INTERIM RESULTS

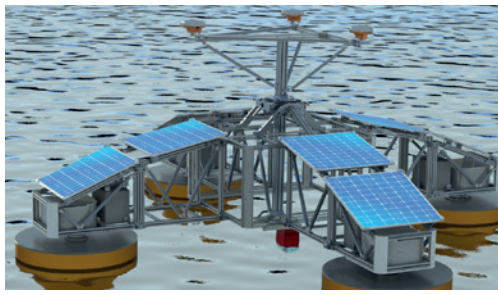
NaWaM
Sustainable Water Management
ReWaM

Regional Water Resources Management for Sustainable Protection of Waters in Germany







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FONA
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BMBF

Contents

The BMBF funding measure ReWaM

Application-oriented research for regional water resources management

REGIONAL ANSWERS TO GLOBAL CHALLENGES

Growing cities, changes in land use, pollution and the impacts of climate change: In many regions of the world, measures urgently need to be taken to safeguard the quality, availability and long-term protection of surface- and groundwater resources.

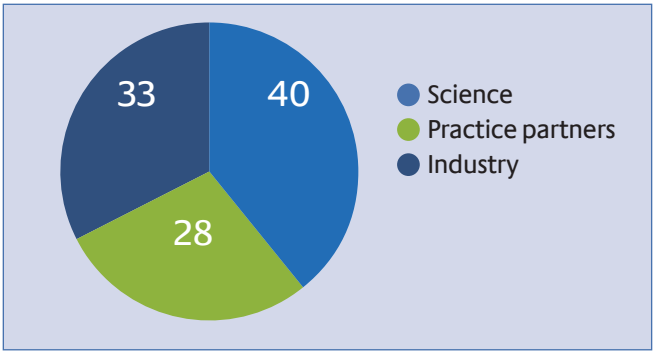
This is why one of Germany's most pressing challenges in the coming years will be the sustainable management of water resources, considering in ongoing developments in nature and society. People need water to drink, for their personal hygiene, as well as for irrigation and in manufacturing. Rivers, streams and lakes are also popular recreation areas and habitats for countless animal and plant species. However, only about 10% of the reportable water bodies currently achieve a '"good" or "very good" ecological status as laid down by the European Water Framework Directive (WFD). More than half of Germany's rivers and streams are considered to be substantially modified or even artificial. The most common causes for not achieving a "good ecological status" are dams, river straightening and a lack of ecological passability as well as high nutrient loads. Up till now, groundwater, rivers, streams and lakes in Germany have been managed primarily at the local level. Regional concepts and their implementation are still the exception in many areas. In order to achieve the targets laid down by the WFD, water management thus needs application-oriented knowledge-, information- and decision-making bases which include all regional stakeholders and the public.

RESEARCH GEARED TOWARDS PRACTICAL APPLICATION

Against this backdrop, the German Federal Ministry of Education and Research (BMBF) has launched the funding measure "Regional Water Resources Management for Sustainable Protection of Waters in Germany" (ReWaM). The BMBF is funding a total of 15 joint projects and an associated networking and transfer project. Funding of the projects will end after three years, in 2018 and/or 2019 respectively. ReWaM is part of the BMBF funding priority "Sustainable Water Management" (NaWaM) within the framework programme "Research for Sustainable Development" (FONA^3). Through ReWaM, the NaWaM topical

focus area “Water and the Environment” will be underpinned by research geared towards practical application.

ReWaM’s goal is to show how the various kinds of usage of water bodies can be reconciled with their protection, so that the diversity and environmental performance of different aquatic ecosystems can be permanently preserved. This applies not only to rural, but also to suburban and urban regions. All ReWaM projects are transdisciplinary to ensure that the results can be practically applied and to align the research and development work with the needs of users. The scientific and water management communities are cooperating closely in all the joint projects. The BMBF is supporting 101 subprojects. These are being implemented by research-, business-, and water management institutions in approximately equal measure. Other organisations and companies are also involved in the funding measure, as associated partners or via subcontracts.



