many parts of the Kielstau markedly changed from its natural course: river straightened, incised and thus disconnected from its floodplains; relative low hydromorphological variety and value, some near-natural river sections still exist, overall morphological state of the stream is poor - moderate
9. Kielstau is part of the flora fauna habitat protection area (FFH-directive; EC, 1992)
10. 175 ha of land along the river and around Lake Winderatt are owned by nature conservation foundations

Instrumentation and data

Measured hydrological parameters	Station, Measuring period	Temporal resolution	Operator
Water level & discharge	Soltfeld, 1985-cont.	hourly	LLUR
Water level	Soltfeld,		Ecology Centre
NO3, NH4, NtotPO4, Ptot, Cl, SO4	Soltfeld, 2006-cont.	daily	Ecology Centre
Temp, O2, pH, EC	Soltfeld, 2005-cont.	weekly	Ecology Centre
Water quality along longitudinal sections, precipitation, interaction groundwater-surfacewater, lake water quality, macrozoobenthos	different locations in basin, starting 2005	diverse	Ecology Centre

Applied models

SWAT (Soil and Water Assessment Tool, Arnold et al. 1998)

- water balance, N balance, sediment transport

Main scientific results

1. The measured and modelled discharges at the catchment outlet show a good agreement for the SWAT model set-up of the study area. The model performance (calibration) shows a Nash-Sutcliffe index between 0.80 (calibration period 2002-2007; Kiesel et al. 2008) and 0.77 (calibration period 1998-2004; Lam et al. 2008, 2009).

2. The results of sensitivity analyses show that groundwater and soil parameters were found to be most sensitive in the studied lowland catchment and they turned out to be the most influential factors on simulated water discharge (Schmalz & Fohrer 2009). The model efficiency for daily nitrate loads is 0.64 for the calibration period (June 2005 to May 2007) at gauge Soltfeld (Lam 2009).

3. A high seasonal variability in water levels and flow dynamics in the shallow groundwater as well as in the drainage ditches and the river was observed. Far from the river, at the ditch origins, the interactions in the riparian wetland are characterised by continuous effluent conditions which originate from positive differences in groundwater heads. Close to the river, at the mouth of the ditches, lower differences in groundwater heads are observed. They are partially negative, or change between positive and negative differences and result in a change between influent and effluent conditions (Schmalz et al. 2008b).

4. The measurement results showed that the in-stream water quality was influenced both from diffuse and point sources. Using a German classification system (LAWA, 1998), the NO_3-N results can mostly be assigned to water quality class III (heavily contaminated) and NH_4-N to class II (moderately polluted). Tributaries with waste water treatment plants show higher NH_4-N concentrations. High NO_3-N-values from diffuse entries were observed in most inflows, but some tributaries increased the main stream NO_3-N concentrations especially in autumn (Schmalz et al. 2008a).

5. The water quality in the drainage ditches showed a variability dependent on their hydrological integration. At the far-from-river end, groundwater and ditch water quality were in most parameters much more alike than at the close-to-river end. The composition of ditch water at the close-to-river end of the ditch was determined by transformation processes and dilution which took place along the ditch much more than exfiltration processes like those that were dominant at the far-from-river end (Schmalz et al. 2009, submitted).

Key references for the basin

1. Schmalz, B., Bieger, K. & Fohrer, N. (2008a) A method to assess instream water quality – the role of nitrogen entries in a North German rural lowland catchment. Adv. Geosci. 18: 37-41.
2. Schmalz, B., Springer, P. & Fohrer, N. (2008b) Interactions between near-surface groundwater and surface water in a drained riparian wetland. Groundwater–Surface Water Interaction: Process Understanding, Conceptualization and Modelling. IAHS Publ. 321, 21-29.
3. Schmalz, B., Tavares, F. & Fohrer, N. (2008c) Modelling hydrological lowland processes in mesoscale river basins with SWAT - Capabilities and challenges. Hydrological Sciences Journal, 53(5), 989-1000.

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http://www.schleswig-holstein.de/LLUR/

Hydrological research area of Krofdorf

Krofdorf, Germany

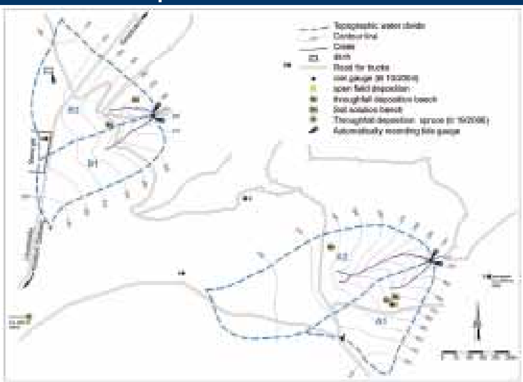
NW-FVA

HESSEN

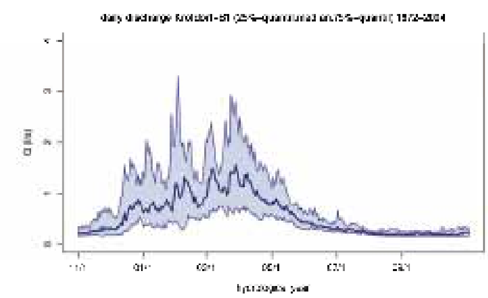
Basin characteristics

River Basin / River Basin (according EU-WFD)	Lahn river basin
Operation (from… to…)	Since 1972, still in operation
Gauge coordinates / Gauge datum:	8° 39' E; 50° 41' N; 233 m (A area), 253 m (B area)
Catchment area:	Four small catchments: A1 (0.09 km²); A2 (0.2 km²); B1 (0.11 km²); B2 (0.14 km²)
Elevation range:	232.6 - 336.0 m a.s.l.
Basin type: (alpine, mountainous, lowland)	mountainous
Climatic parameters: (mean precipitation, temperature and others)	700 mm (1972-2004); DWD Gießen: 644 mm (1972-08); 9.4 °C
Land use:	Forestry with deciduous leave trees (European beech: 50-83%, oak: 13-20%)
Soils:	Brown earth, lessivated brown earth, Pseudogley
Geology:	Shale, greywacke
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Porous aquifer over dense impermeable schistous rock
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	A1: 0.3 l/s; 263 l/s; 8.6 l/s B1: 1.2 l/s; 299 l/s; 7.6 l/s A2: 0.3 l/s; 188 l/s; 5.3 l/s B2: 0.5 l/s; 156 l/s; 5.7 l/s

Map of the research basin



Mean hydrograph / Pardé flow regime



Special basin characteristics

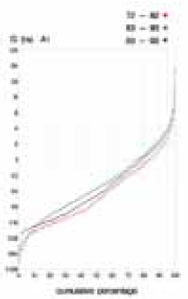
Effect of clear cut in A1 on the discharge of creek A1

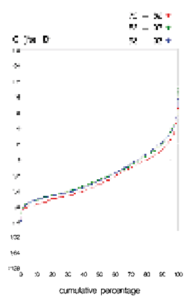
1972 to 1982: calibration period

1983 to 1987: final felling in A1

1986 to 1988: planting of beech on the clear cut

1993 to 2003: thinning in B1 (41 fm/ha) in 1997





Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	Nov 1971 – cont.	1h 15 min (since 2007)	4
Precipitation	Nov.1971 – cont. Nov.1987 – cont. Nov.1971 - 2004	Daily 30 min. monthly	1 1 9
Air temp., humidity	1987 – cont.	30 min.	1

Applied models

1. Brook 90
2. NuCM

Main scientific results

1. The hydrological research area of Krofdorf was designed as a paired/multiple Watershed Experiment
2. The average ratio of runoff (1972-04) to precipitation is 24% (A2), 26% (B2), 34% (B1) and 39% (A1). The rate of runoff hasn't shown any vectored trend since the beginning of the observation.
3. 10-year-calibration-period (1972-1981) showed a strong correlation between the two experimental sites A1 and A2 and the reference basin B1 concerning runoff.
4. Reduction of stand density index from 0.83 to 0.62 in A1 increased runoff by 20 mm * year (5%).
5. Runoff increased by 46 mm (16%) in the year following clear cut of the upper part of watershed A1 (1986).
6. During the first seven years after the final cutting in A1 runoff was on average 70 mm (30%) higher than in the reference basin B1.
7. Mean nitrate concentration in creek A1 during the calibration period was 5 mg/l with maximum values up to 15 mg/l. As a result of clear cutting mean nitrate concentration doubled to10 mg/l with maximum values to 23 mg/l. 6 years after clear cut nitrate concentrations decreased to values before clear cut.
8. Concentration of sulphate in precipitation and throughfall decreased until 2000 and remained on a constant level since then. Sulphate concentration in creek water of all 4 basins is also decreasing.
9. The water balance as well as the matter balance could be analysed and described with the models BROOK 90 and NuCM. The concequences of thinning and clear cutting could be simulated satisfactorily.

Key references for the basin

1. Kennel, M. (1998) Modellierung des Wasser- und Stoffhaushalts von Waldökosystemen- Fallstudien: Forsthydrologisches Forschungsgebiet Krofdorf, Referenzeinzugsgebiet Große Ohe. Forstliche Forschungsberichte München, Nr. 168/1998
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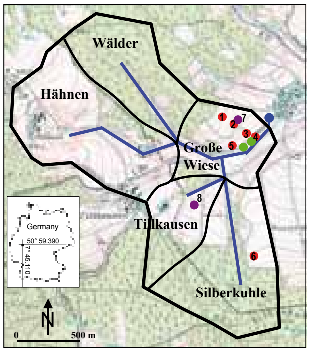
Husten

Obere Brachtpe, Germany

Basin characteristics

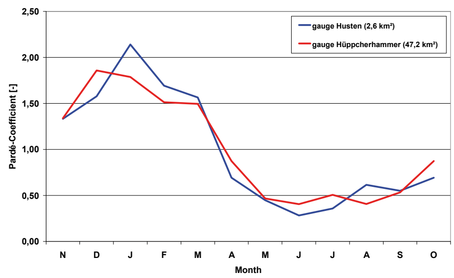
River Basin / River Basin (according EU-WFD)	Rhine
Operation (from… to…)	1999 to 2007
Gauge coordinates / Gauge datum:	N 50° 59.390, E 007° 45.110
Catchment area:	2,55 km²
Elevation range:	382 to 425 m a.s.l.
Basin type: (alpine, mountainous, lowland)	low mountain range
Climatic parameters: (mean precipitation, temperature and others)	P: 1250 mm/a; T: ø 8°C
Land use:	pasture, spruce forest
Soils:	Cambisol, Stagnosol, Gleysol, Anthrosol
Geology:	clay and silt shale, fine graided sandstone
Hydrogeology: (Type of aquifers, hydraulic conductivity)	unconfined aquifer hydraulic conductivity: $2*10^{-5}$ m/s (shallow groundwater)
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Q_{min}: 0,006 m³/s; Q_{max}: 3,16 m³/s; Q_{mean}: 0,078 m³/s

Map of the research basin



- soil hydrological measurement stations
  1) upperslope
  2) middleslope
  3) footslope
  4) bottom
  5) divergent slope
  6) middleslope north
- climate station
  7) middleslope south
  8) middleslope north
- groundwater monitoring
- gauge Husten
- catchment „Obere Brachtpe"
- subcatchments
- channel „Brachtpe"

Mean hydrograph / Pardé flow regime

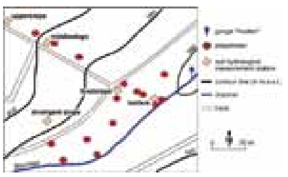


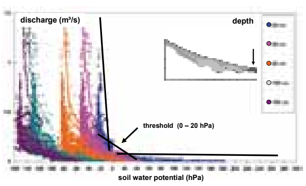
Pardé flow regime for gauge Husten (2000-2008) and gauge Hüppcherhammer (1966-2007). Gauge Husten is part of catchment Hüppcherhammer.

Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

1. Landscape of the catchment "Obere Brachtpe" is typical for this region.

3. Hydrometric data (i.e. soil water potential and groundwater level) is available in a very high spatial and temporal resolution at a convergent and a divergent hillslope.





Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
precipitation, temperature, air moisture, wind speed, wind direction	2000 - 2007 2003 - 2006	10 min 10 min	1 1
discharge	since 1999	15 min	1
soil water potential	2000 – 2007 2002 - 2007	10 min 10 min	4 2
groundwater level	2001 - 2007	10 min	8
groundwater level	2000 - 2007	weekly	6

Applied models

1. Kinematic wave model (Rezzoug et al. 2005)

Main scientific results

1. Influence of relief on runoff processes:

Based on the relationship between groundwaterlevel respectively soil moisture and the runoff measured at the catchment outlet, the hillslope catchment area can be distinguished between two hydrological systems; the "upslope zone" and the "riparian zone". While the relationships of the piezometers in the riparian zone have an exponential correlation and indicate a groundwater storage, the relationships of the piezometers in the upslope zone show a linear correlation. This distinction is caused by the decreasing slope inclination in the riparian zone and consequently by the decreasing hydraulic gradient.

The analysis of temporally high-dissolved data of the groundwater dynamics in relation to the discharge of the receiving stream during several rainfall/runoff events shows the influence of the slope form and of the flat „riparian zone" on the runoff processes. Due to the convergent slope form the subsurface runoff is concentrated in the depth contour of the hillslope. Caused by the small slope inclination in the flat riparian zone the velocity of water flow is reduced and groundwater from the slope is transported to the channel with a time lag. In consequence of this delayed groundwater flow the runoff in the receiving stream also shows a delayed increase.

2. Influence of the antecedent soil moisture on runoff processes

The influence of the antecedent soil moisture is quantified by the multivariate-statistical analysis of 137 rainfall-runoff events. By using the hierarchical cluster analysis six soil moisture clusters can be distinguished which represent different moisture conditions of a convergent hillslope "husten". Based on this distinction a linear regression function was calculated for estimating the peak flow in every cluster. During wet conditions the independent variables total rainfall amount of an event and the initial runoff have a strong influence on the peak runoff. In case of more dry conditions, the total rainfall amount and the rain intensity have a strong influence on the peak runoff. The variance of the independent variables marks the transition of the dominating influence of the rainfall characteristics (e.g. rainfall amount, rainfall-intensity) to the dominating influence of the catchment characteristics (e.g. soil, relief).

Key references for the basin

1. Chifflard, P. (2006): Der Einfluss des Reliefs, der Hangsedimente und der Bodenvorfeuchte auf die Abflussbildung im Mittelgebirge. Experimentelle Prozess-Studien im Sauerland. – Bochumer Geographische Arbeiten 76, 162 S.
2. Chifflard, P. & Zepp, H. (2008a): Erfassung der zeitlichen Variabilität der Abflussbereitschaft eines Einzugsgebietes auf Grundlage von Bodenfeuchtemessungen. – Hydrologie und Wasserbewirt-schaftung 3:98-109
3. Rezzoug, A., Schumann, A., Chifflard, P. & Zepp, H. (2005): Field Measurement of soil moisture dynamics and numerical simulation using kinematic wave approximation. – Advances in Water Resources 28:917-926

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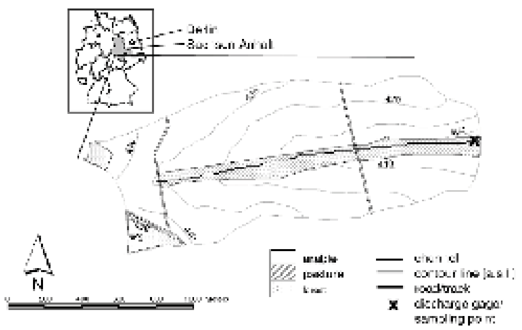
Schäfergraben

Schäfertal, Harz Mountains, Germany

Basin characteristics

River Basin / River Basin (according EU-WFD)	Selke, Bode, Saale, Elbe
Operation (from… to…)	1968 - ongoing
Gauge coordinates / Gauge datum:	11°3´10´´ E, 51°39´16´´
Catchment area:	1.44 km²
Elevation range:	392 – 474 m asl
Basin type: (alpine, mountainous, lowland)	Low mountain
Climatic parameters: (mean precipitation, temperature and others)	630 mm a^{-1}, 6.9 °C (Station Schäfertal 1968-2006)
Land use:	> 80% arable, pasture / set aside, forest
Soils:	Cambisol, Luvisol, gleyic Luvisol
Geology:	Palaeozoic greywacke and argillaceous shale
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Fractured rock aquifer
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0 / 36 / 0.33 [mm/d]

Map of the research basin



Mean hydrograph

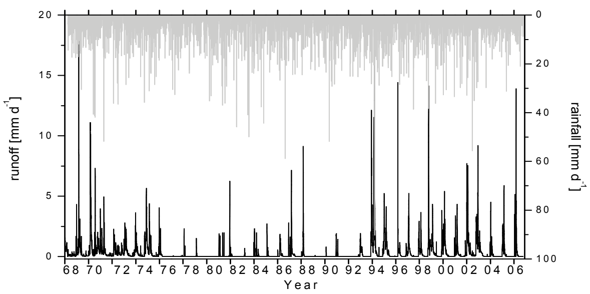


Fig. 1 Rainfall and discharge variation of the Schäfertal from 1968 until 2006

Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

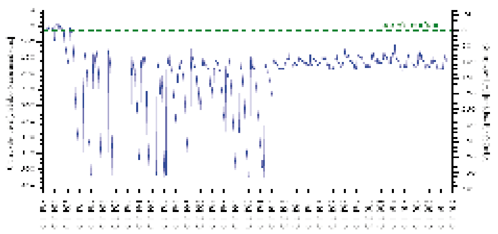


Fig. 2 Modification of groundwater level and discharge and runoff generation by mining activities

Instrumentation and data

Meteorology	Hydrology	Others
air temperature air humidity and air pressure wind speed (2, 5, 10 m) wind direction short and long wave radiation PAR heat-flux several temperature sensors at different above-ground heights and soil depths	five automatic rainfall gages “watermark” soil moisture sensors, TDR and tensiometers continuous measurements of discharge, ground water table at numerous points snow cover height and water equivalent tile drain flows	temperature in discharge electric conductivity of discharge biweekly manual and automatic event water sampling for sediment yield, phosphorus nitrogen DOC / LC-DOC soil water sampling with suction plates and chemical characterisation

Applied models

1. AKWA-M, WASIM-ETH, DIFGA
2. Candy, Integrated Winter erosion and Nutrient Load Model
3. Erosion3D

Main scientific results

Detailed analyses of the hydrograph and groundwater measurements allow the separation of three periods with distinct differences in water balance and runoff generating processes (Fig. 1). The first period until 1973 is characterised by a naturally balanced water flow with soil moisture increase and storage filling in winter and high discharge situations during spring. Base flow contribution guaranteed a minimum of water flow during summer time. The following periods were characterised by plot realignment and draining of a pasture area. Most important was the opening of an underground mining that leads to a decrease of the regional groundwater level. The related hydrological situation with long dry periods and episodic flash floods had significant negative effect on the chemical and biological water quality. In the course of the safe keeping at the end of the mining activity the groundwater level rose again since 1993 and has reached a new stable situation in 1999.

The complex catchment response to runoff generation and sediment or P loads is documented in varying hysteresis curves. There is also evidence for depletion of sediment availability during some events. An event specific sediment/P relationship can be identified as a result of source area characteristics and connectivity aspects.

To simulate the transformation of precipitation into runoff regression models are suitable. From preconsiderations correlations between discharge, precipitation, temperature, snowmelt and soil water runoff can be postulated. The quantification of snowmelt and soil water runoff is currently not possible because a continuous running runoff model is actually still in preparation. Therefore, a reduced regression model between the parameters runoff Q and precipitation P was established. The reduced model is a coupling between “moving averages” for Q with a part to consider P. For the case of m = 2 the following formulation was found:

$$Q(t) = \gamma_o P(t) + \gamma_1 P(t-1) + \beta_1((Q(t-2) + Q(t-3) + Q(t-4) + Q(t-5))/4) + \varepsilon_n$$

with Q(t) … discharge at day t, γ, β_1… weighting factors, P(t) … precipitation at day t and ε_n … certain degree.