Partners from science, industry and practice partners (public authorities, municipalities, national federations and administrative bodies) are taking part in the BMBF-funding measure

All projects address the diverse challenges of regional water resources management in model regions. The model regions and study sites are located throughout the entire Federal Republic of Germany. This will allow research findings to be transferred not only to other regions in Germany, but also to other European countries.

PROJECT CLUSTERS

The joint projects cover a wide range of topics with different research approaches. The four project clusters illustrate the projects’ joint remits:

- **Development and Management of Water Bodies**
  The joint projects in this cluster address integrated development- and action strategies for water resources management. The key focus is on reconciling flood risk management and the development of water bodies. Emphasis is laid on water management in urban areas including urban water development and watershed management, as well as the municipal water balance and rainwater management.

- **Monitoring of waters**
  Innovative methods for monitoring the physical and chemical parameters in surface waters are what the joint projects of this cluster have in common. Water bodies are dynamic systems and react in different ways to the input of substances and to change. To improve the way of mapping these processes, the joint projects are working on measuring devices with high spatial, temporal and content-related resolution. In addition to traditional methods, autonomous measuring vehicles are being developed.

- **Assessment Methods for Aquatic Ecosystems**
  This cluster focuses on analysing and assessing ecosystem services. The research goal is to develop new criteria as a basis for decision-making, so that groundwater and surface waters can be managed sustainably. The focus is

PROJECT CLUSTERS	JOINT PROJECTS
Development and Management of Water Bodies	In_StröHmunG KOGGE NiddaMan StucK WaSiG
Monitoring of waters	BOOT-Monitoring HyMoBioStrategie RiverView
Assessment Methods for Aquatic Ecosystems	GroundCare RESI
Water Quality Management	CYAQUATA FLUSSHYGIENE MUTReWa PhosWaM SEEZEICHEN

Allocation of the ReWaM joint projects to project clusters

on bio-indicators and on services which a water body and its adjacent areas provide and which can be used by humans.

- **Water Quality Management**
  The joint projects of this cluster study novel kinds of water pollution and develop risk assessment methods and new problem-solving strategies. The focus is on drinking and bathing water quality and on the impact pathways between ground- and surface waters. The impact on human health makes this especially relevant for society.

STEERING COMMITTEE

An associated body supports the work of the joint projects in the BMBF funding measure ReWaM: The Steering Committee is composed of selected outside experts, the heads of the 15 joint projects, and of representatives from the networking and transfer project ReWaMnet, from the BMBF and from the project management agency. The goal of the committee is to ensure the practical applicability of research and the involvement of the general public so that the research projects generate relevant new knowledge which can be implemented.

CROSS-CUTTING ISSUES

The ReWaM projects overlap with regard to their methods, research questions and the types of water bodies being studied. The ReWaM steering committee has thus defined so-called cross-cutting issues (CCI) so that existing synergies and potential can be fully exploited. To date, project overarching working groups have been formed to cover the following topics:

- **CCI 1 „Transferring knowledge into practical applications“**
  How do research results get transferred into practical applications and what do water managers need from scientists? The members of this working group are addressing these and other questions. Through knowledge sharing, it should become apparent what tools can be used to best promote the transfer of theoretical knowledge and its application.

- **CCI 2 „Sampling strategies and methods“**
  The ReWaM joint projects are recording a large number of different measurement values. The goal of this working group is to collaboratively develop strategies for measuring and analysing some of these parameters more efficiently. The focus is on, among other things, online probes, data validation methods, data management as well as recording the structure of water bodies.

- **CCI 3 „Ecosystem services in water management“**
  In the practice of water management there is a need for objective and comparable decision-making. One solution to this is the concept of ecosystem services, which the joint projects approach in different ways. The cross-cutting issue serves as the basis for the methodical exchange between the projects.