Key references for the basin

1. BORCHARDT, D. 1982. Untersuchungen zur Variabilität von Abflussbildungsprozessen in Hochwasserentstehungsgebieten des unteren Mittelgebirges. Wasserwirtschaft-Wassertechnik, 11: 382-385.
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4. OLLESCH, G., KISTNER, I., MEISSNER, R. and LINDENSCHMIDT, K.-E. 2006. Modelling of snowmelt erosion and sediment yield in a small mountain catchment. Catena 68: 161-176.

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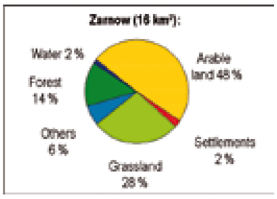
Brook Zarnow gauging station

Zarnow basin, Germany

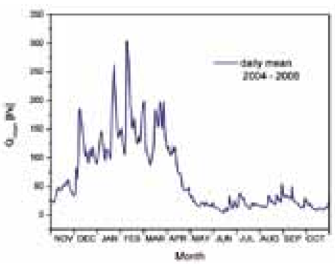
Basin characteristics

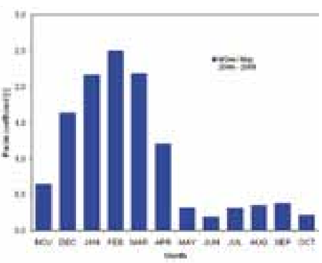
River Basin / River Basin (according EU-WFD)	Warnow-Peene basin (Mecklenburg-Vorpommern)
Operation (from… to…)	2001, still in operation
Gauge coordinates / Gauge datum:	54°01'N; 12°13'E / 34.5 m a.s.l.
Catchment area:	15.5 km^2
Elevation range:	34.5 - 50.6 m a.s.l.
Basin type: (alpine, mountainous, lowland)	lowland
Climatic parameters: (mean precipitation, temperature and others)	665 mm mean precipitation, 8.2°C mean temperature, 490 mm mean crop reference evapotranspiration (1979-2008)
Land use:	Mainly agricultural (arable land, grassland), forest
Soils:	Luvisols, Gleysols, Histosols, Cambisols
Geology:	Quaternary (ground moraine, Weichsel ice-age)
Hydrogeology:	Quaternary deposits (Mergel)
(Type of aquifers, hydraulic conductivity)	Confined and unconfined aquifers (heterogeneous conditions)
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Q_{min} = 0.0 l s^{-1}, Q_{max} = 1094 l s^{-1}, Q_{mean} = 64 l s^{-1}

Map of the research basin

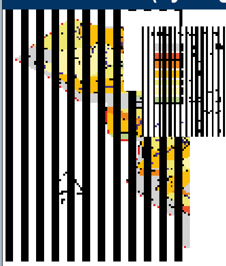


Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



Drainage spacing and hydrological units for modelling with MHYDAS-DRAIN

Background and choice of the research catchment:

- To improve soil moisture and aeration conditions, agricultural land in lowland areas is frequently artificially drained.
- Tile drainage shortens the residence time of water in the soil and may therefore accelerate and increase the losses of nutrients and contaminants to surface water bodies.
- Especially the ubiquitous drainage of peatlands caused the loss of valuable ecosystems and environmental damage.
- Most of the tile drainage studies have concentrated on the plot scale.
- The Zarnow catchment is a typical artificially drained lowland catchment with tile drainage of arable land on mineral soils and ditch drainage of grassland on organic soils.

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Ditch and brook discharge	2001 - 2003 2003 - cont.	Daily 15 minutes	2 1
Tile drain discharge	2003 - cont.	Hourly	3
Precipitation	2001 - 2003 2003 - cont.	Daily Impulse/ 0.1 mm	1
Air temperature, humidity, wind speed	2001 - 2003 2003 - cont.	Daily 15 minutes	1
Groundwater level	2003 - 2005 2005 - 2008	Daily to weekly	17 33
Surface water: Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+}	2001 - 2003 2003 - cont.	Daily to weekly	2 4
Surface water: P_t and PO_4-P	2003 - 2006	Daily - biweekly	4
Groundwater: Cl^-, NO_3^-, SO_4^{2-}, Na^+, NH_4^+, K^+, Ca^{2+}, Mg^{2+}, P_t	2005 - 2008 (winter only)	Daily - weekly	18
Groundwater: TOC, Fe_t, Al_t, Mn_t, colour	2007/08 (winter only)	Daily - weekly	6
Stable isotopes of nitrate: $\delta^{15}N$ and $\delta^{18}O$	2003/04 (winter only)	Event-based	2

Applied models

1. MHYDAS-DRAIN **2. SWAT (in preparation)**

Main scientific results

- Artificially drained areas dominate the hydrological dynamics and the hydrochemistry of lowland catchments and must thus be prioritarily addressed when combating diffuse pollution.
- Discharge generation is dominated by tile drainage and groundwater flow, while overland flow only occurs when snowmelt, heavy rainfall and frozen soils concur. The main discharge period is the winter. Tile drainage amounts to 27 % of the total rainfall on an annual basis, and to 54 % in winter.
- Nitrate-nitrogen concentrations are very high, especially in the artificially drained subcatchments: 32 % of all samples exceeded the drinking water limit of 11.3 mg l^{-1} NO_3-N, and 79 % of all samples exceeded the limits of water quality class (2.5 mg l^{-1} NO_3-N, "good quality" according to the WFD).
- During nearly all discharge events, the highest NO_3-N concentrations went along with the peak discharge rate, even in the end of the winter.
- The annual NO_3-N losses of up to 55 kg ha^{-1} are strongly depending on the annual rainfall (0,7034< R^2 <0,8876), while the fertiliser application shows no effect (yet) on the studied time-scale.
- Applying a mixing model for subcatchments IA, II and IV (in which the grassland is probably less degraded than in SC III) shows that ca. 25 % of the total catchment area is responsible for 75 % of the NO_3-N losses.
- With the exception of the peatland, phosphorus concentrations and losses are, in contrast, generally low.
- Solute concentrations in the groundwater of the subcatchment dominated by artificially drained peatlands showed a high temporal and spatial variability. Concentrations and losses of most solutes where highest in this subcatchment, and due to ongoing drainage and degradation, improvement is not in sight.
- The model MHYDAS-DRAIN can be used for modelling small catchments dominated by artificial drainage. However, snowmelt events aroused problems with model calibration and validation.
- Calibration parameters for MHYDAS-DRAIN could be identified with a multi-target sensitivity analysis. The spatial and temporal resolution of the modelling domain and the calibration criteria determine the calibration results.
- Therefore, they need to be urgently considered when addressing the reduction of diffuse pollution.

Key references for the basin

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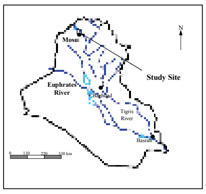
Fayda and Al-Baqaq Basins

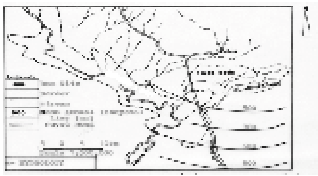
North East Mosul Dam, Iraq

Basin characteristics

Characteristics	Basin	
	Fayda	Al-Baqaq
Area (Km^3)	97.97	88.22
Average slop of the basin (m/m)	0.0701	0.0923
Average overland flow (km)	42.16	48.08
Perimeter of basin (km)	0.46	0.44
Length of basin (Km)	15.45	17.74
Shape factor	2.51	3.57
Sinuosity factor	1.19	1.11
Average elevation of the basin (m.a.s.l)	530.14	567.77
Drainage density (km^{-1})	1.086	1.136
Soil type	Loam	Silt loam
Curve number (CN)	85	84

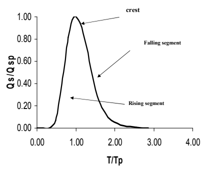
Map of the research basin



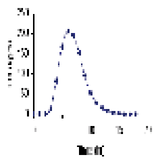


Location map of the study area in Iraq

Sediment Hydrograph



Dimensionless sediment hydrograph



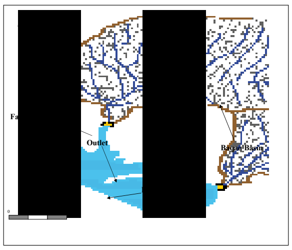
Sediment hydrograph for Fayda and Al-Baqaq wadies

Qs/Qsp = 46.1 (T/Tp)6 – 148.41(T/Tp)5 +171.5(T/Tp)4 -85.72(T/Tp)3+19(T/Tp)2-1.5(T/Tp) -----------------(For rising limb of hydrograph T/Tp<1)

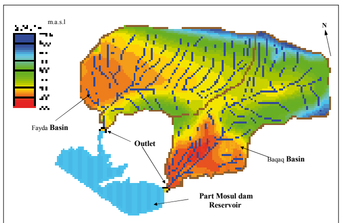
Qs = Qsp ----------------------------(At the hydrograph crest T/Tp =1)

Qs/Qsp = -0.082(T/Tp)6 +1.28(T/Tp)5 -8(T/Tp)4 + 25.91(T/Tp)3-44.37(T/Tp)2 +37(T/Tp) -10.68 ------------(For falling limb of hydrograph T/Tp >1)

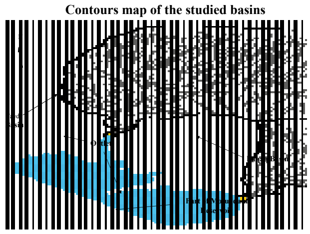
Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



TIN model



Contours map of the studied basins



Flow patterns of the studied drainage basin.

Instrumentation and data

Using 39 recorded rainfall storms in the meteorological station located near the case studyFayda and Al-Baqaq basins during the years (1980 to 1990) , the surface runoff quantities and the maximum discharge were predicted applying the curve number method (CN), while the sediment yield was calculated using the modified universal soil loss equation (MUSLE).

Applied models

Predicting a model in any watershed area is considered an important tool in analyzing and study the present case study basins . Such model is defined as a simple system in which the behavior of this system is represented by number of equations that contribute with logical aspects and relations between the variables to predict the required results.

The watershed modeling system (**WMS**) which works on the principle of finite elements three dimensions is applied on the Fayda and Al-Baqaq basins. To simulate the morphological characteristics of these basins, the WMS model was fed by main input data which represents the surface elevations of large number of points coordinates and fixation of the main streams in these basins.

As a result of the simulation process, the model predicts the drainage basin boundary then divide the basin into unregulated triangulation network (TIN Model).The surface gradation of the elevation, the flowing paths and the order distribution of the drainage basins were conducted too. Finally the main morphological characteristics of the Fayda and Al-Baqaq basins were calculated.

Main scientific results

A model to simulate surface runoff, morphological characteristic and sediment yield for Fayda and Al-Baqaq basins north iraq was predicted for 39 recorded rainfall storms during the years (1980 and 1990). The runoff coefficient was found to be function of rainfall depth with a value ranged between 0.02 and 0.54 for effective rainfall depth 12 and 75.9 mm respectively. The rainfall storm which was less than 9 mm did not produce any surface runoff due to the infiltration process and other losses in the soil. The sediment yield of Fayda and Al-Baqaq basins was simulated and correlated with the volume of runoff and peak discharge. The maximum annual sediment yield for Fayda and Al-Baqaq basins was 24659 ton and 22868 ton for peak discharge of 195 and 189 m3/sec respectively. An empirical equations for runoff coefficient, peak discharge and sediment yield were predicted. A non-dimensional sediment unite hydrograph was predicted to calculate sediment curve in the future for any rainfall storm on these basins .

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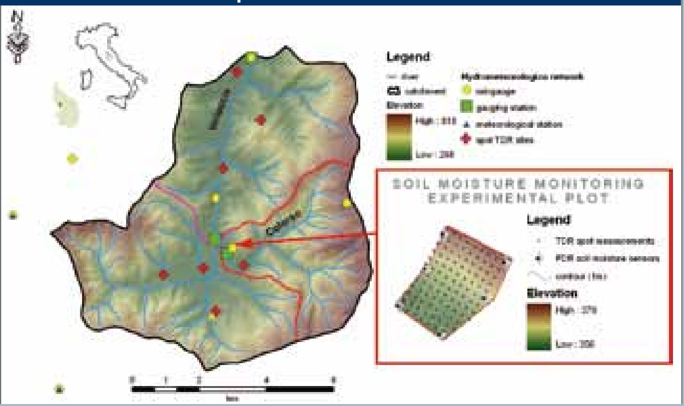
Vallaccia Catchment, Italy

NATIONAL RESEARCH COUNCIL

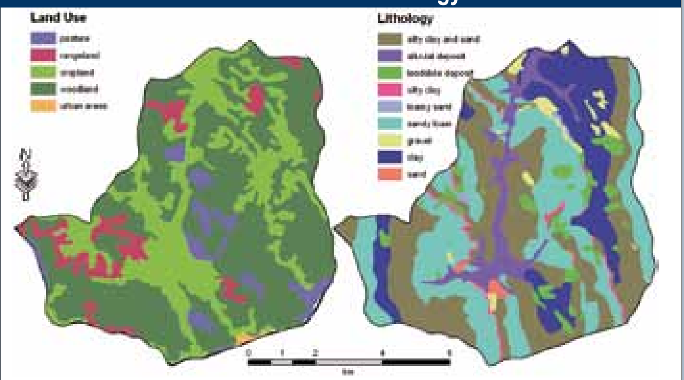
Basin characteristics

River Basin / River Basin (according EU-WFD)	Upper Tiber River Basin/ Niccone River Basin
Operation (from… to…)	Since 1995, still in operation
Gauge coordinates / Gauge datum:	12°12' E; 43° 16' N / 288 m a.m.s.l.
Catchment area: Colorso at C. Mandorle, Vallaccia at P. Marte, Vallaccia at Molino	12.9 km², 34.1 km², 57.6 km²
Elevation range:	288 – 818 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	lowland / mountainous
Climatic parameters: (mean annual rainfall, runoff, temperature and potential evapotranspiration)	930 mm, 302 mm, 12.7 °C, 800 mm (1994-2008)
Land use:	57.7% woodland, 29.6% cropland, 5.1% pasture, 7.4% rangeland, 0.3% urban areas
Lithology:	16.6% clay, 1.5% silty clay, 34.6% silty clay and sand, 2.3% gravel, 31.5% sandy loam, 0.6% sand, 0.4% loamy sand, 7.6% alluvial deposit, 4.9% landslide deposit
Characteristic water discharges: Colorso at C. Mandorle, Vallaccia at P. Marte, Vallaccia at Molino (Q_{min}, Q_{max}, Q_{mean})	0 m³/s, 14.4 m³/s, 0.077 m³/s (2002-2008) 0 m³/s, 26.3 m³/s, 0.101 m³/s (1998-2008) 0 m³/s, 48.9 m³/s, 0.350 m³/s (1998-2008)

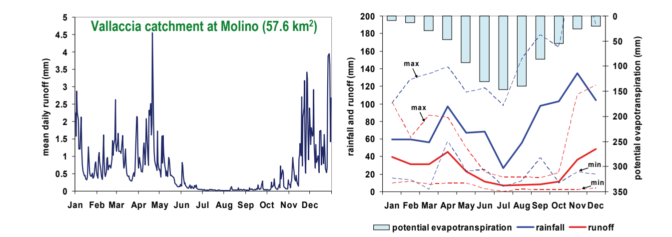
Map of the research basin



Land use and Lithology



Monthly rainfall, runoff and potential evapotranspiration



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1998 – cont. (Molino, P.Marte) 2002 – cont. (C.Mandorle)	30 min.	3
Precipitation	1951 – cont. 1985 – cont.	daily 30 min.	2 8
Air temperature, humidity, wind	1951 – cont. 1988 – cont.	daily 30 min.	2
Soil moisture (continuous)	2002 – 2006 2006 – cont.	30 min hourly	6 in 1 plot 6 in 4 plot
Soil moisture (spot measurements)	Oct 2002 – Jan 2006 Nov 2006 – Nov 2007	7 times weekly (35)	108 points 210 points

Applied models

1. MISD [3, 10, 15]
2. MISDc [9]
3. CRRM [4, 10]
4. HBV
5. IHACRES
6. PDM

Main scientific results

SOIL MOISTURE SPATIAL VARIABILITY [2, 6, 8, 10, 11, 14]

a. Characterization of soil moisture spatial variability across scales through statistical and geostatistical methods.
b. Identification of the factors influencing soil moisture spatial variability (topography, vegetation, soils, ...).
c. Optimization criteria for a soil moisture monitoring network aimed at flood prediction and forecasting through temporal stability analysis.
d. Reliability assessment of geophysical methods (self potential, electrical resistivity) for soil moisture monitoring.

MODELING SOIL MOISTURE TEMPORAL VARIABILITY [4, 7, 9, 10, 13]

a. Characterization of the soil moisture temporal variability at the plot and small catchment scale.
b. Identification of principal factors determining soil moisture temporal evolution at the short and long time scale.
c. Development of a robust conceptual water balance model for soil moisture estimation based on widely available meteorological data.

ANTECEDENT WETNESS CONDITIONS ESTIMATION FOR RAINFALL-RUNOFF MODELING [1, 3, 4, 7, 9, 10, 12, 15]

a. Representativeness of spot measurements for soil moisture estimation at the catchment scale.
b. Assimilation of ground-based and remotely sensed soil moisture observations in rainfall-runoff modeling.
c. Development of a continuous rainfall-runoff model based on the outcomes of soil moisture monitoring at different scales.

REMOTE SENSING OF SOIL MOISTURE [1, 5]

a. Reliability assessment of satellite sensors for soil moisture estimation in view of flood prediction and forecasting.

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Vauz Basin

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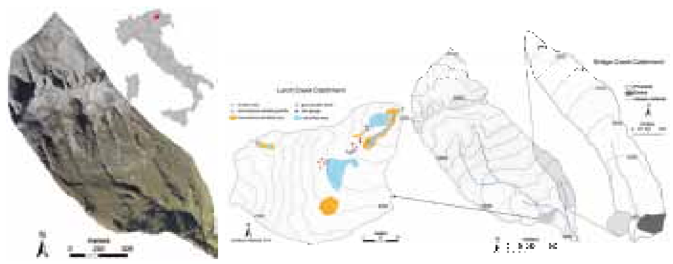
University of Padova

Department of Land and Agro-Forest Environments

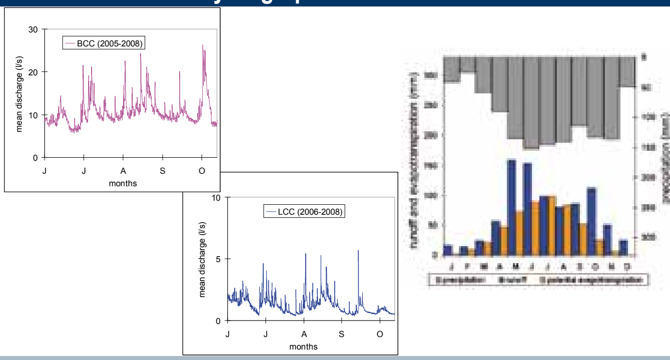
Basin characteristics

River Basin / River Basin (according EU-WFD)	Vauz Creek Basin
Operation (from… to…)	From 2003 to present
Gauge coordinates / Gauge datum:	46° 29' 19.14'' N; 11° 50' 43.48'' E
Catchment area:	1.9 km^2. Two monitored subcatchments: 0.14 and 0.032 km^2
Elevation range:	1847-3152 m asl
Basin type: (alpine, mountainous, lowland)	Alpine
Climatic parameters: (mean precipitation, temperature and others)	Mean annual precipitation: 1220 mm (49% as snow); average monthly temperature: -5.7 / 14.1°C
Land use:	Alpine grassland, scattered shrubs, conifers (*Picea abies*, *Larix decidua*)
Soils:	Cambisoil with by clay or silty-clay layers underlying a deep organic matter portion
Geology:	Upper Triassic Dolomitic formations + Quaterary till deposits
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Ksat: $1.1 \cdot 10^{-4}$ to $2.0 \cdot 10^{-7}$ m/s; mean: $1.1 \cdot 10^{-6}$ m/s.
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	LCC: 0.01-16.5 l/s; BCC: 4.0-90.6 l/s

Map of the research basin



Mean hydrograph / Climatic conditions



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Main hydrological processes in reference to geological units

(Gardi L., 2003: *Hydrogeology of the Cordevole catchment*. Free University of Amsterdam, Faculty of Earth and Life Sciences, modified)

Hydrogeological processes	Dolomite	Volcanic tuffs	Alluvium	Morain deposits
Interception	0	X	0	0
Transpiration	0	X	0	0
Surface storage	0	X	0	0
Ground water storage	X	0	XX	0
Ground water flow	X	0	XX	0
Surface runoff	0	XX	0	XX
Evaporation	0	X	0	0
Infiltration	X	X	XX	0
Interflow	0	XX	0	X

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
streamflow	May-October 2005-2009 winter 2008-2009	5 min. (15 min. in 2009)	2
precipitation	May-October 2005-2009	impulse (0.2 mm)	2
soil moisture at 0-6, 0-12 and 0-20 cm depth	summer months 2005-2009	manually, twice a day	three hillslopes:26+26+64
soil moisture at 0-30 cm depth	May-October 2005-2009	1 hour (15 min. in 2009)	4
groundwater level	May-October 2005-2009 winter 2008-2009	5 min. 15 min. in 2009)	50
environmental isotopes ^2H, ^{18}O	event based	event dependent	event dependent

Applied models

1. **snowmelt** (Cazorzi & Dalla Fontana, 1996)
2. **shallow landslides** (Borga et al., 1998, 2002a,2002b)
3. **kinematic subsurface wave model** (Norbiato & Borga 2008)
4. **Teuling's soil moisture model** (Penna et al., 2009)
5. **ARFFS continuous hydrological model** (Norbiato et al., 2009)

Main scientific results

1. Quick hydrological response of streamflow due to the fast soil saturation of the riparian zone.
2. Different dynamics of groundwater in the near- and far-stream zone → hysteretic behaviour between streamflow and basin-averaged water table level and between groundwater in the riparian and hillslope zone.
3. Threshold effect in the soil moisture-streamflow relathionship: initial moisture condition determine the extent of the riparian zone close to saturation. Similar non linear behaviour between antecedent moisture condition, runoff coefficient and water table: surface and subsurface runoff generation occur above a soil moisture threshold of 45-48%.
4. Strong linear correlation between streamflow and precipitation amount above a 20 mm rain threshold; when this value is exceeded also subsurface flow from the hillslopes and the entire watershed contributes to flow.
5. Good temporal stability of spatial patterns of soil moisture over three sampled hillslopes, mainly due to soil properties; strong correlation among moisture patterns at different depths.
6. Detections of CASMM (Catchment Average Soil Moisture) sites within the sampled hillslopes.
7. Marked effect of dew on the 0–6 cm soil depth layers: the surface layers are usually wetter and show lower space–time variability than deeper soil layers, particularly during dry-down.
8. Negative relationship between the mean soil moisture and the standard deviation. The spatial variability patterns are well represented by linear negative functions between the mean and the coefficient of variation of soil moisture.
9. Pre-event water contribution to total discharge accounts between 29 and 78%.

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Centre de Recherche Public Gabriel Lippmann

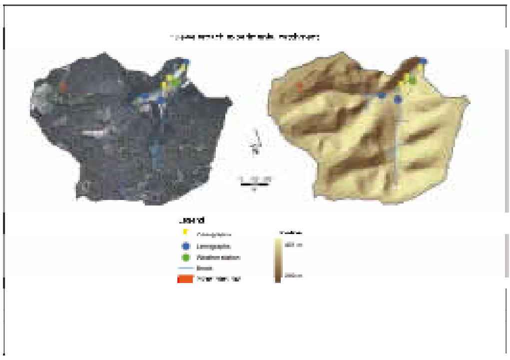
Huewelerbach

Huewelerbach catchment, Luxembourg

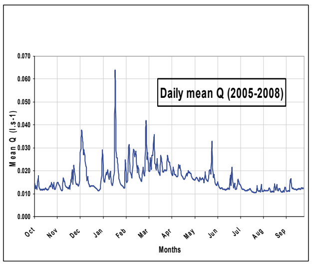
Basin characteristics

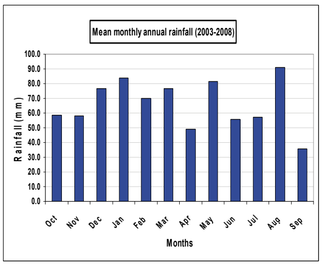
River Basin / River Basin (according EU-WFD)	Upper Attert basin / Mosel basin
Operation (from… to…)	Since autumn 2001
Gauge coordinates / Gauge datum:	49°43'6.1'' N / 5°54'20.5'' E / 288.50 m a.s.l.
Catchment area:	2.7 km ^{2}
Elevation range:	289 m - 401 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	796 mm, 8.8 °C (2005 – 2008)
Land use:	91.5 % forest, 7 % grassland, 1.5 % urbanised
Soils:	Hypoluvic Arenosol, Regosol (Arenic), Planosol (Ruptic, Clayic)
Geology:	Sandstone, alternation of marls and limestones
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Porous and fractured aquifer, average HC of the sandstone in Luxembourg: 5.10^{-5} $m.s^{-1}$
Characteristic water discharges: (daily Q_{min}, Q_{max}, Q_{mean})	5.0 $l.s^{-1}$, 156 $l.s^{-1}$, 16.3 $l.s^{-1}$ (2005 – 2008)

Map of the research basin

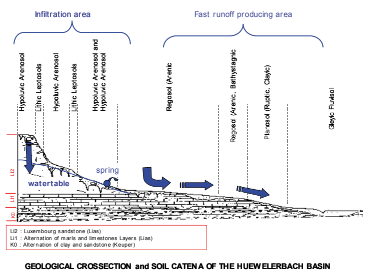


Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow outlet secondary study specific	Oct. 2002 --- Spring 2004 --- 2004 – 2008	15 min	1 2 10 (not continuous)
Meteorological station (T/RH-GR-R-WV&WD)	April 2003 ---	15 min	1
Groundwater level	May 2003 --- May 2003-Oct. 2008	1 h 2 weeks	3 21
Chemical analysis (anions-cations-others)	2002 ---	1 h to 1 week	1 to more than 30
Sediment trapping	2005 - 2008	Period depending	1
Interception plot (beeches, around 150 y old)	Automn 2003 ---	15 min 2 weeks	4 pluviographs 80 pluviometers

Applied models

1. Various conceptual models with regionalised parameters
2. EMMA for hydrograph decomposition

Main scientific results

1. At baseflow level, water is coming from the springs emerging at the base of the Luxembourg Sandstone (at the interface with the underlying marls), with a very stable chemical signal.
2. After a rainfall event, the falling limb of the hydrograph is systemtically very steep and initial baseflow levels are reached very rapidly, indicating the influence of a rapid surface and/or subsurface runoff.
3. Discharge observed in the western creek of the Huewelerbach is stable and is due to very constant feeding through springs located in the sandstone, whereas the discharge of the southern creek gets higher contributions through surface runoff. Most storm runoff eventually is produced in the footslope area, where the two creeks converge. In this part of the basin, the soils are clayey (Planosol (Ruptic, Clayic)).
4. At peak flow, the overland flow contribution can reach up to 75 %.
5. The piezographs in the lower, mainly alluvial, part of the basin show a rapid reaction to all rainfall events. The water table is close to the surface during wet periods.
6. At the interception plot, located in a beech forest, stemflow and throughfall are continuously measured all over the year at very high spatial and temporal resolution. Average stemflow ranges from 5 to 6 % and total rainfall interception varies between 0 to 10 % in winter and reaches up to 20 % in summer.
7. The sediments exported from the basin originate principally from bed sediments, with major fluxes occurring during flood events.

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Kharaa

Kharaa river basin, Mongolia

Basin characteristics

River Basin:	Kharaa river basin
Operation (from… to…):	Since 1990, still in operation
Gauge coordinates / Gauge datum:	105°54'E; 49° 32'N / 674 m.a.s.l.
Catchment area:	14,500 km²
Elevation range:	656- 2518 m.a.s.l.
Basin type:	Mountainous
Climatic parameters:	Precipitation and temperature
Land use:	59% grassland/ pasture, 28% forest, 7% arable land, 4% fallow, 2% riparian area
Soils:	-
Geology:	-
Hydrogeology:	-
Characteristic water discharges: (Q_{min}, Q_{mean}, Q_{max})	0.0 m³/s, 14.6 m³/s, 75.5 m³/s

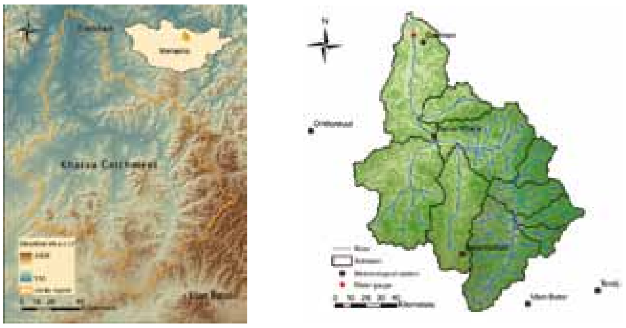
Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Air temperature	1986 - 2002	Daily	6
Precipitation	1986 - 2002	Daily	6
River runoff	1990 - 2002	Daily	1

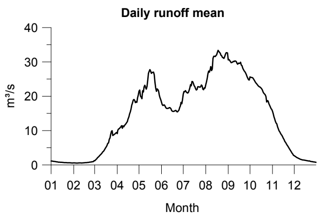
Applied models

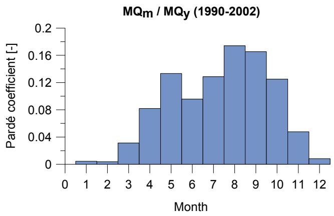
1. HBV-D (resolution: small scaled subbasins)
2. TRAIN (resolution: 1 x 1 km)
3. WaterGAP (resolution: 0.5°)

Map of the research basin



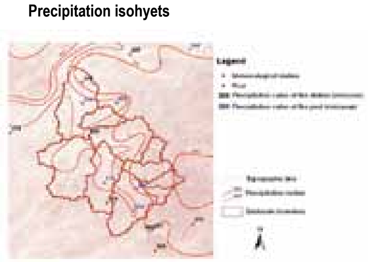
Mean hydrograph / Pardé flow regime



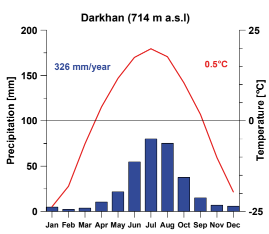


Special basin characteristics

Precipitation isohyets



Climate diagram



Main scientific results

1. Causes of observed runoff decrease:
A drastic decrease of runoff was in the middle 1990s observed in the basin. The data in the region is scarce but the causes of the decrease could be investigated by applying the HBV-D model. The idea was that, if the observed runoff decrease could be simulated, it would indicate that it would be due to climate variability. If instead HBV-D would be unable to simulate the runoff decrease by delivering a runoff of the same magnitude as the earlier years, the decrease would be harder to justify with climate variability. An explanation of the runoff decrease could then be due to hydrological changes at the measurement site or increased water exploitation in Kharaa, e.g. from the mining activities in the basin.
The observed runoff decrease could be simulated. That indicates that the decrease is due to climate variation and not due to hydrological changes at the measurement site or an increased water exploitation.

2. HBV-D parameter uncertainty:
To assess the parameter uncertainty of the HBV-D model a Monte Carlo analysis was performed with a high amount of parameter combinations where the parameters had been randomized within stated intervals. The well performing parameter settings had a variation that was low compared to the observed runoff. Hence, the runoff could be simulated with an acceptable uncertainty of the parameters.

3. Runoff prediction in ungauged subbasins:
The runoff contribution from each sub-basin was quantified and it was investigated whether the simulated low flows coincided with the occasionally observed dry out of some specific watercourses. The simulated runoff for an average year was computed and the uncertainty was estimated by the simulated maximum and minimum monthly average for each specific month during the time period 1990-2002. The runoff within the ungauged subbasins were simulated as valuable knowledge for the establishing of a monitoring system.

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Mahurangi Catchment

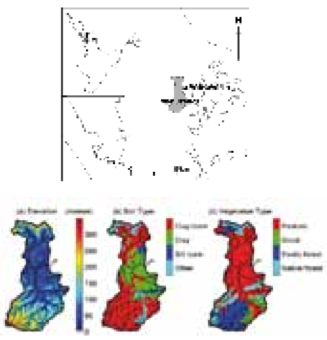
Northland, New Zealand

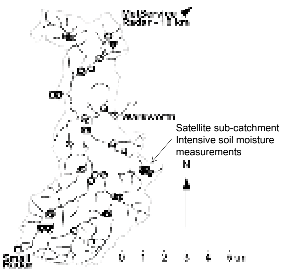
Contributors to the MARVEX campaign:
- NIWA, New Zealand
- University of Auckland, New Zealand
- University of Melbourne, Australia

Basin characteristics

River Basin / River Basin (according EU-WFD)	Mahurangi River Basin
Operation (from… to…)	1997 – 2001 (MARVEX programme)
Gauge coordinates / Gauge datum:	29 nested stream gauges. Approx 36.4ºS,174.7ºE
Catchment area:	47 km².
Elevation range:	0 - 250m a.s.l.
Basin type: (alpine, mountainous, lowland)	Hills and lowland
Climatic parameters: (mean precipitation, temperature and others)	Annual rainfall 1628mm, Annual pan evaporation 1315mm, Annual streamflow 842mm, Mean temp. 14 degC
Land use:	50% pasture, 25% plantation forest, 25% native forest
Soils:	Clay loams, < 1m deep
Geology:	Alternating layers of sandstone and siltstone
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Runoff is dominated by baseflow from soil and regolith reservoirs

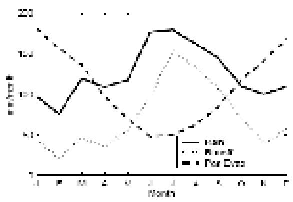
Map of the research basin



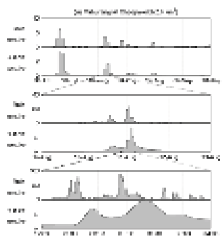


Location of catchment instrumentation.
Circles = flow gauges, triangles = rain gauges

Mean hydrograph / Example hydrograph



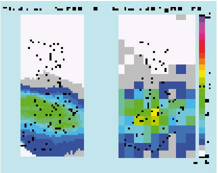
Mean monthly values for rain, runoff and pan evaporation



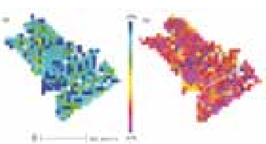
Exploration of temporal variability in rainfall and runoff

Spatial Variability

The MARVEX campaign focused on spatial variability of hydrological variables



Instantaneous rainfall rates, X-band and C-band radar



Soil Moisture patterns for (a) August 1998 and (b) February 1999

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Rainfall – Tipping bucket gauges	1997 – 2001	2 mins	13
Rainfall – C band radar	1997 – 2001	15 mins	1 km grid
Rainfall – X band radar	Individual events	5 secs / 2 mins	150 m grid
Streamflow	1997 – 2001	2 mins	29
Soil Moisture (pseudo-TDR)	1997 – 2001	30 mins	18
Soil Moisture (TDR)	6 * campaigns	N/A	10-40m grid

Applied models

Mahurangi catchment has been used as a test site to explore model building techniques and model complexity (e.g. Chirico *et al.*, 2003; Atkinson *et al.*, 2003; McMillan *et al.*, this workshop), rather than as a site for application of standard models.

Main scientific results

1. Streamflow spatial variation: Rainfall is the dominant source of spatial pattern in streamflow at space scales of 1 km2 and greater, for all timescales
2. Streamflow generation: The runoff process is associated with a clear threshold in soil moisture, with significant runoff being generated only for moisture contents above about 42%. It is also thought that at these high average moisture contents, the spatial distribution of soil water is critical in the control of runoff behaviour.
3. Soil Moisture: at space scales from 10 m to 1 km², topography is a relatively weak control of soil moisture. Small-scale variability (< 100m) of soil moisture is associated with soil structure and preferential flow pathways.
4. Flow pathways: "The soils have residence times of at least several months to a few years. The streams are reactive, but this appears to be driven by a combination of direct channel interception and local runoff from the near-stream margin. One quarter to one third of total runoff occurs as quickflow. The largest portion of streamflow originates as baseflow from soil and regolith reservoirs that may be several metres to perhaps several 10's of metres deep" (Bowden *et al.*, 2000).
5. Model Complexity: During winter periods the soils are wet and accurate predictions of stormflow can be achieved using lumped models. Conversely, during summer periods the soils are dry, and complex and fully distributed models are required for accurate predictions of stormflow (Atkinson *et al.*, 2003). The storage-discharge relationship varies through the year depending on recharge history, and hence models require multiple storage reservoirs (McMillan *et al.*, this workshop).

Key references for the basin

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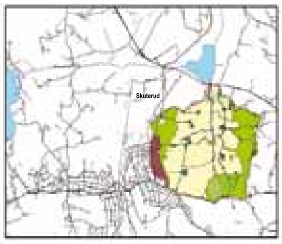
Skuterud catchment

Norway

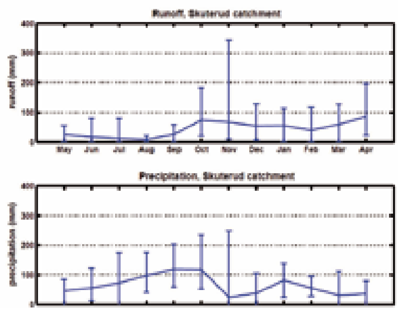
Basin characteristics

River Basin / River Basin (according EU-WFD)	Skuterud catchment
Operation (from… to…)	From 1993 - present
Gauge coordinates / Gauge datum:	30 km south of Oslo.
Catchment area:	4.5 km^2.
Elevation range:	91 – 146 m. above mean sea level
Basin type: (alpine, mountainous, lowland)	Lowland
Climatic parameters: (mean precipitation, temperature and others)	Mean precipitation; 785 mm. Mean air temperature; 5.3 °C
Land use:	Agriculture
Soils:	Silt loam, silt clay loam, loamy sand
Geology:	Marine deposit
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Low hydraulic conductivity
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Q_{min} = ± o m^3 s^{-1}, Q_{max} = 4,3 m^3 s^{-1}, coeff. var.= 239 %

Map of the research basin

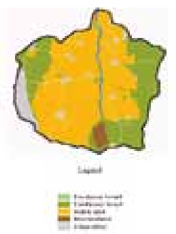


Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

The Skuterud catchment



Land use	Area (ha)
Arable land	272
Forested area	129
Urban/other	38
Total area	449

The Skuterud catchment is part of the JOVA-programme, the Norwegian Agricultural Environmental Monitoring Programme

The catchments represent different climatological conditions and agricultural practices as well as different geo-hydrological settings. Agriculture with cereals is the dominating land use form in the many of the catchments in the national monitoring programmes.

In general, the Norwegian catchments are intensively drained, with a drain spacing of 8 – 10 m and a drain depth 0.80 – 1 m.