THE NETWORKING- AND TRANSFER PROJECT ReWaMnet

The funding measure ReWaM is flanked by the networking- and transfer project ReWaMnet. ReWaMnet supports the joint projects in many different ways: The focus is on strengthening the collaboration and exchange of knowledge between the joint projects as well as the transfer of solutions, new knowledge and results into practical water management. Other focal points are preparing the content and organisation of working sessions and workshops and the presentation of the funding measure to the public, for example by being present at scientific events.

The German Federal Institute of Hydrology (BfG) was assigned to implement the networking- and transfer project by the BMBF. As a departmental research institute, the BfG is traditionally involved at the intersection between science and policy and is active on various federal and state government committees. The extensive network and broad experience of the BfG are a key element to help perpetuate the insights and solutions from ReWaM and to transfer the exemplary implementation and testing of measures in the model regions to other regions in Germany.

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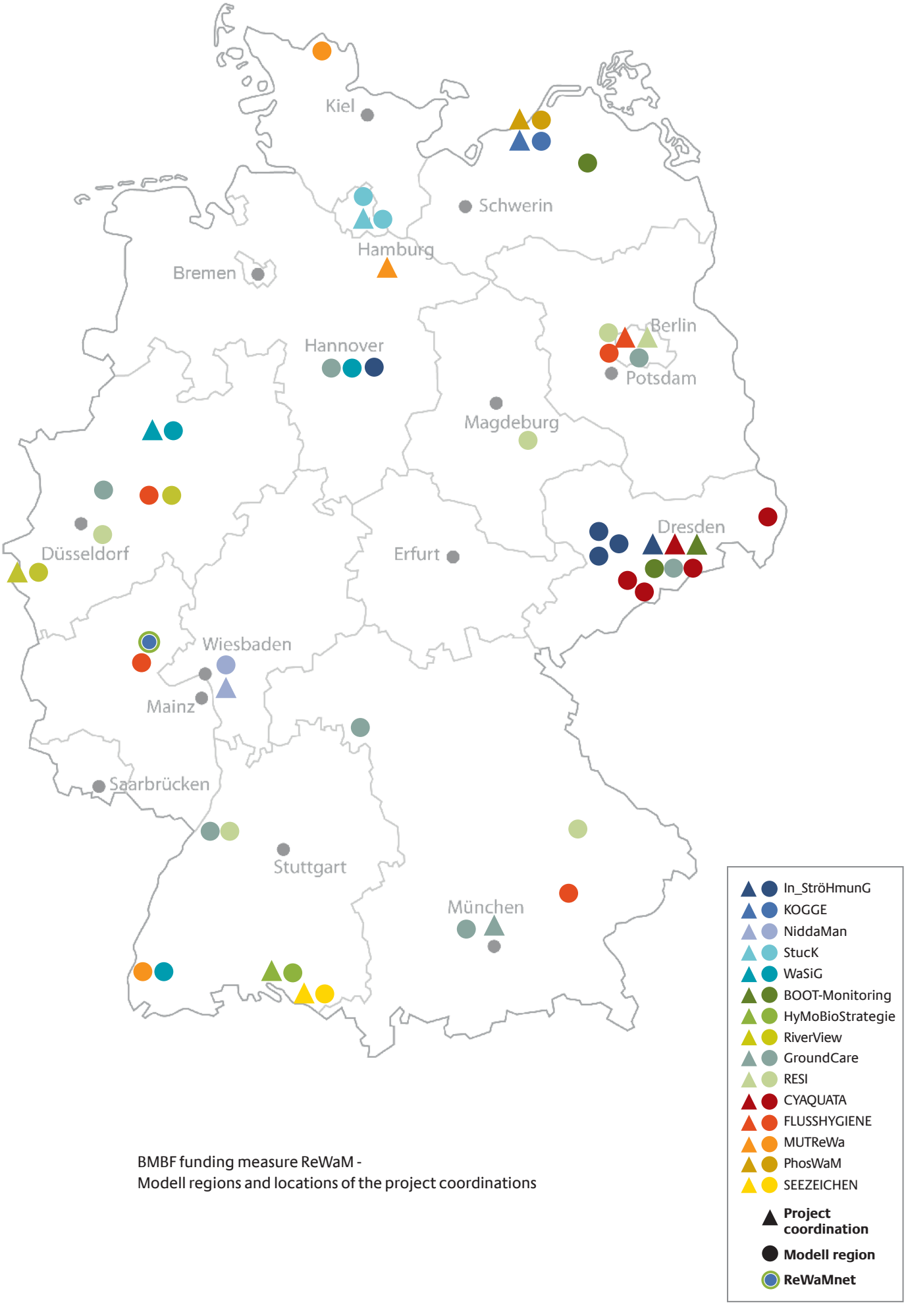
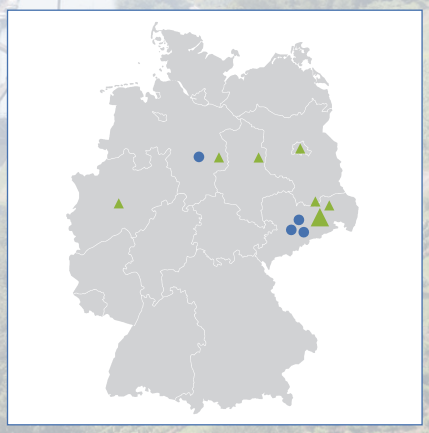