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Discharge	1993 – present	30 min – 1 hr resolution	3
Precipitation, temperature, rel. hum., solar radiation, wind speed, soil temperature, snow depth	1950 – present	1 hr - daily	4
suspended solids, tot-N, tot-P, NO3, PO4, turbidity, EC, pH, more	1993(2006) - present	14 day average, 30 min – hour	3

Applied models

1. SWAT (water balance, nutrient and soil loss)
   The SWAT model has also been applied in Norway as part of EuroHarp and Striver, two EU – projects (large scale). The model is tested in Skuterud.
   Needs modification (saturation from below, subsurface drainage, winter)
2. DRAINMOD, developed at NCSU (Skaggs) simulating subsurface drainage/surface runoff/nitrogen dynamics
3. HBV – model (hydrology)
4. INCA – model (hydrology, nutrient dynamics)
5. SOIL/SOIL_NO and COUP (hydrology,nitrogen), have been tested.
6. WEPP (Water erosion prediction model) tested on small plots

Main scientific results

1. Yearly catchment discharge shows a high variation and is extremely outlier prone.
2. Large in-day variation in discharge occurs during periods with excess rainfall/snowmelt.
3. A large difference exists in specific discharge when calculated on average daily and hourly discharge values respectively.
4. 50 - and 90 % of the yearly runoff is discharged in 28 and 141 days respectively. The same applies for nitrogen. Phosphorus and suspended solids are discharged in less days due to being linked to extreme events.
5. No major runoff, erosion and nutrient loss occurs during the growing season
6. The construction of wetland at catchment outlet has a significant effect on reducing loss of suspended solids and total phosphorus. The effect on reduction of nitrogen loss is negligible.

Key references for the basin

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Small ungauged basins in the Polish part of the Carpathian Mts. investigated for the maximum discharge during flash floods

Basin characteristics

River Basin / River Basin (according EU-WFD)

No.		
	Basins located in the Beskidy region	
1	creek without the name - Szymbark	Ropa river basin/Wisłoka river basin
2	creek without the name - Siary	Ropa river basin/Wisłoka river basin
3	Kalniczka - Kalnica	Osława river basin/San river basin
4	Zasypnica - Sucha Beskidzka	Stryszawka river basin/Skawa river basin
5	Bielanka - Szymbark	Ropa river basin/Wisłoka river basin
6	Borowiec - Mokre	Osława river basin/San river basin
7	Dołżyca - Dołżyca	Osława river basin/San river basin
8	Barbarka - Czystochorb	Osława river basin/San river basin
9	Tarnawka - Kalnica	Osława river basin/San river basin
10	Targaniczanka	Wieprzówka river basin/Skawa river basin
11	Osławica - Radoszyce	Osława river basin/San river basin
	Basins located in the Foothills region	
12	creek without the name - Grybów	Biała river basis/Dunajec river basin
13	creek without the name - Niebocko	Stobnica river basin/Wisłok river basin
14	creek without the name - Zagórze	Jodłówka river basin/Wisłoka river basin
15	creek without the name - Gromnik	Biała river basis/Dunajec river basin
16	Sudoł - Biała Niżna	Biała river basis/Dunajec river basin
17	creek without the name - Błędówka	Chmielnik river basin/Strug river basin
18	Zalasówka - Zalasowa	Szwedka river basin/Biała river basin
19	creek without the name - Słotowa	Wisłoka river basin/Wisła river basin
20	creek without the name - Pilzno	Wisłoka river basin/Wisła river basin
21	creek without the name - Niebocko-Grabownica	Stobnica river basin/Wisłok river basin
22	Świnka - Jabłonka	Świnka river basin/San river basin
23	Wątok - Szynwałd	Biała river basis/Dunajec river basin
24	Wolanka - Lubcza	Jodłówka river basin/Wisłoka river basin
25	Ryjak - Zabartówka	Chmielnik river basin/Strug river basin
26	Dulcza - Łęki Górne	Wisłoka river basin/Wisła river basin

Operation (from… to…) Ungauged

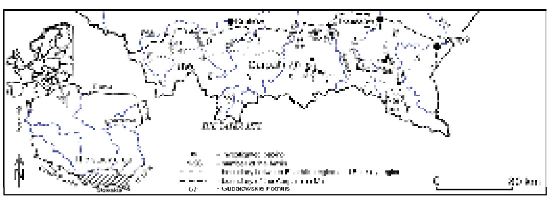
Cross-section coordinates / Cross-section datum:

No.		
	Basins located in the Beskidy region	
1	creek without the name - Szymbark	49º 37' 48''N 21º 07' 12''E 289 m. a.s.l.
2	creek without the name - Siary	49º 35' 44''N 21º 12' 48''E 354 m. a.s.l.
3	Kalniczka - Kalnica	49º 21' 47''N 22º 12' 49''E 475 m. a.s.l.
4	Zasypnica - Sucha Beskidzka	49º 44' 09''N 19º 34' 25''E 345 m. a.s.l.
5	Bielanka - Szymbark	49º 37' 29''N 21º 06' 58''E 310 m. a.s.l.
6	Borowiec - Mokre	47º 27' 49''N 22º 09 50''E 350 m. a.s.l.
7	Dołżyca - Dołżyca	49º 19' 42''N 22º 01 23''E 525 m. a.s.l.
8	Barbarka - Czystochorb	49º 21' 22''N 22º 01 27''E 507 m. a.s.l.
9	Tarnawka - Kalnica	49º 21' 27''N 22º 12 15''E 482 m. a.s.l.
10	Targaniczanka	49º 51' 02''N 19º 20 21''E 290 m. a.s.l.
11	Osławica - Radoszyce	49º 18' 52''N 22º 04 01''E 486 m. a.s.l.
	Basins located in the Foothills region	
12	creek without the name - Grybów	49º 37' 28''N 20º 57' 08''E 323 m. a.s.l.
13	creek without the name - Niebocko	49º 40' 33''N 22º 06' 22''E 320 m. a.s.l.
14	creek without the name - Zagórze	49º 55' 21''N 21º 18' 28''E 210 m. a.s.l.
15	creek without the name - Gromnik	49º 50' 16''N 20º 57' 42''E 240 m. a.s.l.
16	Sudoł - Biała Niżna	49º 37' 36''N 20º 58' 06''E 325 m. a.s.l.
17	creek without the name - Błędówka	49º 58' 10''N 22º 09' 34''E 239 m. a.s.l.
18	Zalasówka - Zalasowa	49º 53' 01''N 21º 08' 12''E 260 m. a.s.l.
19	creek without the name - Słotowa	49º 57' 02''N 21º 19' 03''E 210 m. a.s.l.
20	creek without the name - Pilzno	49º 58' 33''N 21º 17' 19''E 255 m. a.s.l.
21	creek without the name - Niebocko-Grabownica	49º 39' 16''N 22º 04' 54''E 315 m. a.s.l.
22	Świnka - Jabłonka	49º 41' 52''N 22º 08' 27''E 275 m. a.s.l.
23	Wątok - Szynwałd	49º 57' 53''N 21º 07' 32''E 260 m a.s.l.
24	Wolanka - Lubcza	49º 54' 22''N 21º 15' 24''E 230 m a.s.l.
25	Ryjak - Zabartówka	49º 57' 12''N 22º 12' 10''E 260 m. a.s.l.
26	Dulcza - Łęki Górne	49º 58' 27''N 21º 11' 11''E 240 m. a.s.l.

No.	Basin name	Catchment area km²	Elevation range m. a.s.l.	Basis type	Climatic parameters: Temperature (1950-1980) °C [a]	Climatic parameters: Precipitations mm [b]	Land use %: Forest	Land use %: Settlement areas	Land use %: Arable areas	Soils [c]	Geology [d]
	Basins located in the Beskidy region										
1	creek without the name – Szymbark	1.8	289 – 635	Mountainous	6	700-900	77% pine, beech	2	21	Lithosols, Rankers, Cambisols, Luvisols	Sandstones mixed with shales
2	creek without the name – Siary	3	354 – 635				93% fir, beech	2	5		
3	Kalniczka – Kalnica	4.3	475 – 782			900-1200	65% fir, beech	1	34		
4	Zasypnica – Sucha Beskidzka	6.2	345 – 871		5	700-900	58 spruce, fir	4	38		
5	Bielanka – Szymbark	6.5			6		70% beech, fir	2	28		
6	Borowiec – Mokre	9.2	350 – 663			900-1200	77% fir, beech	1	22		
7	Dołżyca – Dołżyca	9.7	525 – 837				83% fir, beech	1	16		
8	Barbarka – Czystochorb	13.4	507 – 806				40% fir, beech	1	59		
9	Tarnawka – Kalnica	13.7	482 – 997				81% fir, beech	0	19		
10	Targaniczanka	23	290 – 883			700-900	48% spruce, beech	6	46		
11	Oslawica – Radoszyce	31.0	486 – 735			900-1200	31% hornbeam, pine, fir	50	1		
	Basins located in the foothills region										
12	creek without the name – Grybów	1.4	323 – 535			700-900	17% spruce, beech	31	52		
13	creek without the name – Niebocko	3.6	320 – 474				0%	8	92		
14	creek without the name – Zagórze	4.1	210 – 389		7		5% riparian forest	9	85		
15	creek without the name – Gromnik	4.6	240 – 402				32% pine, beech	9	59		
16	Sudoł – Biała Niżna	4.8	325 – 562		6		29% spruce, beech	8	63		
17	creek without the name – Błędówka	5	239 – 366		7		1% riparian forest	3	97		
18	Zalasówka – Zalasowa	5.2	260 – 367				4% pine, oak, hornbeam	3	92		
19	creek without the name – Słotowa	6.0	210 – 391				6% riparian forest	11	82		
20	creek without the name – Pilzno	7.5	205 – 379				21% pine, oak	4	75		
21	creek without the name – Niebocko–Grabownica	8.6	315 – 527				50% fir, beech	6	44		
22	Świnka – Jabłonka	9.3	275 – 447				45% pine, beech	6	49		
23	Wątok – Szynwałd	10.0	260 – 387				20% fir, beech	6	74		
24	Wolanka – Lubcza	13.1	230 – 370				18% beech, fir	6	76		
25	Ryjak – Zabartówka	14.5	260 – 377				81% beech, pine	2	17		
26	Dulcza – Łęki Górne	16.6	240 – 409				16% fir, beech	3	81		

a – on the basis of Atlas Republic of Poland, Part II Natural Environment, Główny Geodeta Kraju, Warszawa 1994
b – on the basis of Geographic Atlas, PRWK, Warszawa-Wrocław 1999
c – on the basis of Soil Map of Poland 1:300 000
d – on the basis of Geology Map of Poland 1:200 000

Map of the research basin



Instrumentation and data

The maximum discharge was calculated using velocity-area method. The velocity was computed using Manning's equation.

No.	Name of the river - Name of discharge profile	A km²	Qmax m³/s	qmax m³/s/km²
	Basins located in the Beskidy region			
1	creek without the name - Szymbark	1.8	16.29	9.1
2	creek without the name - Siary	3	15.6	5.2
3	Kalniczka - Kalnica	4.3	28.8	6.7
4	Zasypnica - Sucha Beskidzka	6.2	11.7	1.9
5	Bielanka - Szymbark	6.5	75	11.5
6	Borowiec - Mokre	9.2	9.3	1.0
7	Dołżyca - Dołżyca	9.7	42.6	4.4
8	Barbarka - Czystochorb	13.4	67	5.0
9	Tarnawka - Kalnica	13.7	37.8	2.8
10	Targaniczanka	23	43	1.9
11	Osławica - Radoszyce	31.0	84.5	2.7

A – basin's area
Q_{max} – the maximum discharge
q_{max} – tte maximum specific discharge

No.	Name of the river - Name of discharge profile	A km²	Qmax m³/s	qmax m³/s/km²
	Basins located in the Foothills region			
12	creek without the name - Grybów	1.4	10.2	7.3
13	creek without the name - Niebocko	3.6	16.5	4.6
14	creek without the name - Zagórze	4.1	6.3	1.5
15	creek without the name - Gromnik	4.6	5.5	1.2
16	Sudoł - Biała Niżna	4.8	24	5.0
17	creek without the name - Błędówka	5	32	6.4
18	Zalasówka - Zalasowa	5.2	10.2	2.0
19	creek without the name - Słotowa	6.0	10.2	1.7
20	creek without the name - Pilzno	7.5	35	4.7
21	creek without the name - Niebocko-Grabownica	8.6	14.3	1.7
22	Świnka - Jabłonka	9.3	15.8	1.7
23	Wątok - Szynwałd	10.0	20.8	2.1
24	Wolanka - Lubcza	13.1	14	1.1
25	Ryjak - Zabartówka	14.5	31.3	2.2
26	Dulcza - Łęki Górne	16.6	13.2	0.8

Applied models

Equations enabling calculation of the maximum discharge in the basins smaller than 100 km² in area.

$Q_{max} = 100 \cdot A^{0.8}$ Rodier, J. A. Roche, M. (1984) Word Catalogue of Maximum Observed Floods. IAHS Press, Wallingford UK. IAHS Publications 143.

$Q_{max} = 85.7 \cdot A(A+1)^{-0.3667}$ Ciepielowski, A. (1973) Przegląd wzorów empirycznych do określania maksymalnych przepływów letnich (En overview of the empirical equations to calculation of the maximum summers floods). Zeszyty Naukowe AR w Warszawie, Melioracje Wodne, 12.

$1/\log Q = 0.248 + 0.483 \cdot \exp[-\log(A)]$ Bartnik, A. Jokiel, P. (2007) Odpływy maksymalne i indeksy powodziowości rzek europejskich (Maximum runoff and flood's index of the European rivers). Gospodarka Wodna 1, 28-32

$Q = 230A^{0.43}$ Herschy, R.W. (2002) The word's maximum observed floods. Flow Measurement and Instrumentation 13, 231–235

$Q_{max} = 22.4 \cdot A^{0.727}$ Fal, B. (2004), Maksymalne przepływy rzek polskich na tle wartości zaobserwowanych w różnych rzekach świata. (Maximum discharge in the polish rivers compared to values observed in in different rivers of world). Gospodarka Wodna 5, 188–192.

$Q_{max} = 361A/12.2+A$ Dębski, K. (1969) O potencjalnym największym odpływie z krótkotrwałych deszczów nawalnych. (Potential maximum outflow inducted by rainstorms). Rozprawy Hydrotechniczne 23, 51–63.

SCS-CN GIUH

Main scientific results

1. In the Polish part of the Carpathian Mts., flash floods in small basins are inducted by short-duration convective rainstorms. Precipitation vary from 80 to 120 mm, whereas time duration is usually lower than three hours.

2. Small basins affected by local floods are ungauged and information about hydrological parameters of flash floods in small basins is superficial. These phenomena should be investigated in more detail.

3. Hydrological data should be collected immediately after the flood event. The data allows for evaluation of the maximum discharge and maximum specific discharge in the basins suffering from local floods.

4. Data collected after flood events usually constitutes the only source of the information about the maximum discharge in small basins.

5. In the Polish part of the Carpathian Mts. twenty six basins affected by flash flood were investigated for the maximum discharge. Results indicated that the maximum discharge varied from 5 to 85 m³/s, whereas maximum specific discharge ranged from 0.8 to 11.5 m³/s/km².

6. In the basins smaller than 10 km² in area the maximum discharge and maximum specific discharge ranged from 5 to 21 m³/s and from 1 to 9 m³/s/km² respectively.

7. For the basins larger than 10 km², the maximum discharge varied from 14 to 85 m³/s whereas maximum specific discharge ranged from 0,8 to 5 m³/s/km².

8. In the mid-mountain part of the Carpathian Mts. (Beskidy region) maximum discharge varied from 9 to 85 m³/s and maximum specific discharge reached almost 12 m³/s/km². In the basins located in the Carpathian Foothills the maximum discharge varied from 5 to 35 m³/s and the specific discharge was lower and reached 6.5 m³/s/km²

9. The maximum discharges recorded during flash floods in the Carpathian Mts., were significantly lower than those which were calculated using the models mentioned above. Therefore, based on the Pagiari formula assumptions and using collected hydrological data equation: $Q_{max} = 87A/1.07A$; where Q_{max} – maximum discharge (m³/s), A – basin's area (km²) enabling the calculation of the maximum discharge in the small Carpathian basins was created. The equation is valid for basins smaller than 32 km² in area.

10. SCS-CN and GIUH models indicated that transformation from rainfall into outflow in the basins affected by flash flood is similar what was conformed by maximum specific discharge.

Key references for the basin

1. Bryndal, T. (2006) Natural and anthropogenic causes of small-scale flooding in Poland. PhD. Thesis, Pedagogical University, Kraków, Poland, 1-196.
2. Bryndal, T. (2007) Transformacja opadu w odpływ w karpackich zlewniach przy wykorzystaniu GIUH. (Transformation of rainfall into runoff in Carpathian drainage basins using GIUH), (In) Badania hydrograficzne w poznaniu środowiska (Hydrographic research in environmental science), Tom (Vol.) VIII Obieg wody w środowisku naturalnym i przekształconym (Water circulation in natural and transformed environments) , Z. Michalczyk (Ed.), UMCS, Lublin, 117-126.

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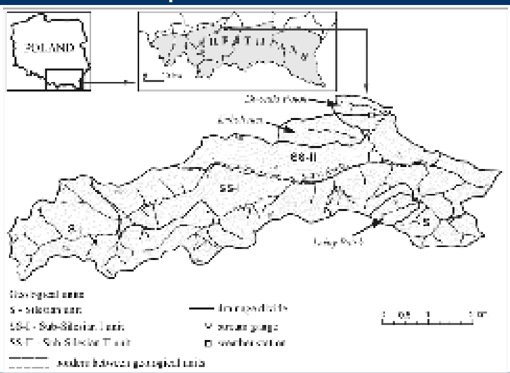
Łazy

Stara Rzeka, Poland

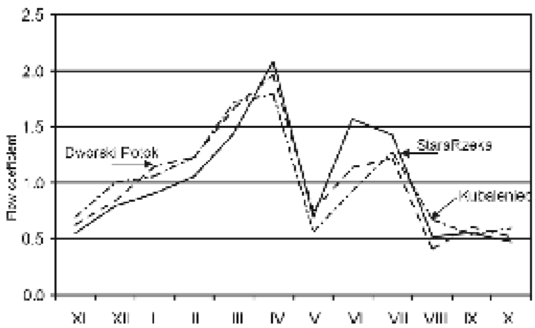
Basin characteristics

River Basin / River Basin (according EU-WFD)	Stara Rzeka / Wisła
Operation (from… to…)	Since 1987
Gauge coordinates / Gauge datum:	49.964845 N; 20.501259 E / 216.5 m asl
Catchment area:	22.22 km^2
Elevation range:	216.5-361.5 m asl
Basin type: (alpine, mountainous, lowland)	Mountain foothills, low elevation hills, flat main valley floor
Climatic parameters: (mean precipitation, temperature and others)	P = 580 mm
Land use:	Forests 41.8%; arable land 36.3%; meadows 14.9%, orchards 2.5%; built up areas 4,5%
Soils:	*Haplic Luvisols, Stagnic Luvisols, Cambic Luvisols*
Geology:	Tertiary and Cretaceous flysch (sandstones, claystones, shales), Miocene clay covered with loess-like formations
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Porous aquifer, poor hydraulic conductivity
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Stara Rzeka: Q_{min} 0.02; Q_{max} 20.3; Q_{mean} 0.158 [m^3/s]

Map of the research basin



Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

The Stara Rzeka basin represents the northern edge zone of the Carpathian Foothills with rolling hills dominating. Within the basin, there are three distinct sub-catchments under research: Leśny Potok (woodland, 0.48 km^2), Kubaleniec (agricultural, 1.03 km^2), and Dworski Potok (farmland, 0.29 km^2). The area straddles two levels of elevation: the higher being built of resistant flysch of the "Silesian tectonic unit" (36.9% of the area) and the lower being built of less resistant flysch of the "Sub-Silesian tectonic unit" consisting of two subunits: "Sub-Silesian I" (41.3%) and "Sub-Silesian II" (21.8%). The "Silesian tectonic unit" - sandstones and shales. The "Sub-Silesian I tectonic unit" - sandstones, claystones, shales, clays and conglomerates. "Sub-Silesian II tectonic unit" - claystones, marly clays, gypsum, sandstones and a salt series. Clayey Miocene formations atop flysch "Sub-Silesian tectonic unit" formations. The entire area lined with a thick layer of dusty loess-like formations, up to more than ten metres thick. Generally, the area is poor in groundwater. Poor permeability of superficial formations cause quick reaction to precipitation and snowmelt. Dense network of field roads favours surface runoff.
Number of villages exert significant influence on the quality of streamwater and groundwater.

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Discharge, water levels, precipitation	Since 1987	Daily (periodically hourly)	4

Field instruments: recording gauges, slope wash plots, weather station (air temperature, air humidity, wind speed, ground and ground surface temperature, rain acidity, wind speed and direction, snow cover).
Basic hydrochemical and soil laboratory at the Field Station of the University's Institute of Geography and Spatial Management in Łazy

Applied models

No models applied

Main scientific results

M Most of the research is focused on factors influencing the dynamics of streamwater chemistry

1. **1.** Seasonal changes of the chemistry are related to monthly changes in river discharge which affects characteristics connected with geology (SC, main ions). The higher the discharge, the lower the concentrations. Changes are controlled by dilution process. For some nutrients, the discharge causes different changes in catchments of different land use. In a woodland catchment, a growing discharge increases the concentration of these ions while in an agricultural catchment, the opposite is true.
2. **2.** The relationship between stream discharge and chemical concentration is different and depends on the source from which ions are derived. Increases in discharge caused by mid-winter and spring melt-water induce a reduction in chemical concentrations related to deeper bedrock sources (SC and most main ions) or to point sources, such as household wastewater discharge (eg. NO_2, NO_3, PO_4 in agricultural catchment). Simultaneously, concentrations of compounds derived from diffuse sources (e.g. NO_3 and K in woodland and mixed catchments) increase. The pattern is reversed during the low flows of summer and autumn.
3. **3.** Chemical composition is influenced by the degree to which soils is flushed and the subsequent availability of chemicals for transport. The effect of seasonal hysteresis is observed. The majority of ions records lower concentrations in spring and early summer, when chemicals are flushed from the soil during the preceding thawing periods. Resources of available compounds are replenished by intense chemical weathering of the soil covers during the warm season which increases concentrations during autumn and winter.
4. **4.** In the agricultural and mixed-use catchments SC and concentrations of main ions (except for HCO_3^-) are higher during floods caused by prolonged rainfall than during storm-induced floods. In the woodland catchment SC values and main ion concentrations are higher during storm-induced floods as opposed to floods caused by prolonged rainfall. This is the result of different water circulation patterns during floods in the woodland catchment where the dominant role was played by subsurface runoff. In catchments largely transformed by human agricultural activity, the dominant role was played by surface runoff. Higher SC values and ion concentrations are observed in the agricultural and mixed-use catchments during snowmelt-induced floods when the soil is unfrozen versus when the soil is frozen. This is the result of a number of infiltration opportunities being available, leaching processes and deliveries of chemical compounds occurring from surfaces to river channels. In the woodland catchment, this type of relationship does not exist.
5. **5.**Lower concentrations of NH_4^- are detected during rain-induced summer floods (both storm-induced and prolonged rainfall-induced) than during snowmelt floods both with the soil frozen and not frozen. This is related to stronger nitrification processes during the summer season. The opposite is true of PO_4^{3-} which is related to higher concentrations of suspended matter – an important source of the phosphate ion – during summer floods versus winter floods.

Key references for the basin

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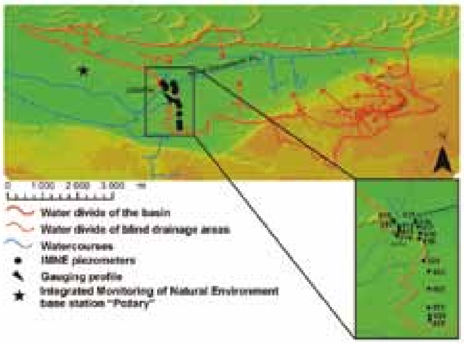
Pożary

Pożary basin, Poland

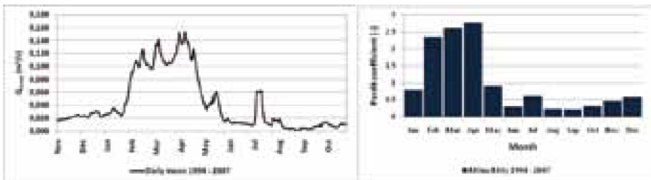
Basin characteristics

River Basin / River Basin (according EU-WFD)	Bzura river basin / Vistula river basin
Operation (from… to…)	Since 1.11.1993, still in operation
Gauge coordinates / Gauge datum:	20°29'E; 52°17'N; 70.00 m a.s.l.
Catchment area:	20.17 km^2
Elevation range:	71.7 – 103.75 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Lowland
Climatic parameters: (mean precipitation, temperature and others)	500 mm (1991 – 2008), 8.2°C (1994 – 2007)
Land use:	40% pine forest, 20% alder wood, 20% lowmoor, 10% deciduous forest, 10% grasslands
Soils:	Peat soils, black earths, podsol soils, rusty soils
Geology:	Quaternary sediments: sands and peats
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Main aquifer in sands; in places under the peats water table is confined and perched aquifer occurs.
Characteristic water discharges: (Q_{min}, Q_{mean}, Q_{max})	0.0 l/s, 44.0 l/s, 683.0 l/s (1994 – 2007)

Map of the research basin

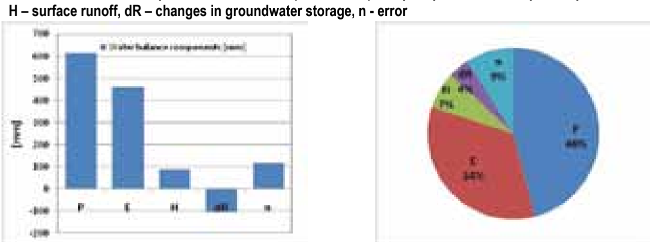


Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Mean water balance components in mm and % (1999 – 2000): P – precipitation, E – evapotranspiration, H – surface runoff, dR – changes in groundwater storage, n - error



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
River water stages	1.11.1993 – cont.	1 day	1
Groundwater level	1.11.1993 – cont.	1 day	16
Precipitation	1.11.1993 – cont. 1.11.2000 – cont.	1 day 1 h	1
Air temperature, humidity, soil temperature	1.11.1993 – cont. 1.11.2000 – cont.	7, 13, 19 hrs 1 h	1
Chemical composition of precipitation waters	1.11.1993 – cont.	1 month	1
Chemical composition of surface waters	1.11.1993 – cont.	1 month	1
Chemical composition of groundwaters	1.11.1993 – cont.	1 year	16

Applied models

DYSCHEM – mathematical model of water and solute transport in unsaturated zone

Main scientific results

1. The biggest part of precipitation in the interception process is stopped by forest plant communities in juvenile form which is caused by their high stand density;
2. The favourable infiltration conditions in the dune area and less favourable on the wetlands cause the dune zones to be the main place of groundwater recharge in the basin area. At the same time the groundwater beneath the dunes are have low levels of mineralization. This is caused by the very long way the water and solutes must travel from the soil surface to the groundwater table;
3. The greatest role in summer recharge of groundwaters is played by long lasting intensive precipitation causing an immediate reaction of the swamp area groundwater; only during such a precipitation episodes the recharge losses caused by evapotranspiration are the smallest;
4. The main source of chloride ions in the basin are precipitation waters, this is illustrated by their concentration decrease in the groundwater while a quite small load in precipitation waters is observed;
5. The vertical component prevails in the basin water and chemical substance circulation due to the good permeability of surface formations and small possibilities of overland flow forming;
6. Water storage in wetlands increasing thanks to overgrowing and not maintained watercourses enables relative quick evolution of meadows into lowland moor. General tendency to lowering of groundwater levels in years 1994 - 2004 has not restrained this process. The most probably, limitation of river runoff in the result of relinquishment of channel maintenance causes increase in water storage capacity of the basin and is conductive to expansion of hygrophilous plants species.

Key references for the basin

1. Andrzejewska A., 2003, *Klimat Puszczy Kampinoskiej (Climate of the Kampinos Forest),* [in:] *Kampinoski Park Narodowy tom I (Kampinos National Park, vol. 1),* Andrzejewski R. (ed), KPN, Izabelin, 41-68.
2. Lenartowicz M., Andrzejewska A., Ferchmin M., Owadowska E., Wierzbicki A., 2006, *Stacja Bazowa Pożary (Base stadion „Pożary"),* [in:] *Aktualny stan, przemiany i funkcjonowanie geoekosystemów Polski w latach 1994-2004 na podstawie Zintegrowanego Monitoringu Środowiska Przyrodniczego (Actual state, evolution and functioning of geoecosystems in Poland in years 1994-2004 on the base of Integrated Monitoring of Natural Environment),* Kruszyk R. (ed), Biblioteka Monitoringu Środowiska, IOŚ, Warszawa, 173-212.
3. Lenartowicz M., 2005, *Modelowanie procesów hydrologicznych i geochemicznych w bagiennej zlewni nizinnej (na przykładzie zlewni Pożary) (Modeling of hydrological and geochemical processes in lowland swampy basin – case study of „Pożary" basin),* Monografie Komitetu Gospodarki Wodnej PAN, z. 25.

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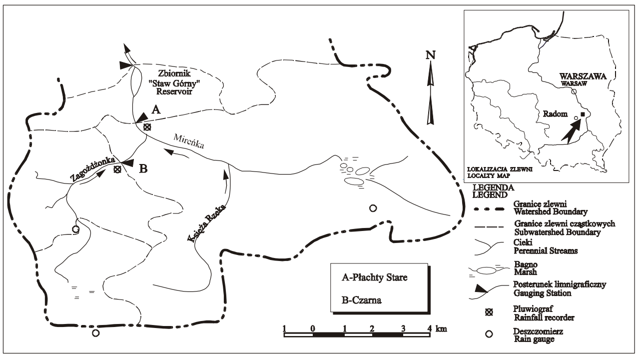
Płachty Stare and Czarna
Zagożdżonka, Poland

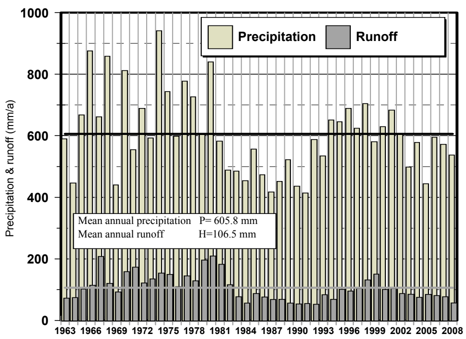
Basin characteristics

River Basin / River Basin (according EU-WFD)	Vistula River
Operation (from… to…)	Płachty Stare – since 1963, Czarna – since 1980
Gauge coordinates / Gauge datum:	Płachty Stare – 21⁰27ʹ E and 51⁰27ʹN
Catchment area:	Płachty Stare- 82,4 km², Czarna 23,4km²
Elevation range:	148 – 185 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Lowland
Climatic parameters: (mean precipitation, temperature and others)	Precipitation 605,8 mm, Runoff 106,5 mm
Land use:	Agricultural
Soils:	Sandy
Geology:	-
Hydrogeology: (Type of aquifers, hydraulic conductivity)	-
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Płachty Stare : Q mean- 0,278 m³/s, 100 Years flood- 25.1 m³/s

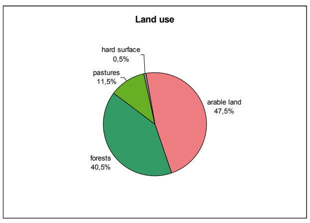
Map of the research basin

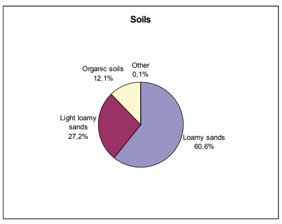


Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)





Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Station Name
Water stage/discharge	1963-cont.	Daily (since 2003 -10min)	Plachty Stare
Rainfall	1982-1996	Daily	Plachty Stare
Water stage/discharge	1995-cont.	10 minutes	Czarna
Rainfall	1996-cont.	Daily, Impuls /0.1mm	Czarna
Water and air temp., humidity	1996-cont.	10 minutes	Czarna
Soil temp.	2003-cont.	10 minutes	Czarna
Ground water level	2008-cont.	10 minutes	Czarna
Abedo,wind velocity	2007-cont.	10 minutes	Czarna/Plachty

Applied models

1. SEGMO (SEdimentGraph MOdel – Warsaw University of Life Sciences)
2. AGNPS (Agricultural Non Point Source Pollution Model – USDA – ARS)
3. CCHE1D (Center for Computational Hydrosciences and Engineering- The University of Mississippi)

Main scientific results

- rainfall-runoff model development for agricultural catchments (SEGMO)
- estimation of lag times of rainfall events
- probable annual maxima of flow for small catchment
- bed load (sediment trap) and suspended sediment transport in agricultural catchment
- river and reservoir sedimentation modelling (CCHE1D model)
- impact of various land management on water quality (AGNPS model)
- grain size distribution of suspended sediment during floods (laser diffraction method)
- relation between phosphorus concentration and suspended sediment transport
- erosion processes (DR-USLE model – Warsaw University of Life Sciences)
- suspended sediment transport during snowmelt periods
- environmental monitoring station development: http://www.traxelektronik.pl/pogoda/hydro/stacja.php?idst=90&c9=1237902000

Key references for the basin

- Sediment transport intensity and reservoir siltation on the Zagożdżonka river / Zbigniew Popek, Kazimierz Banasik, Leszek Hejduk.TEKA Commission of Protection and Formation of Natural Environment 2007, Vol. 4, s. 207-212
- Estimation of T-year flood discharge for a small lowland river using statistical method / Kazimierz Banasik, Andrzej Byczkowski.Annals of Warsaw Agricultural University. Land Reclamation 2006, nr 37, s. 27-31
- Prediction of siltation process of a small reservoir in Poland using CCHE1D model / Leszek Hejduk, Kazimierz Banasik, Zbigniew Popek. Advances in hydroscience and engineering, Vol. 7 : the 7th International Conference on Hydroscience and Engineering / ed. M. Piasecki [i in.]. - Philadelphia, 2006. - S. 471-472

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Additional references (since 2006) available at: http://www.bg.sggw.waw.pl/ang/index.html

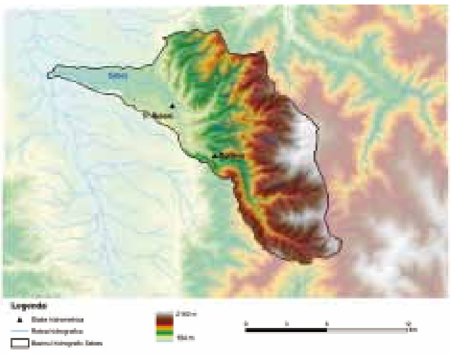
Sebes

Sebes River Basin, Romania

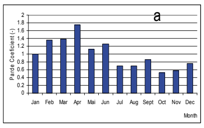
Basin characteristics

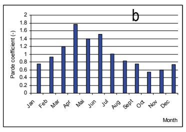
River Basin / River Basin (according EU-WFD)	Timis
Operation (from… to…)	Since 1974 – still in operation
Gauge coordinates / Gauge datum:	22°31'00" E 45°17'05" N / 287 m a.m.s.l.
Catchment area:	124 km²
Elevation range:	287 – 1802 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	867,8 mm (1975-2006); 9,5°C (1975-2006)
Land use:	alpine pasture; coniferous and deciduous forests; agricultural areas
Soils:	stagnic luvisol, cambisol, spodosol
Geology:	crystaline schists and volcanic rocks
Hydrogeology: (Type of aquifers, hydraulic conductivity)	
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0,450 cum/s; 146 cum/s; 2,94 cum/s

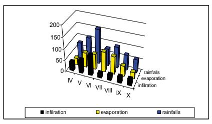
Map of the research basin

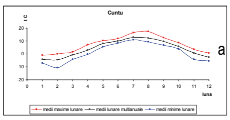


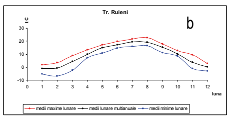
Mean hydrograph / Pardé flow regime











The Pardé coefficient for the smallest surface (a) and the main gauging station (b) in the Basin

The relation between rainfalls, evaporation and infiltration

The meam multiannual temperature in the upper part (a) and the lower part (b) of the Basin

Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

There is no specific research on the hydro-geographic features of the area

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Water level	August 1974 – contin.	12 hours	8
Air and water temperature	August 1974 – contin	12 hours	8
Precipitations	August 1974 – contin	12 hours	8
Growndwater level	August 1974 – contin	3 days	2
Discharge	Jan 1978 – contin.	7 days	8
Suspended and bed load transport	Jan 1978 – contin.	3 days	1

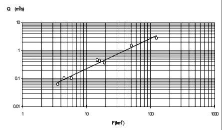
Applied models

1. Concept models

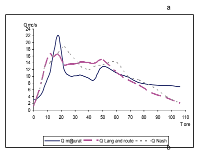
Main scientific results

1. A relation has been established between the mean multi-annual discharge and the surface of river basin (the graph on the right) to calculate the discharge in basins with similar physic geographic features. The formula of calculation is presented below:

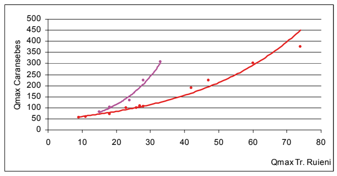
$$Q = 0{,}0186 \cdot F^{1{,}0814}$$



2.The use of mathematical patterns has lead to the conclusion that the most accurate results are obtained through models *Lad and route* and *Nash cascade with two reservoirs*; below are offered examples of checking of a high flood registered.



3.The establishment of a relation between the maximum discharge between Turnu Ruieni (from Representative Basin) and gauging station Caransebes on the river Timis (here below); this allows some prognosis with reduced accuracy (-13.5 to +37.9%), but with a period of forecast (36-48 hours)



Key references for the basin

N. I. Teodorescu (2005) - The Water Leakage Conditions in the Representative Basin Sebes, Mirton Publishing House, Timisoara, 151 pg.

* * * (1980) - The First Results Obtained in the Experimental and Representative Basins in Romania, The Metrology and Hydrology Institute, Bucuresti, 230 pg.