BMBF funding measure ReWaM -
Modell regions and locations of the project coordinations

Development and Management of Water Bodies

10 In_StröHmunG



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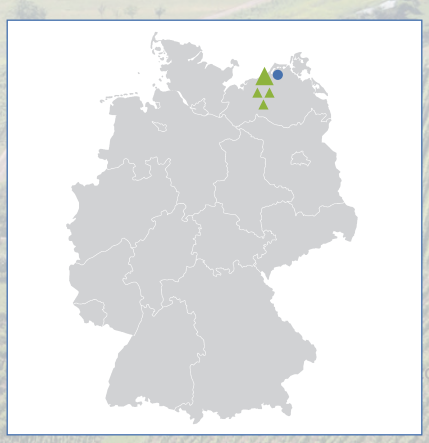

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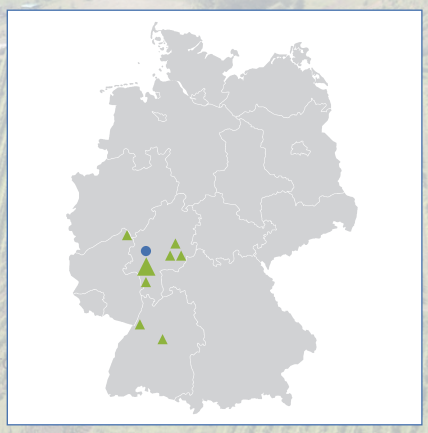

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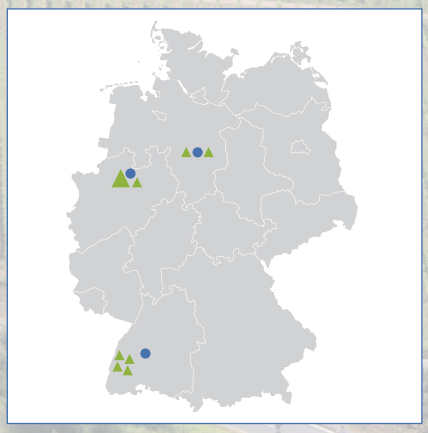

▲ Project coordination ▲ Joint project partners ● Model regions

In_StröHmunG – Innovative systems solutions for transdisciplinary and regional ecological flood risk management and natural watercourse development