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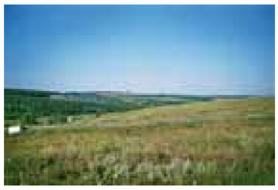
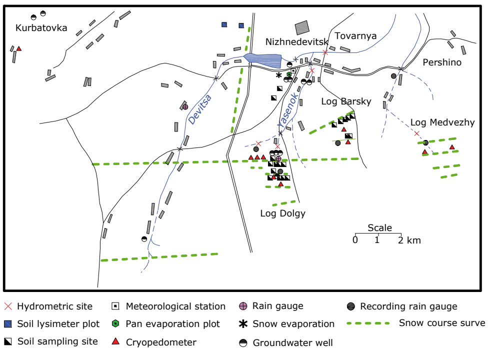
Nizhnedevitsk Water Balance Station (NDWBS), Devitsa basin, Russia



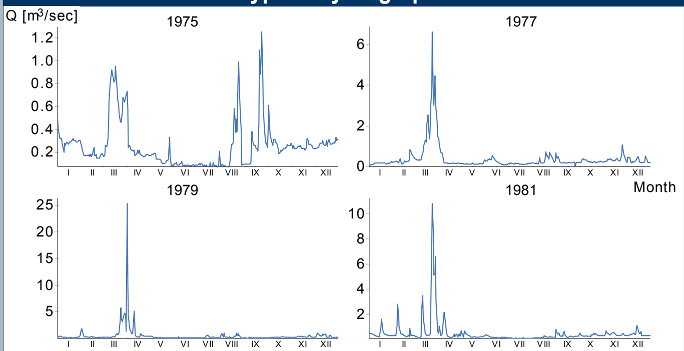
Basin characteristics

River Basin / River Basin	Don River
Operation (from... to...)	Since 1948, still in operation
Gauge coordinates:	51°54' E; 38°23' N/ 208 m a.m.s.l.
Catchment area:	103 km²
Elevation range:	135 – 265 m
Basin type:	Forest-steppe, hills with gullies and gorges
Climatic parameters:	560 mm; 6.0°C (1948-1996)
Land use:	67% Arable lands, 19% meadow, 14% forest
Soils:	Common medium-thick chernozem
Geology:	Sandy-laminated clays and loams, quartz sand, chalk
Hydrogeology:	Shallow throughflow horizon (sand), two deep aquifers (quartz sand)
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Qmin = 0 m³/s, Qmax = 26.3 m³/s, Qaverage = 0.40 m³/s (1974 – 1984)

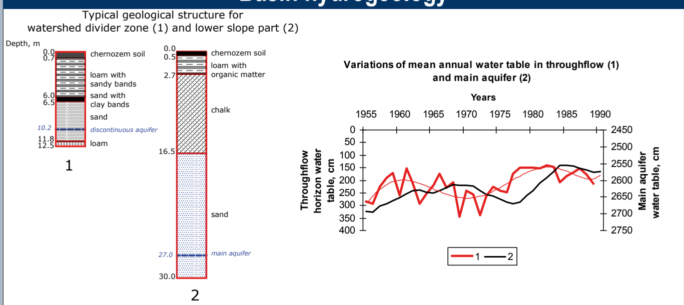
Map of the research basin



Typical hydrographs



Basin hydrogeology



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1948 – 1992	Minutes	2 (8)
Precipitation	1948–cont.	daily, minutes	3 (10)
Snow surveys	1948–cont.	Monthly, decadely, event based	5
Evapotranspiration	1950–cont.	1 per 5 days	1
Snow evaporation	1950–cont.	Daily	1
Pan evaporation	1950–cont.	Daily (warm period)	1
Soil moisture content	1950–cont.	Monthly decadely	11 (19) 2
Soil temperature at depths 0.1 – 3.2 m	1974–1981	Daily	1
Soil freezing/thawing	1958–cont.	1 per 5 days	8
Energy balance	1950–cont.	Decade	1
Ground water tables	1955–1992	1 per 10 days	14
Flow water chemistry	1950–cont.	Event based	2
Suspended sediments	1950–cont.	Daily, event based	6

Applied models

1. The model "Hydrograph" (in process)

Main scientific results

1. Volume of snow melting peak flood depends from formation of "lock layer" in unsaturated zone (combination of soil moisture content more 0.7 field capacity and soil freezing depth).
2. Direct flow (surface flow and throughflow) equals to about 8-10% of total. The rest part of runoff is forming by ground water from main aquifers.
3. Annual value of moisture seepage below throughflow horizon is change from 20 mm to 110 mm from year to year.
4. Time of moisture seepage from throughflow horizon to main aquifer is about 8-10 years.

Key references for the basin

1. Zhuravin, S.A. (2004) Features of forest-steppe small basins water balance: Nizhnedevitsk Water Balance Station case study. In: Northern Research Basins Water Balance. IAHS publ. № 290, 2004, p 78 – 90.
2. Zhuravin, S.A. (2002) Change of hydrological regimes over the central part of European Russia resulting from climate variations. In: *FRIEND 2002, Regional Hydrology: Briging the Gap between Research and Practice* (ed. by H.A.J. van Lanen & S.Demuth) (Proc. Fourth FRIEND Conf., Cape Town, October 1993), 441-447. IAHS Publ. No.274.
3. Vershinina, L.K., Krestovsky, O.I., Kaliuzhny, I.L. & Pavlova, K.K. (1985) Assessment of snow melting water losses and forecasting of spring flood volume. Leningrad, Cidrometeoizdat, 189 p. (In Russian).

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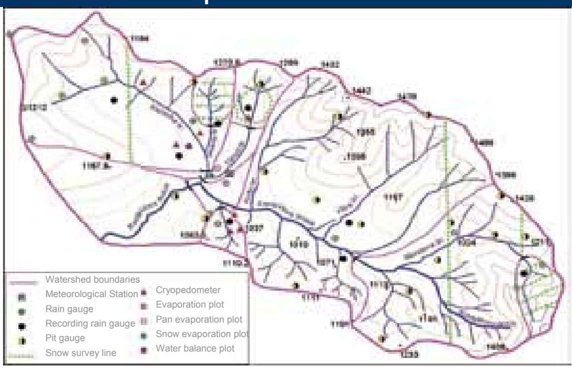
Kolyma Water Balance Station (KWBS)

Kontaktovy basin, Russia

Basin characteristics

River Basin / River Basin	Kulu River / Right Kolyma River
Operation (from… to…)	Since 1948, still in operation
Gauge coordinates:	61°54' E; 147°25' N/ 1070 m a.m.s.l.
Catchment area:	21.2 km^2
Elevation range:	800 – 1700 m
Basin type:	Mountainous
Climatic parameters:	405 mm; -13.1°C (1948-1992)
Land use:	31% Barren Alpine tundra (Talus), 27% cedar and alder woods, 14% larch open woods, 11% open terrain and sloping woods
Soils:	Stony-rock debris, clayey podzol
Geology:	Shale, granite, diorite
Hydrogeology:	Fractured rock, ground water outflow from deep aquifer in not frozen channel area ("talik")
Water discharges	Q_{min} = 0 l/s, Q_{max} = 7610 l/s, $Q_{average}$ = 195 l/s (1974 – 1984)

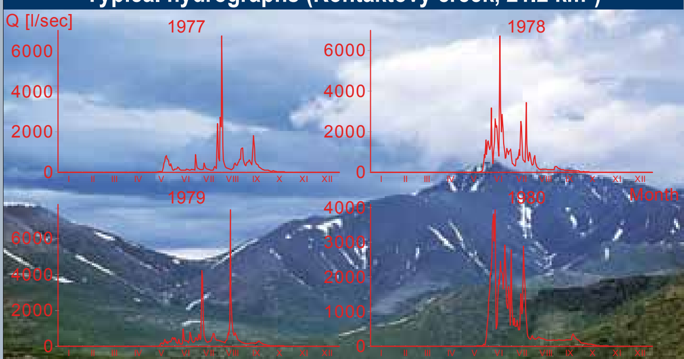
Map of the research basin



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1948–cont.	Minute Daily	7
Meteorological observations	1948–cont.	3h	1
Precipitation	1948–cont.	Minute Pentad, decade in winter, daily in summer Decade Month	10 5 10 10
Snow surveys	1948–cont.	Monthly (October – March), decadely (April…)	5
Evapotranspiration	1958–cont.	Pentade	4
Snow evaporation	1958–cont.	September – October, March – April (12-hourly)	1
Pan evaporation	1970–cont.	Decade	1
Energy balance	1958–cont.	Decade	1
Soil freezing/thawing	1958–cont.	Once in 5 days	5
Soil temperature at depths 0.1 – 3.2 m	1974–1981	Daily	1
Flow water chemistry	1958–cont.	Event based	2

Typical hydrographs (Kontaktovy creek, 21.2 km^2)



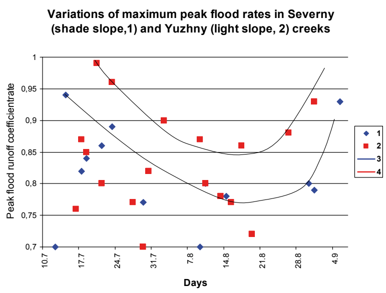
Main scientific results

1. Regional equation for the rain peak flood discharges computation. This equation takes into account effective rain depth and intensity, density of working drainage network.
2. Transient moisture that forms during the autumn period as subsurface storage of ice (in rock glaciers and talus slopes) provides additional runoff recharge reaching 120-130 mm from areas occupied by these landscape types.
3. Evaporation (E) from surfaces covered by reindeer moss and talus depends on water availability 5 mm, number of rain events (*N*) and moss holding capacity. It may be computed using relationship $E=5\sum N$. Evapotranspiration from sphagnum can be twice greater compared to evaporation from water surface.
4. Maximum rain peak flood coefficients depends on depth of seasonal thawing soil layer and changes within 0.86 - 0.98 range for shaded slopes and 0.77-0.95 for illuminated slopes.

Applied model

1. The model "Hydrograph" (in process)

Special basin characteristics – continuous permafrost



The permafrost thickness over Kontaktovy Creek basin area ranges from 120-210 m in the valleys to 300-400 m in the hills. Maximum depth of the seasonal soil thawing is 30-40 cm in the shaded slopes (Yuzhny Creek) and 1.5-2 m in the light slopes (Severny Creek). It influences on the landscape types formation and changes of maximum rain peak floods runoff coefficients during the warm period.

Key references for the basin

1. Boyarintsev, E.L., Serbov, N.G., Dovbysh V.N. & Popova N.I. (2006) Experimental studies of evaporation and condensation in mountainous permafrost regions. In: Proc. VI Hydrological Conference, 28 September – 1 October 2004, St.Petersburg, Russia, Section 5, part I, Meteoagentstvo Press, Moscow, p.78-82. (In Russian)
2. Zhuravin, S.A. (2004) Features of water balance for small mountainous watersheds in East Siberia: Kolyma Water Balance Station case study. In: Northern Research Basins Water Balance. IAHS publ. № 290, 2004, p 28 – 40.
3. Boyarintsev, E.L. (1988) Specific factors of the rain peak flood formation for the Kolyma Water Balance Station area. Proc. DVNIGMI, vol.135, Gidrometeoizdat, Leningrad, p.67-93 (In Russian).

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Slovak Hydrometeorological Institute, Bratislava

Institute of Hydrology SAS Bratislava

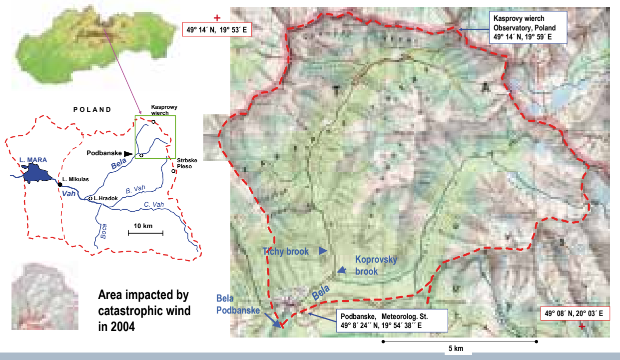
Bela, Podbanske

Bela river basin, Slovakia

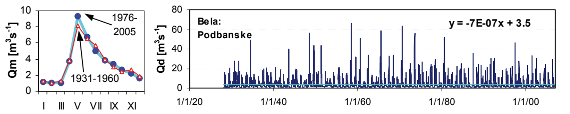
Basin characteristics

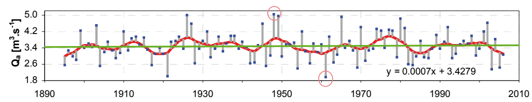
River Basin / River Basin (according EU-WFD)	SKV0011, Vah River Basin / Danube River basin
Operation (from… to…)	Since 1924, still in operation
Gauge coordinates / Gauge datum:	49° 8´ N, 19° 54´ E, 922.72 m a.s.l.
Catchment area:	93.49 km^2
Elevation range:	1571 m, max=2494 m.a.s.l., mean 1551 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Alpine in The Tatras National Park (TANAP)
Climatic parameters: (mean precipitation, temperature and others)	Preliminary results P=1473 mm, R=1181 mm. (1901-2000), Runoff coef. 0.8, t= -0.8°C -Kasprowy, 4.6°C -Podbanske
Land use:	Forest-61%, pine dwarf-26%, rock-13%, lakes-0.239 km^2,
Soils:	Up to 1500 m brown forest soils
Geology:	crystallinicum, small parts limestones dolomites
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Impermeable bedrock
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	Qmin = 0.48; Qmax = 170; Qmean = 3.5 m^{3}s^{-1}

Map of the Bela basin



Flow regime



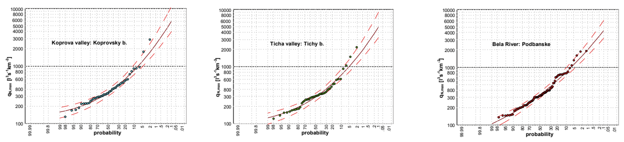


Long-term monthly *Qm* (two periods) and average daily *Qd* flows, measured series, long-term trend 1928–2006, (above).

Average annual discharge *Qa*, 1895–1927 supplemented series, residuals of 5-year moving averages (below), trend 1895–2006, Bela river.

Extreme runoff characteristics in Bela subbasins

$q_{N,max}$, log-Pearson III. type distribution



Comparison of N-year specific yields in three subbasins (1941-1960 and 1971 – 1999).

Instrumentation and data

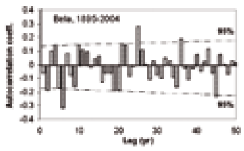
Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
water level Bela:Podbanské, 922.7 m a.s.l.	1924-1948, 93.5 rkm 1949-60 limnigraph 91.1 rkm 1961-89 limnigraph 93.5 rkm 1989-09 hourly 93.5 rkm	Observer, 3x daily Mean daily Mean daily Hourly	
water level Koprovsky creek	1941-1960 observer 1972-1989 limnigraph 1989-1999 limnigraph	Mean daily Mean daily Hourly	
water level Tichy creek	1941-60 observer 1972-89 limnigraph 1989-1999 limnigraph	Mean daily Mean daily Hourly	
Meteo station, Liptovsky Hradok	1881-2009	T, P Daily T Hourly	
Meteo station, Podbanske	1960-2009	Daily	
Observatory Kasprowy wierch Poland, 1991 m a.s.l	1938-up to day	N / A	

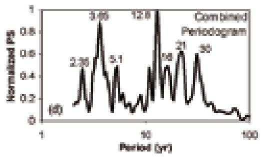
Applied models - no

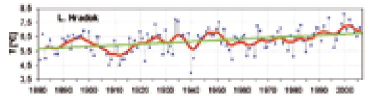
Main scientific results

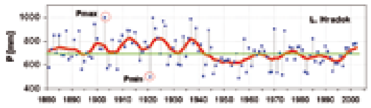
Auto-correlogram of the discharge series of Bela River and spectral analysis of the mean annual discharge of Bela River

The spectral analysis by method MESA, identified as the most significant period of 3.6 year. Other significant periods are those of 12.8, 5.1, 4.2, and 2.47 years. Using method of the combined periodogram (Pekarova et al., 2003), long periods of 16, 21, and 30 years were identified.









From the Bela at Podbanske mean annual discharge analysis, it follows:

1. Annual discharge series Belá at Podbanské is homogeneous.
2. The series long- term trend is zero.
3. The most significant period, identified by spectral analysis is of 3.6 years. Significant are also periods of 29- years ; 21- years , 36- years ; 13- years ; 4,2- years.

Key references for the basin

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3. Pekarova P., Pekar J., Pacl J. (2005): Time variability of annual discharge in the Bela mountainous catchment during 1901–2000. (In Slovak.) In Proc. Hydrology for integrated management of water resources, Bratislava, (eds. Majercakova O., Nachazel K., Szolgay J.), SHMU, CVUT, STU, CD ROM, ISBN 80-88907-53-5, 2005, 417-429.

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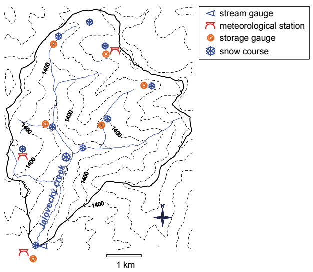
The Jalovecký creek, mountain part

The Jalovecký creek basin, Slovakia

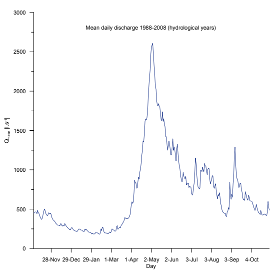
Basin characteristics

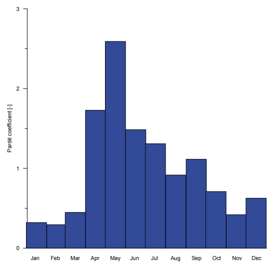
River Basin / River Basin (according EU-WFD)	the Váh river basin/ the Danube basin
Operation (from… to…)	1987 till present
Gauge coordinates / Gauge datum:	19°38’44’’E; 49°9’46’’N / 816 m a.s.l.
Catchment area:	22.2 km^2
Elevation range:	816-2178 m a.s.l.
Basin type: (alpine, mountainous, lowland)	mountain
Climatic parameters: (mean precipitation, temperature and others)	1570 mm (1989-2008), 3.5 C (1989-2008)
Land use:	conifer. forest 44% , dwarf pine 31%, meadows 25%
Soils:	Cambisol, Podzol, Lithosol
Geology:	Crystalline rocks, granodiorite, Quaternary sediments
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Fissured aquifer, deep weathering zone , moraines
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	58 l/s, 6797 l/s, 702 l/s – daily discharges (1988-2008)

Map of the research basin



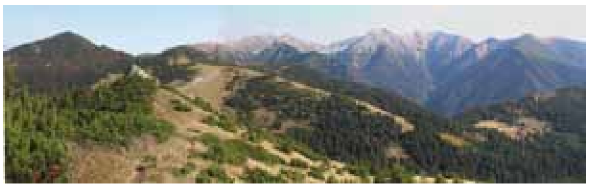
Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

1. The basin is situated in the national park, i.e. human interventions are restricted.



View to the highest part of the catchment from its south-western boundary

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Runoff	since June 1987	hourly 10-min. since 2002	1
Precipitation	since November 1987 1988-2008 since 2002	weekly monthly 10-min., summer	2 6 3
Air temperature	since June 1987	hourly	2
Snow depth, water equivalent	1987-2008 since 1996	3-4 times per winter weekly	4-36 2
Environmental isotopes ^2H, ^{18}O	since November 1990	varying	varying

Applied models

1. WaSim-ETH
2. UEB (Utah Energy Balance Snow accumulation and Melt model)
3. SOIL

Main scientific results

1. Spatial differences in (annual) precipitation in the mountains are relatively small compared to the difference between the mountains and foreland.
2. Precipitation increases with altitude only until certain altitude, similar effect is observed for snow characteristics (depth, water equivalent).
3. The range of precipitation interception in the forest even at the same characteristics locations (forest window, dripping zone, near-stem zone) reaches tens of percents.
4. Despite the importance of snow cover in runoff regime (the highest discharges are mostly connected with snowmelt period), extreme floods caused by snow melt did not occur (almost 300 mm of snow can melt in a week).
5. Diurnal runoff oscillations during snowmelt that are typical for glaciated catchments occur almost every year although the catchment is not glaciated.
6. Soils in the forests are drier than outside of the forests.
7. Overland flow occurs very rarely. It seems its occurrence is more frequent after after heavy rainfalls, than during snowmelt.
8. Hydrological response of the catchment is fast. Flood peaks typically occur within 2 hours after rainfall peaks. However, the relation of hydrological response to antecedent wetness conditions is weak.
9. Water conductivity and temperature measurements did not indicate sudden inflows of groundwater into the main streams. Stream water conductivity at catchment outlet seems to respond only to bigger runoff events following relatively drier periods.
10. Mean residence time of water in the catchment is about 2 years.
11. Catchment mean annual evapotranspiration is about 500 mm which is much higher than the values calculated by climatologists (about 300 mm). The difference may be caused by the fact that standard networks do not provide correct data (e.g. for precipitation) for small mountain catchments and by underestimating of the role of forests in the long-term water balance.

Key references for the basin

1. Kostka, Z., Holko, L. (1997) Soil moisture and runoff generation in small mountain basin. SVH Publ. 2, Inst. of Hydrology SAS and Slovak NC IHP UNESCO, ISBN 80-967808-1-6., 90 p.
2. Holko, L., Kostka, Z. (2006) Hydrological research in a high-mountain catchment of the Jalovecký creek. J. Hydrol. Hydromech., vol. 54, no. 2., 192-206.