RECONCILING ENVIRONMENTAL PROTECTION WITH FLOOD RISK MANAGEMENT

In 2015, towards the end of the first management plan period of the European Water Framework Directive (WFD), only about ten percent of the watercourses in Germany were rated as having a „good“ or „very good“ ecological status. Recent surveys conducted during the DWA's 16th workshop on “River Basin Management” showed that the main reason why necessary measures to improve the structure of water bodies are not being implemented is the lack of availability of land. Within the framework of the joint project In_StröHmunG, a consortium of research- and water management institutes is developing tools to manage watercourses in a manner which is sustainable and which refers to the whole river catchment. The project is focusing on measures at model watercourses which support the implementation of both the European Water Framework Directive (WFD) and the EU Flood Risk Management Directive (FRMD).

INTERIM RESULTS

In 2015 and 2016, large-scale hydro-biological sampling was performed at a total of 44 sampling sites on the model watercourses. The macrozoobenthos and the fish fauna were studied. An initial causal analysis in 2015 showed that a “good ecological status” of the sampling sites for the macrozoobenthos is achieved only in the model regions of Kohlbach and Zwönitz. At the other sites there is a decisive need for action. Academics from the field of hydraulic engineering are laying the scientific groundwork in the laboratory and in the model regions with a view to transferring new insights to other regions. In order to assess the impact of riverbank vegetation on riverbed structures, a section of the Mortelbach is being recreated on a 1:4 scale. The vegetation and riverbed substrate used were chosen in collaboration with hydrobiologists. The outcomes should enable researchers to determine to what extent ecological and flood-compatible watercourse maintenance can maintain and/or promote a beneficial environment for the macrozoobenthos and for fish.

An idealised physical model was also constructed in order to evaluate what impact building a flood channel has on flood protection and on the dynamics of riverine sediments. The construction of a flood channel usually leads to significant hydraulic and morphological changes which have an effect both on flood protection and on

Mutzschen River, Photo: N. Müller, TU Dresden

a river's ecology. For example, analysis of the biological sampling from the project area of the Aller River near the city of Celle showed that the flood channel created there provides a near-natural habitat for fish, comparable to that of natural side-arms. At the same time it became evident that local sedimentation- and erosion processes had changed due to the construction of the flood channel. These processes are being studied in an idealised physical model, also against the backdrop of changing floodplain vegetation.

During flood events sediment is often deposited in the floodplains and ridge-like deposits form along the main channel of the river. These structures, called natural levees, can become several metres high and in time can substantially impact the interaction between the floodplain and the river. In sedimentological model experiments, researchers were able to simulate the complex interplay between flow and sediment during levee formation and to identify the processes involved. The flooding height of the floodplain, for example, was found to be a key parameter influencing levee formation. The next step is to study

Taking measurements at the Mortelbach, Photo: N. Müller, TU Dresden

the impact of various forms of riverbank vegetation and of different maintenance strategies on levee formation.

An ecosystem's monetary value (benefit) can be assessed on the one hand by specifically evaluating measures and their morphological and ecological impact, on the other hand the cultural ecosystem service can be assessed through a choice experiment. In preparation for this survey, which is to be carried out in collaboration with the ReWaM project RESI, several focus group workshops and numerous interviews with experts, i.e. maintenance workers and decision-makers, were held in the village of Fremdiswalde. Analysis of these interviews showed clearly that at 2nd order watercourses, the most relevant cultural ecosystem services are biodiversity, recreation (e.g. taking walks along the river) and opportunities for playing near the water. This includes the need to ensure that accessibility to a watercourse is created and/or maintained.

In order to turn these insights into practical solutions, one of the key products of In_StröHmunG is the development of a software solution which graphically depicts planning- and implementation processes and provides instructions for implementing measures. In addition to the already integrated data, the management system PROGEMIS® consists of a basic plan, a work plan, a documentation level and a catalogue of measures, among other things. An implemented communication platform enables municipalities to involve relevant stakeholders and citizens in the implementation of development- and maintenance measures for watercourses. The first municipalities will begin testing PROGEMIS® by the end of 2016.

OUTLOOK

In addition to implementing specific measures in the model regions as well as the PROGEMIS® software, data will be collected by means of sampling and pilot projects. This data should allow researchers to draw scientifically sound conclusions on the interplay between watercourse morphology, vegetation, floods and aquatic organisms, which in turn can be applied to other watercourses. Knowledge about the synergies in ecological flood risk management and near-natural watercourse development is thus made available.

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More contacts and partners: page 48 - 49

KOGGE – Mutual development of municipal water bodies in urban areas

MEASURES FOR THE RENATURALISATION OF SMALL STREAMS

Watercourses fulfil a variety of functions in cities and communities, e.g. they serve as drainage for rainwater and thus as a protection against flooding. They are also a habitat for numerous aquatic plants and animals and enrich the urban habitat. Up till now there have been no key methods for assessing and developing all these functions in an integrated manner. This is especially true for small flowing- and standing water bodies as well as for wetlands. While very precise specifications exist for assessing the ecological status of e.g. larger rivers and standing water bodies, reporting on small water bodies is not mandatory and thus these are not documented. The Hanseatic city of Rostock (model region) has more than 200 km of smaller watercourses such as streams and ditches. It also has almost 400 standing water bodies and a 600 km long sewer system. For these bodies of water, the project partners want to develop a city-wide, strategically-oriented water body development concept and implement it in pilot projects.

INTERIM RESULTS

Small watercourses in the city of Rostock were systematically divided into 50 metre long sections and evaluated during the project. Three basic elements were laid down for the water body development concept: drainage function, ecological function and sociocultural function.

To assess drainage function, three scale levels with different depths of detail were defined. Scale Level 1 (macro-model) enables a general overview of the entire city so that at-risk areas can be quickly identified. Based on an existing map of the actual land use, a method was developed for the largely automated allocation and parameterisation of drainage areas for the sewer system model. At the moment, Scale Level 2 is only being developed for the reference model “Schmarler Bach”. The aim here is to determine the interaction between the sewer system and the stream by means of bilateral coupling. Scale Level 3 outlines ‘focus areas’ which need to be studied in detail to improve flood protection. This is achieved by using two-dimensional flood models with high spatial resolution. With the help of a remote-controlled drone, a digital terrain model with 2 cm grid was built in a focus area. Currently, the flood model is being built using the various existing data and its cost and benefit are being compared.

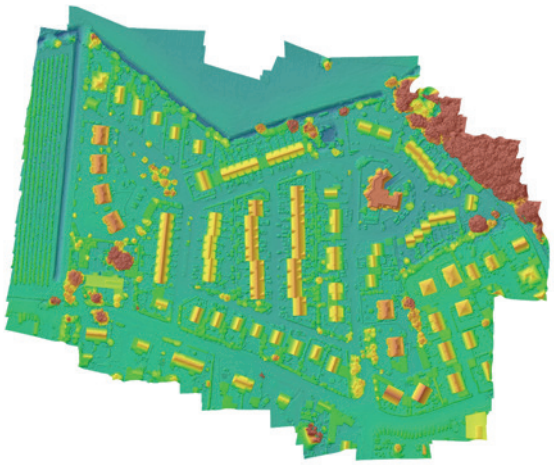
Flow measurement in small watercourses, Photo: University of Rostock

The ecological function includes determining a water body’s status and assessing its structural quality, biological status and contaminant load. All urban stream sections were inspected to determine their structural quality. Because of their often poor accessibility, standing water bodies were assessed by reviewing aerial images. The overall rating was divided into five grades. Approxi-

mately 40% of the watercourses in the city of Rostock are rated as being Grade 1 or 2 (not impacted and/or slightly anthropogenically impacted), while 36% are rated as being Grade 5 (wholly anthropogenically impacted).