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Euskal Herriko Unibertsitatea
eman ta zabal zazu
University of the Basque Country

Aixola

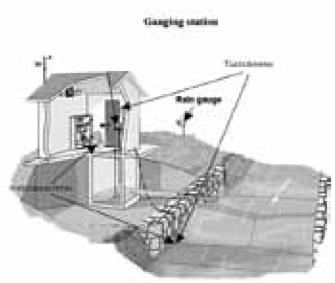
Aixola catchment, Basque Country

Zientzia eta Teknologia Fakultatea
Science and Technology Faculty

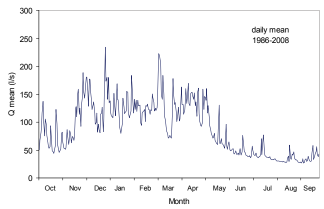
Basin characteristics

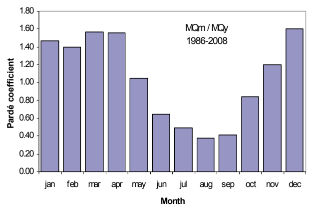
River Basin / River Basin (according EU-WFD)	Deba river basin
Operation (from… to…)	Since 1986, still in operation
Gauge coordinates / Gauge datum:	X=540642 Y=4778125 Z=349
Catchment area:	4.8 Km^2
Elevation range:	340 – 750 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	1480 mm (1986-2007), 11.9 ºC (1990-2008)
Land use:	80% *Pinus radiata*, 10% grassland, 10% mixed wood.
Soils:	Cambisol and Regosol.
Geology:	>90 % Calcareous flysch.
Hydrogeology: (Type of aquifers, hydraulic conductivity)	No aquifers of interest
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	4.7 l/s, 10634 l/s, 90 l/s (1986-2008).

Map of the research basin

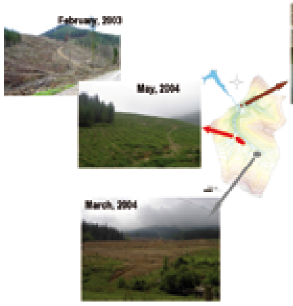


Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



Sediment trapped in small dams is being monitored since January 2009.

This basin is anthropically very disturbed as it is mostly reforested for industrial use. Thus, tree cutting and site preparation for reforestation (scalping and down-slope ripping) have been usual activities. Apart from this, in March 2004 a filling of land of about 5 ha was made in the upper part of the catchment.

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Discharge	since 1986	10 min.	1
Precipitation	since 1986	10 min.	1
Air temperature	since 1989	10 min.	1
Turbidity	since 2003	10 min.	1
Suspended sediment conc.	since 2003	Event based	1
Electrical conductivity	since 2003	Event based	1

Applied models

SWAT and TOPMODEL will be applied shortly.

Main scientific results

1. At the annual scale:
   - Runoff coefficient is about 40 %.
   - The catchment has a considerable regulation capacity to face up to drier years, probably related to soils.
   - Suspended sediment yield is about 36 t/Km^2 (2003-2008).

2. Observation of data at the event scale evidences that:
   - There is a direct response of the catchment to rainfall events in water and sediment, so the type of events observed are of "flash flood" type. There is no need of high or intense precipitations to observe a response (in water and SS) in the gauging station, a very small precipitation of 2.5 mm can produce a runoff event with a sediment response.
   - Total precipitation influences water and sediment response in terms of total and maximum discharge and sediment yield, however discharge and sediment increase depend more on precipitation maximum intensity. Relationship between discharge and suspended sediment is also strong, particularly between maximum discharge and discharge increase and maximum sediment concentration and sediment yield. Antecedent conditions seems not to have any influence on discharge and sediment values registered.
   - Analysis of the evolution of discharge and suspended sediment concentration during events, the hysteretic loops, determined that: events that show a lineal relationship between discharge and SSC are events with low total precipitation, discharge and sediment yield; events with clockwise hysteretic loops usually register high precipitation, discharge and suspended sediment yield and important precipitation before events; counter clockwise events differ from the previous because they show lower precipitation, discharge and suspended sediment records, and they are observed under high or low antecedent precipitation conditions; only one eight shaped hysteretic loop was observed and it is related with very intense precipitations and dry conditions; the rest of the events were not classified, they also take place during dry conditions and under high precipitation intensities.
   - Analysis of the evolution of electrical conductivity during events showed a quite homogeneous behaviour of water mineralization during runoff events. After a decrease of EC during discharge increase, initial conductivity is very rapidly recovered in any of the hydrological situations. Moreover, pre-event waters are present in high proportion in runoff, even during events.

Key references for the basin

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2. Zabaleta A., Martínez M., Uriarte JA., Antigüedad I., 2006. Determinant factors for discharge/suspended sediment hysteretic loops in a small headwater catchment in the Basque Country. *5th World FRIEND Conference. Climate Change and Hydrological Impacts. Conference Proceedings CD.*
3. Zabaleta A., Martínez M., Uriarte JA., Antigüedad I., 2007. Factors controlling suspended sediment yield during runoff events in small headwater catchments of the Basque Country. *Catena* 71, 179-190.

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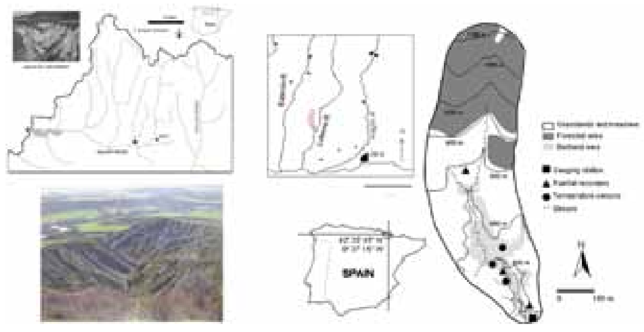
Araguás catchment

Upper Aragón Valley, Spain

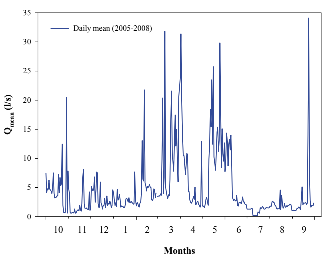
Basin characteristics

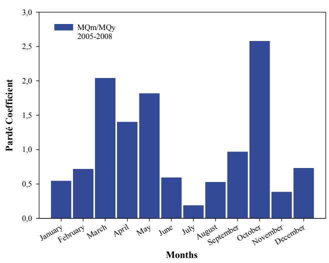
River Basin / River Basin (according EU-WFD)	Lubierre river basin/ Aragón river basin
Operation (from… to…)	Since 2004, still in operation
Gauge coordinates / Gauge datum:	42° 35' 45''N; 0° 37' 15''W/ 917 m a.m.s.l.
Catchment area:	0.45 km^2
Elevation range:	780-1105 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	mountainous
Climatic parameters: (mean precipitation, temperature and others)	800 mm (1976-2006), 11.4 °C (1976-2006)
Land use:	45.3% shrubs, grassland and meadows, 27.5% forest, 27.2% badlands
Soils:	Regosoil, Haplic Kastanozem
Geology:	Eocene marls and Eocene Flysch
Hydrogeology: (Type of aquifers, hydraulic conductivity)	
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0 l/s, 2050 l/s, 3.09 l/s

Map of the research basin



Mean hydrograph / Pardé flow regime

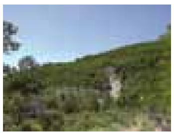




Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

The Araguás catchment is characterized by the presence of a dense network of badlands in its lower part. The upper part of the catchment was cultivated until the middle of the 20th century, before being reforested with *Pinus sylvestris* and *Pinus Nigra*. Nowadays, 30% of the catchment is covered by forest.

A gauging station measures discharge and sediment output at the outlet of the catchment and a water-level probe, installed above the badland areas, controls the hydrological response of the forested and upper part of the catchment.



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Air temperature and precipitation	February 2004-cont	30 minutes	2 and 3
Regolith physical indicators and moisture	February 2004-January2007	Weekly	2 sampling plots
Regolith temperature	February 2004-cont	30 minutes	2
Stream flow	October 2005-cont	5 minutes	2
Suspended concentration	October 2005-cont	5 minutes	1
Solute concentration	October 2005-cont	Event dependent	Event base

Applied models

Main scientific results

1. The Araguás catchment is characterized by the presence of a Mediterranean humid badland areas, with intense processes of weathering, hillslopes erosion and sediment transport.
2. The relatively high values of annual precipitation in combination with contrasting trends in temperature and moisture at different temporal scales, and easily weathered bedrock (Eocene marl) explain the capacity of the catchment to yield and deliver high quantities of sediment.
3. Clear seasonal weathering dynamics were observed, with the most active weathering processes in winter when hillslopes regolith becomes increasingly susceptible to erosion.
4. The seasonal trend of sediment transport dynamics was linked to weathering and erosion temporal processes and discharge distribution.
5. The hydrological response tends to be related with different land uses and to rainfall characteristics (rainfall intensity and rainfall volume).
6. Runoff generation occurs throughout the year, even during summertime.
   i. During dry conditions, infiltration excess runoff process (Hortonian flows) was found to be the only active runoff processes occurring in response to short and intense rainstorms, and the hydrological and sedimentological response was limited to badland areas.
   ii. During wet periods, both infiltration excess runoff and saturation excess runoff were the runoff processes operating within the catchment. Saturation excess is the only mechanism on the forested area.
7. Badlands areas in the Araguás catchment always yield significant volumes of sediment. Nevertheless, most of the annual sediment yield was a result of just a few precipitation events.
8. The values of sediment outputs recorded during a hydrological year were about 57000 Mg km^{-2} yr^{-1}.

Key references for the basin

1. Nadal-Romero, E. & Regüés, D. 2009. Detachment and infiltration variations as consequence of regolith development in a Pyrenean badland system. *Earth Surface Processes and Landforms*.
2. Nadal-Romero, E. 2008. Las áreas de cárcavas (badlands) como fuente de sedimento en cuencas de montaña: procesos de meteorización, erosión y transporte en margas del Pirineo Central. Phd Tesis. Zaragoza
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4. Nadal-Romero, E., Latron, J., Lana-Renault, N., Serrano-Muela, P., Martí-Bono, C., Regüés, D. (2008). Temporal variability in hydrological response within a small catchment with badland areas, Central Pyrenees. *Hydrological Science Journal*, 53 (3): 629-639.
5. Nadal-Romero, E., Latron, J., Martí-Bono, C., Regüés, D. (2008). Temporal distribution of suspended sediment transport in a humid Mediterranean badland area: The Araguás catchment, Central Pyrenees. *Geomorphology*, 97 (3-4): 601-616. doi:10.1016/j.geomorph. 2007.09.009.
6. Nadal-Romero, E., Regüés, D., Martí-Bono, C., Serrano-Muela, P. (2007). Badland dynamics in the Central Pyrenees: temporal and spatial patterns of weathering processes. *Earth Surface Processes and Landforms*, 32 (6), 888-904.

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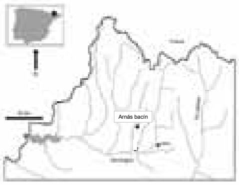
Arnás catchment

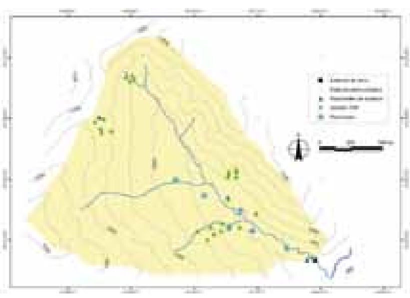
Upper Aragón valley, Spain

Basin characteristics

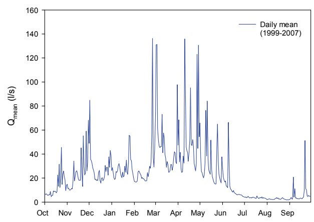
River Basin / River Basin (according EU-WFD)	Lubierre river basin/ Aragón river basin
Operation (from… to…)	Since 1996, still in operation
Gauge coordinates / Gauge datum:	0°35'W; 42°38'N/ 910 m a.s.l.
Catchment area:	2.84 km^2
Elevation range:	910-1430 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	950 ± 220 mm (1999-2005)
Land use:	20% forest, 73% shrubs, 5.5% grass, 1.5 bare soil
Soils:	Regosols rich in carbonates and Cambisols
Geology:	Eocene flysch
Hydrogeology: (Type of aquifers, hydraulic conductivity)	
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0.0 l/s, 22.3 l/s, 4290 l/s

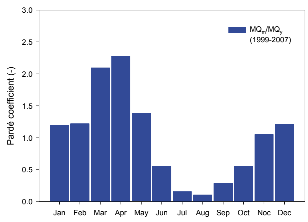
Map of the research basin





Mean hydrograph / Pardé flow regime

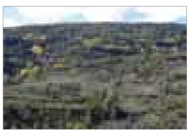




Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Tha Arnás catchment was totally cultivated in non-terraced fields until the middle of the 20th century, then progressively abandoned and naturally re-vegetated with shrubs.

Such environment, affected by past agricultural practices, with more intensive uses in some areas and more conservative uses in others, now constitutes a "mosaic" of land patches that react differently under varying rainfall and catchment moisture conditions.



Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1996 – cont.	5 min	1
Precipitation	1996 – cont. 2001, 2005 – cont.	5 min Impuls/ 0.2 mm	1 2
Air temp., Air hum, wind speed, radiation	1996 – cont.	15 min	1
Groundwater level	Nov 2003 – cont	20 min	7
Soil water moisture	1996 - 98 Jul-Dec 2005	Once every 2/3 weeks	25 points at 4 locations
Suspended sediment transport	1996 – cont.	5 min	1
Solutes transport	1996 – cont.	15 min	1
Bedload transport	Sept 2003 – Sept 2006	Flood event	1

Applied models

1. TOPMODEL

Main scientific results

1. Rainfall and runoff show a strong non-linearity during the hydrological year; sreamflow response is determined by catchment moisture conditions, in particular by water-table dynamics.
2. Water-table is highly seasonal, with a dry period in summer, followed by a progressive rise in piezometric levels during the autumn wetting-up period, and a saturation period in winter. Spatial variability in the water table is low within the catchment during wet and dry periods, but increase significantly during the wetting-up period.
3. During dry conditions, infiltration excess runoff over areas devoid of vegetation is the main active runoff process, occurring in response to short and intense rainstorms.
4. During wet periods, both saturation excess runoff over vegetated areas and subsurface flow are the dominant runoff processes operating within the catchment, generating slower streamflow responses.
5. During the wetting-up transition, the magnitude of the streamflow response is highly variable, depending mainly on the water-table level prior to the event and to a lesser degree on rainfall depth and intensity. Both infiltration excess runoff and saturation excess runoff processes can occur at the same time in different parts of the catchment.
6. Sediment sources are concentrated in a few places, mainly in areas adjacent to the main channel. In contrast, the slopes have limited geomorphic activity due to the presence of dense shrubs and grasslands, or are hydrologically disconnected from the fluvial network (i.e. bare scars of landslides)
7. The results reveal the importance of intense but infrequent events in the sediment response. Higher amounts of suspended sediment are found to be exported during spring and autumn, when the catchment is hydrologically more active, confirming the strong influence of runoff on sediment transport.
8. At the flood event, the analysis of SSC-Q relationships is useful for interpreting both the catchment hydrological and sedimentological behavior, confirming that during dry conditions infiltration excess runoff is the dominant process over the main sediment sources areas, whereas the wetting of the catchment causes dilution effects due to enlargement of the saturated areas, together with an increase in the base flow discharge.
9. The sediment balances for two hydrological years indicated the prevalence of solutes (48% and 61%, respectively), followed by suspended sediment (46% and 34%) and bedload (6% and 5%).

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Contact

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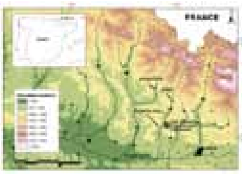
San Salvador catchment

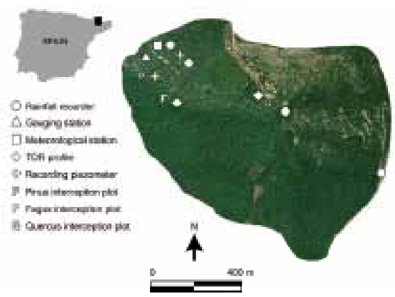
Upper Aragón valley, Spain

Basin characteristics

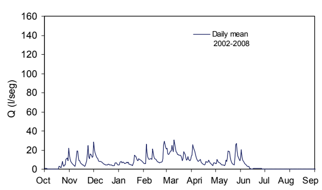
River Basin / River Basin (according EU-WFD)	Estarrún river basin/ Aragón river basin
Operation (from… to…)	Since 1998, still in operation
Gauge coordinates / Gauge datum:	42º37'51" N/0º38'33" W m a.s.l.
Catchment area:	0.92 km²
Elevation range:	878-1325 m a.s.l.
Basin type: (alpine, mountainous, lowland)	Mountainous
Climatic parameters: (mean precipitation, temperature and others)	929,7 mm (1999-2006)
Land use:	98% forest, 1% shrubs, 0% grass, 1% bare soil
Soils:	Regosols, Cambisols, Kastanozems and Phaeozems
Geology:	Eocene flysch
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Limestones
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0.0 l/s, 6,45 l/s, 1200 l/s

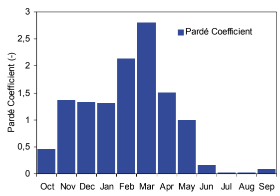
Map of the research basin





Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

The entire catchment is covered by a dense forest of *Pinus sylvestris*, *Fagus sylvatica* (in the shady concavities) and *Quercus gr. faginea* (areas with a sunny aspect). Soils are relatively deep (generally in excess of 50 cm), more in the shady than in the sunny aspect, where some evidence of old agricultural activities appears, particularly in the lowest part.

Few contrasts can be found between the north- and the south-facing slopes of the catchment.

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Stream flow	1999 – cont.	5 min	1
Precipitation	1999 – cont. 2005 – cont.	5 min Impuls/ 0.2 mm	1 2
Air temp., Air hum, wind speed, radiation	1999 – cont.	15 min	1
Groundwater level	2005, 2007 – cont	20 min	2
Soil temp.	2007 – Cont	20 min	2
Throughfall	2006 – 2007 – 2008	At event scale 2/3 month	3
Stemflow	April 2006 – 2007 – March 2008	At event scale 2/3 month	3
Soil water moisture	2008 – Cont	20 min	3

Main scientific results

1. Rainfall and runoff show a strong non-linearity during the hydrological year; streamflow response is determined by catchment moisture conditions, in particular by water-table dynamics.
2. The water table level seems to have a large influence on the discharge: the discharge of the San Salvador catchment only increases in the event of rainfall when the soil is previously saturated, that is, when the water table is close to the soil surface at the start of the rainfall event. It is interesting to note that the water table level undergoes intense fluctuations, with sharp falls once rainfall has ceased.
3. The rainfall events at the beginning of the hydrological year (autumn) produce no or only a very limited hydrological response in the catchment, even though they are relatively intense. This should be attributed to the exhaustion of the water reserves by the previous dry period and the high water consumption by vegetation.
4. The only high flow period in San Salvador arises in spring and coincides with the long rainy period with continuous rainfall from the season.
5. There is no discharge increase in the San Salvador catchment at the end of the hydrological year.
6. The discharge responses to rainfall events are very variable, in the range 0 to 1300 Ls^{-1} km^{-2}, and are not related to the volume or intensity of rainfall.
7. Most sediment exported from the San Salvador catchment is in the form of solutes (75% of the total), and the rest is suspended sediment. There is no bedload.
8. Throughfall (the precipitation that falls directly to the ground) is important in the basin of San Salvador due to the dense cover of forest. Throughfall depends on the type of tree and on the season. In summer it represents 71,7 % of the rainfall under beech, whereas in winter it increases up to 83% under the same type of tree ; 81,85 % under oak and 82,19 % under pine. Such differences are related to the percentage of coverage of each one of the species in every season of the year. Thus, in summer the coverage in the beech plot is 95 %, in the oak plot is around 73 % and in the pine plot is slightly lower, 54 %. In winter the coverage in the decidious tree plot is only 49% and in the oak plot is 40%. Pine cover remains relatively stable the whole year and therefore throughfall does not show seasonal differences. Although oak coverage decreases in winter, througfall under oak remains more or less stable during the whole year.