For small flowing- and standing water bodies, an ecological evaluation using reference conditions which have not been impacted, as is mandated for reportable water bodies, would serve little purpose, since it would only periodically determine a poor ecological status without picking up on indications that the system might have improved.

For this reason, an entirely new approach which evaluates the ecological functionality for various guilds of organisms (e.g. sand/gravel dwellers, aquatic vegetation) was developed as an alternative. By subsequently aggregating this data in an index system, a specific index number can be obtained. However, deficits can also be correlated with probable causes, thus showing what measures need to be taken.



Generated surface model (grid width 0.02 m) based on an UAV aerial survey, Graphics: University of Rostock

The contaminant load in watercourses was a further aspect which was studied. In the “Schmarler Bach” reference model, a fixed contaminant measuring station was installed in 2016. While recording the bioindicative species, corresponding water samples were also taken which were examined in the laboratory for nutrient concentrations. As a summary assessment for the entire city of Rostock, the total load of substances removable through filtration is calculated at the entry points into the water bodies according to the DWA-A 102 (yellow print).

The sociocultural function of water bodies was assessed together with their structural quality. The evaluation was based on the water bodies’ visibility, reachability, accessibility, special characteristics and on the quality of experience they offered. The water bodies in Rostock did not score well in the overall rating. Less than 1% of the urban watercourses and less than 3% of the standing water bodies were rated as Grade 1 to 2 (very high or high).

Now that the status quo- and deficit analysis has been largely completed, the water body development concept will result in a goal-oriented selection of measures through the systematic comparison of the status quo with desired outcomes. Within this context, the availability of usable land is a critical variable in communities. All project partners thus agree that a transparent concept at the municipal level can only be achieved by means of intelligent and largely automatable GIS-analyses. The first algorithms have already been developed and tested using the “Kringelgraben” as a model.

OUTLOOK

The strategic water body development concept will be the focus of the upcoming months. The goal is to identify primarily symbiotic measures which impact various deficits and to launch them in pilot projects in selected neighbourhoods in Rostock. This now also means increasingly involving the general public, whether by informing people about the insights gained thus far and subsequently asking for their suggestions, or by directly debating measures. To this end, usage of the project website and the citizens’ participation platform “HRO-Klarschiff” is to be intensified.

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NiddaMan

NiddaMan – Development of a sustainable water resources management using the example of the Nidda catchment

Panelists at a „NiddaTalk“ citizens’ information evening, Photo: S. Ziebart, University of Frankfurt

SCIENTISTS AND WATER MANAGERS ARE WORKING TOGETHER FOR CLEAN RIVERS IN HESSE

Numerous conflicts of use characterise the Nidda catchment area in the German state of Hesse, making it in many ways representative for anthropogenically influenced rivers in central Europe. The goals of the NiddaMan project partners are to develop new methods for monitoring trace substances and evaluating their suitability for practical application, to analyse stressors on biodiversity using biological test methods, and to refine sustainable water resources management strategies while factoring in insights from socio-ecological research. By pooling the collective data, one objective is to build the web-based information- and management system NiddaPro for water authorities to use. It serves as a basis for more sustainable water resources management of the Nidda River and can be a model for other catchment areas.

INTERIM RESULTS

In the first phase of the project, a multi-substance analysis method was established to quantify approx. 150 chemical agents and transformation products. The next step was to optimise existing non-target analysis methods for use in identifying sources and monitoring water bodies. Initial monitoring campaigns were thus able to track specific discharges from pool operators, agriculture, industry and sewage treatment plants. Researchers were able to detect previously unknown water body-specific trace substances and potential input sources, including the substance o-tolylbiguanide originating from a sewage treatment plant. Further chemical analyses indicated that levels of the herbicide metamitron and the antidepressant venlafaxine exceeded the effect threshold in the Nidda River, thus posing a potential risk to endemic species. The toxicity of river sediments increases from river up- to downstream areas. In laboratory tests, this is reflected in a decreasing reproductive performance in freshwater shrimp, snails and worms. Under field conditions, on the other hand, the reproductive rate of snails and freshwater shrimp is significantly higher, which may indicate that the aqueous phase contains substances that promote reproduction. In an embryo test with the zebrafish *(Danio rerio)* in the laboratory, researchers tested water-sediment-combinations from the Nidda catchment for fish-toxic effects. Samples from the rivers Nidda and Horloff led to delays in development and a low