Key references for the basin

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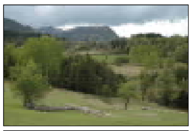
Vallcebre research basins

Vallcebre (Eastern Pyrenees), Spain

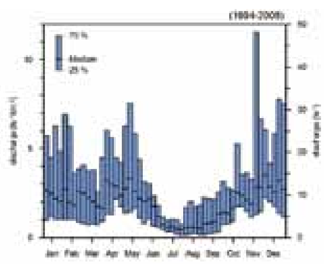
Basin characteristics

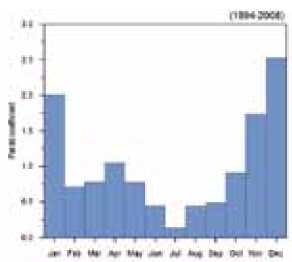
River Basin / River Basin (according EU-WFD)	Saldes river basin / Llobregat river basin
Operation	Since 1991, still in operation
Gauge coordinates / Gauge datum:	402948;4672832 UTM (31n) / 1104 m a.s.l.
Catchment area:	0.56-4.17 km^2
Elevation range:	1104-1643 m a.s.l. (mean = 1299 m a.s.l.)
Basin type:	Mountainous
Climatic parameters:	Sub Mediterranean climate . 862 (1983-2006), 90 rainy days per year, snowfall less than 5% / 9.1ºC
Land use:	60 % Scott Pine, 21% meadows, 9% sparse vegetation, 7% bedrock outcrop, 3% bad-lands
Soils:	Silt loam, silty clay loam / soil thickness: 0 to 3m
Geology:	Limestones, mudstones
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Shallow aquifers, ± connected / perched with respect to regional aquifer
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	0 ls^{-1}km^{-2}, 1093 ls^{-1}km^{-2} , 7 ls^{-1}km^{-2} (daily values, 1994-2008)

Map of the research basin



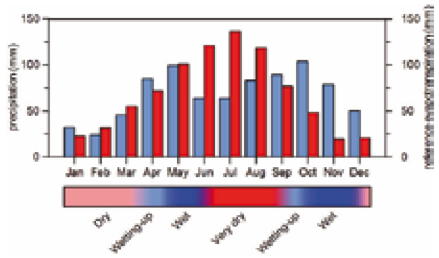
Mean hydrograph / Pardé flow regime





Special basin characteristics

Mean monthly rainfall (blue) and reference evapotranspiration (red). The dynamics of rainfall and evaporative demand during the year cause the succession of dry and wet periods separated by wetting-up phases.



Instrumentation and data

Measured hydrological Parameters	Measuring period	Temporal resolution	Number of stations
Precipitation	1982-1989 1989-cont.	Daily 0.2 mm	1 2-10
Meteorological variables	1989-cont.	5min	1-2
Stream flow	1991-cont.	2min/20min	3-4
Suspended sediment concentration	1995-cont	Automatic samplers 2min	3
Soil water content (0-80cm, TDR)	1994-cont	weekly	6-9 profiles
Soil water tension	1996-1999	10 min	2 profiles
Groundwater level	1994-2003 1995-2006 2006-cont	Weekly 20 min 10min	1 3 20
Rainfall interception	1993-2003 P. Sylvestris 2004-cont Q. Pubescens	5min	1 (9 troughs) 1 (6 troughs)
Trees transpiration (sap flow)	1994-2000 P. Sylvestris 2003-2005 P. Sylvestris 2003-2005 Q. Pubescens	15 min	1 (7 trees) 1 (12 trees) 1 (12 trees)

Applied models

1. Shetran, 2. Topmodel, 3. Topkapi , 4. Sacramento, 5. Kineros

Main scientific results

1. Rainfall interception in forests represents up to 24% of annual precipitation, and is especially efficient during both long rainy periods under atmospheric wet conditions and shorter rainfall events of moderate intensity under atmospheric dry conditions.
2. Soil moisture shows a temporal pattern characterised by significant and frequent changes and by the occurrence of marked deficit periods in summer and, eventually less pronounced, in winter.
3. The overall response to water deficits of Scots pine and Pubescent oak is similar, but Scots pine is more sensitive to soil drought, reducing markedly its transpiration during dry summer periods.
4. The rainfall-runoff relationship at the basin scale is strongly non-linear along the year. Above a given threshold, the water table position can influence the rainfall-runoff relationship. Finally three types of characteristic hydrological behaviour with different dominant runoff generation processes happen during the year.
5. Suspended sediment concentrations are very low in waters coming from vegetated areas but very high in basins with badlands areas. The seasonal pattern of erosion processes in badlands areas is characterised by physical weathering during winter, severe regolith breakdown during spring, intense erosion in summer, and efficient transport in autumn.
6. Tests performed with several types of hydrological models demonstrate their capacity to simulate accurately basin response during wet periods, but also stress the need of an increased model complexity to simulate properly runoff events during summer and wetting up periods and to improve the overall basin water balance.

Key references for the basin

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IACETH

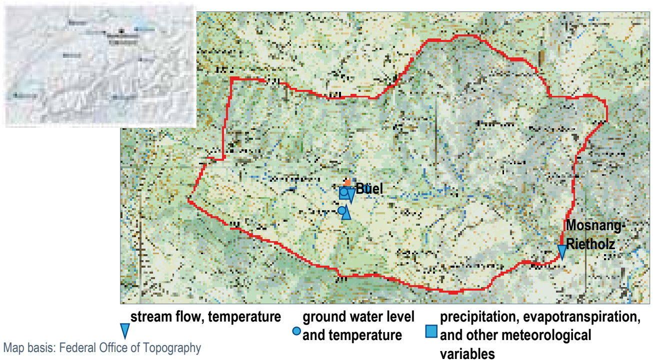
Mosnang-Rietholz

Rietholzbach basin, Switzerland

Basin characteristics

River Basin / River Basin (according EU-WFD)	Thur river basin, Rhine river basin
Operation (from… to…)	since 1976
Gauge coordinates / Gauge datum:	9°0' E; 47° 22'N / 682 m a.s.l.
Catchment area:	3.31 km^2
Elevation range:	682 – 950 m a.s.l.
Basin type: (alpine, mountainous, lowland)	pre-alpine
Climatic parameters: (mean precipitation, temperature and others)	1459 mm, 7.1 °C (1976-2007)
Land use:	73 % pasture land, 24% wood (mainly coniferous forest), 2% settlements, roads, 1% wetlands
Soils:	Cambisol, Regosol, Gley soil
Geology:	'Nagelfluh', sandstones, marl, limestone, gravel pockets
Hydrogeology: (Type of aquifers, hydraulic conductivity)	heterogeneous system of interconnected aquifer layer in the Upper Freshwater Molasse
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	annual means: 67.4, 145, 106 l/s (1976-2007) absolute min-max: 2 – 12044 l/s

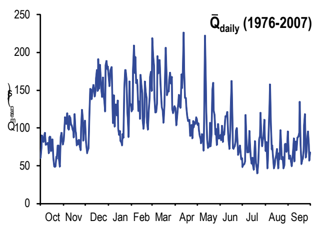
Map of the research basin

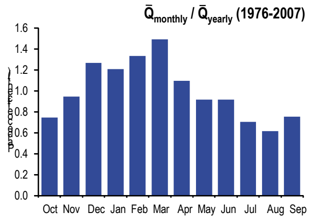


Map basis: Federal Office of Topography

There are two measurement sites:
•Mosnang-Rietholz – the main gauge at the outlet of the catchment which is operated by the Federal Office for the Environment, Hydrology Division, Bern, Switzerland,
• Büel – our site where most of the measurements are carried out.

Mean hydrograph / Pardé flow regime





Special basin characteristics (hydrogeology, lakes, reservoirs etc.)

Human impact by artificial drainage systems and wells for water supply.

Wetland next to the uppermost part of the creek, but no stagnant water.

The hydraulic conductivity of the soils ranges between $1 \cdot 10^{-5}$ to $5 \cdot 10^{-4}$ m s^{-1}. To pass the lysimeter, i.e., a soil column of 2.5 m of gley-cambisol takes ~6 months.

Based on a ^{18}O analysis the mean residence times have been estimated:
The residence time in the Upper Freshwater Molasse, which are particularly located at the slopes, is ~1 year, which is identical to the surface base flow at the catchment outlet.
The Quaternary glacial sediment layers in the bottom of the valley have a buffering effect. E.g., at Büel the mean residence time is ~2 years.
The residence time depends strongly on the hydraulic conductivity of the soil and the aquifer as well as on the slope.

Instrumentation and data

Measured parameters	Measuring period	Temporal resolution●	Remarks
Stream flow / temperature	1976 – cont. 1993 – cont. 1995 – cont.	5'	@Rietholzbach-Mosnang small tributary @Büel upper creek @Büel (w/o temperature)
Precipitation	1976 – cont.	5'	2x @1.5m, 2x @0m
Snow height	2000 – cont.	5'	
Evapotranspiration	1976 – cont. 2009 – cont.	5' 10 Hz	by a lysimeter by EC @ 2, 5.5, 9m
Discharge	1976 – cont.	5'	by a lysimeter
Ground water level/temperature	1996 – cont. 1998 – cont.	60'	@Büel 2x @Büel (north-, and south slope)
^{18}O isotopes	1994 – cont.	~bi-weekly	7x (precipitation, soil water, ground water, stream water)
Radiation	1989 – cont. 1997 – cont. 2001 – cont. 2006 – cont. 2008 – cont.	5'	short-wave incoming radiation short-wave outgoing radiation sunshine duration long-wave radiation direct-diffuse short-wave radiation
Air temperature/ humidity	1976 – cont. 2009 – cont.	5' 10 Hz	2x @2m by EC @ 2, 5.5, 9m
Wind speed	1976 – cont. 2009 – cont.	5' 10 Hz	1976 – 2008 @2.5m 2003 – cont. @10m by EC @ 2, 5.5, 9m
Wind direction	2000 – cont. 2009 – cont.	5' 10 Hz	@10m by EC @ 2, 5.5, 9m
Pressure	2001 – cont.	5'	
Soil temperature	2000 – cont. 2009 – cont.	60' 10'	@-5, -10, -20, -40cm @-5, -15, -25, -35, -55, 80, 110cm
Soil heat flux	2000 – cont. 2009 – cont.	60' 5'	3x @-5cm 3x @-5cm
Soil moisture	1994 – cont. 2009 – cont.	60' 10'	2x @-5, -15, -25, -35, -55, 80, 110cm 4x @-5, -15, -25, -35, -55, 80, 110cm
Sensible, latent, CO_2 flux	2009 – cont.	10 Hz	by EC @ 2, 5.5, 9m

● The resolution changed over time. Generally up to 1996 it was hourly.

Applied models

WaSiM-ETH PREVAH TRAIN BROOK90 TOPMODEL BOWAM DIFGA

Main scientific results

1. (Further) development/validation of models based on catchment data is successful, particularly for WaSiM-ETH and PREVAH.
2. Mean annual water balance derived from lysimeter data (1976-2007): 1459 mm precipitation, 1016 mm discharge, 560 mm evapotranspiration
3. Interflow is the dominating runoff component.
4. Runoff of summer flood events consists mainly (50-80%) of pre-event water.
5. Mean residence time in the catchment is up to 2 years.

Key references for the basin

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Butenya river

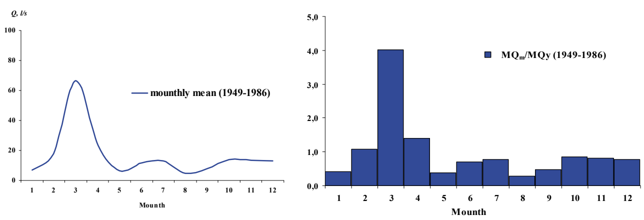
Butenya basin, Ukraine

Basin characteristics

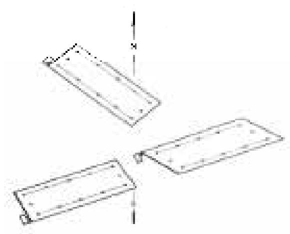
River Basin / River Basin (according EU-WFD)	
Operation (from… to…)	Since 1947, still in operation
Gauge coordinates / Gauge datum:	30,97 ⁰ E; 49,65 ⁰ N
Catchment area:	70.3 km^2
Elevation range:	130-219.1 m a.m.s.l.
Basin type: (alpine, mountainous, lowland)	Lowland
Climatic parameters: (mean precipitation, temperature and others)	537 mm (1949-1986), 7.0 ^{0}C (1949-1986)
Land use:	7 % Wood, 3 % meadow, 74% ploughed field, 16% settlement
Soils:	Podsolic chernozems and gray timbers
Geology:	Sandstones, wood and marl loams, granites
Hydrogeology: (Type of aquifers, hydraulic conductivity)	Upper aquifer in lower layers of water-glacial sands, the main aquifer - in sands of poltavski tier and in the rifts of crystalline rocks
Characteristic water discharges: (Q_{min}, Q_{max}, Q_{mean})	16.6 l/s ($Q_{mean,}$ 1949-1986)

Map of the research basin

Mean hydrograph / Pardé flow regime



Special basin characteristics (hydrogeology, lakes, reservoirs etc.)



Scheme the runoff-plots in the basin of the Butenya river

Instrumentation and data

Measured hydrological parameters	Measuring period	Temporal resolution	Number of stations
Runoff	1949 – 1986 cont. 1986 – incont.	Grapher 2 time in mounth (since 1976)	3
Surface flow	1949 – cont.	Daily	2 – 6
Water level	1949 – cont.	Daily at 8 & 20 h	3
Precipitation	1949 – cont.	Daily at 9 & 21 h	8 – 17
Undergrground water level	1948 –1986	5 & 10 time in month	7 – 30
Air temp., humidity, wind	1949 – cont. 1955 – cont.	8 time in day	1
Soil humidity	1949 – 1986	3 time in month	6-12
Soil evaporation	1948 – 1986	Daily (May-Nov)	1

Applied models

1. Balance methods 2. GIS PCRaster

Main scientific results

1. The information about the conditions of the forming of the maximum, minimum, seasonal and mean annual runoff from the small catchments areas of the forest and steppe zones of Ukraine were received.
2. The significant influence of the local factors on forming the values of the runoff on small river basins was revealed.
3. The results of the observations for the humidity and the waters equivalent in snow and ground-soil on the forest and steppe catchments showed the differences in the supply of water on the different forms of the relief, the irregularity of the distribution of the waters on the catchments.
4. The methods of the calculation of the supply of the productive water in the surface layer of the ground and the intensities of the water yield from the snow were also designed.
5. The supplies of the water in the underlying surface of forest were calculated. It allowed to revising the forming of the water balance on the small river basins.
6. The conditions of the forming of the maximum discharges were researched, the structure and the determination of the parameters of the limiting intensity formula for the conditions when the characteristics of the declivity of the small catchments area the vastly differ the other from the other were revised.
7. The research of the processes of the sorption of water in the soil, of the infiltration abilities the different ground-soils, the detentions of water in the soil and the determinations of the general losses depending on the preceding conditions, of the processes the water erosion were carried out the experimental researches in the conditions of the experimental sprinkling of the runoff-plots.
8. The experimental studies of the migration of the radioactive substances after the Chernobyl accident were made. It was allowed to improve and develop the complex of the methods for the estimation of the structure and dynamics of dissolved in water Caesium-137 removing with water runoff
9. The antierosoin stability of the soil in the Butenya river basin with the using of the experimental sprinkling method and the GIS-technology also was researched.

Key references for the basin

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Abbreviations

BfG	Bundesanstalt für Gewässerkunde (Federal Institute of Hydrology)
BRD	Bundesrepublik Deutschland (Federal Republic of Germany)
DWA	Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (German Association for Water, Wastewater and Waste)
ERB	Euromediterranean Network of Experimental and Representative Basins
EU	European Union
EURO FRIEND	European FRIEND
FRIEND	Flow Regimes from International Experimental and Network Data
FRIEND-5	EURO FRIEND Project 5 “Catchment Hydrological and Biogeochemical Processes in a Changing Environment”
GDR	German Democratic Republic
HWRP	Hydrology and Water Resources Programme of WMO
IAHS	International Association of Hydrological Sciences
IHACRES	Identification of unit Hydrographs And Component flows from Rainfall, Evaporation and Streamflow data
IHD	International Hydrological Decade of UNESCO
IHP	International Hydrology Programme of UNESCO
ISO	International Organization for Standardization
MED FRIEND	Mediterranean FRIEND
NAS	National Academy of Sciences
OHP	Operational Hydrology Programme of WMO
PUB	Predictions in Ungauged Basins
TD	Technical document
TDWG	Top-Down Modelling Working Group of PUB
TRUMPER	Temporal Resolution impacts on Uncertainty in Model Parameter Estimation and Regionalisation
TUBS	Technical University Braunschweig
UK	United Kingdom of Great Britain and Northern Ireland
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WMO	World Meteorological Organization

ERB conferences

ERB is an open association of now 20 European countries operating and managing well instrumented experimental and representative basins for hydrological and environmental research on a long term basis.

The ERB network promotes the exchange of basin information and the cooperation in international programs as FRIEND, HELP and PUB. ERB was established in 1986 and has organised eleven biennial conferences since its beginning.

These conferences will are platform to promote the inventory of small hydrological research basins. The next conference will take place in Seggau Castle, Austria, from 5 to 8 September 2010.

Figure 19 *Rock outcrop (Vlci kameny "Wolf stones"), Czech Republic*

Aix en Provence, France		October 1986
Perugia, Italy	*"Erosion and sediment tranport"*	October 1988
Wageningen, The Netherlands	*"Hydrological research basins and the environment"*	September 1990
Oxford, United Kingdom	*"Methods of hydrological basin comparison"*	September 1992
Barcelona, Spain	*"Assessment of hydrological temporal variability and changes"*	September 1994
Strasbourg, France)	*"Ecohydrological processes in small basins"*	September 1996
Liblice, Czech Republic	*"Catchment hydrological and biochemical processes in changing environment"*	September 1998
Ghent, Belgium	*"Monitoring and modelling catchment water quantity and quality"*	September 2000
Demanovska dolina, Slovakia	*"Interdisciplinary approaches in small catchment hydrology: monitoring and research"*	September 2002
Torino, Italy	*"Progress in surface and subsurface water studies at the plot and small basin scale"*	October 2004
Luxembourg, Luxembourg	*"Uncertainties in the monitoring –conceptualisation-modelling sequence of catchment research"*	September 2006
Krakow, Poland	*"Extreme hydrological events in small basins"*	September 2008
Seggau Castle, Austria	*"Hydrological Responses of Small Basins to a Changing Environment"*	September 2010

Websites

Euromediterranean Network of Experimental and Representative Basins (ERB)
http://www.ih.savba.sk/ihp/friend5/erb7.htm

Flow Regimes from International Experimental and Network Data (FRIEND)
http://typo38.unesco.org/en/about-ihp/ihp-partners/friend.html

EURO FRIEND
http://www.euro-friend.de

MED FRIEND
http://armspark.msem.univ-montp2.fr/medfriend/

Predictions in Ungauged Basins (PUB)
http://pub.iwmi.org

International Association of Hydrological Sciences (IAHS)
http://www.iahs.info/

International Hydrology Programme of UNESCO
http://www.unesco.org/water/

Hydrology and Water Resources Programme of WMO
http://www.wmo.int/pages/themes/water/index_en.html

Department of Hydrology and Landscape Ecology at the Technical University Braunschweig (TUBS)
http://www.tu-braunschweig.de/geooekologie

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