hatching rate, among other things. Rainbow trout were put into the river Nidda in fish cages and removed again after seven weeks in order to extract blood, liver, gonads, brain and filets. Electrofishing was also carried out twice. Chub and loach were the primary target species, with brown trout and gudgeon used as substitute species. Biomarker- and residue analyses are currently being carried out.

The project partners also carried out calculations for the entire catchment area of the Nidda using the water balance model LARSIM. For the rivers Usa and Horloff, detailed areas were extracted and discharges from sewage treatment plants were amended. Data gaps were filled with simulation calculations. Future model calculations will depict the detailed areas using model systems with higher spatial- and temporal resolution. Discharges from sewage treatment plants in the catchment area were modelled using the software MoRE. The proportion of discharge from sewage treatment plants relative to the mean total discharge into the river is approximately 20% at the catchment outlet, while the proportion of cumulative nitrogen- and phosphorus loads on the total load in the river is approximately 42% and 84%, respectively (mean value 2010-2014). A water quality module is currently being designed.

The operating parameters of sewage treatment plants in the Nidda catchment area were recorded and evaluated. For selected wastewater parameters, target values were determined on the basis of which water body-specific threshold values were defined for the discharges from the respective sewage treatment plants. Process engineering measures to reduce the emissions from sewage treatment plants and combined sewer overflows were assessed. Selected wastewater key parameters served as the basis for calculation of threshold values for regional effluent discharge, synergy effects and operating costs to reduce emissions originating from treatment plants and sewer overflows. The procedures assessed form the basis for a modular system which is currently being designed and which in turn serves as the basis for modelling various different scenarios. A guideline for interviews was developed to overcome structural barriers in applied water management. Simultaneously, a regional workshop with representatives from the Hessian water authorities was held. The project's initial outcomes were presented to the public during a citizens' information evening. A social-ecological analysis of the history of the Nidda's usage and of conflicts surrounding the river showed that in the past, decisions to implement regulatory measures on the river had been characterised largely by crises, the prevailing balance of power, a "zeitgeist" distinguished by a belief in technology, and other factors (including population growth and growing areas for housing). In the stakeholder workshops, groups of stakeholders drafted proposals for reducing opposition to the implementation of measures. In addition, the internet platform „NiddaLand" went online at www.niddaland.de.

Schoolchildren studying a river ecosystem during the „NiddaLife" activities day (September 2016), Photo: S. Ziebart, University of Frankfurt

OUTLOOK

The project is currently planning to:

- Evaluate substance discharges
- Determine critical thresholds for Nidda-relevant pollutants
- Analyse the impact and scope of water management measures (e.g. renaturations, sewage treatment plant improvements)
- Simulate substance levels and scenarios
- Carry out interviews and workshops with water authorities, stakeholders and citizens

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StucK – Safeguarding drainage in coastal urban areas while factoring in climate change

FORWARD-LOOKING WATER MANAGEMENT IN COASTAL URBAN AREAS WHILE FACTORING IN CLIMATE CHANGE

In coastal urban rivers, runoff is often compromised by backwater due to the tide – with a negative impact on inland drainage. A high tide low water due to storm surges extends the period of tide locking. This type of event has a considerable impact, especially in combination with inland flooding caused by heavy local precipitation. The goal of StucK is to analyse the hydrological interrelationships of these events and their impact as well as to develop suitable management strategies for the affected rivers. These will be investigated due to the context of ecological and economic consequences. The outcomes from planning- and management activities are to be integrated into the operational activities of the public authorities, e.g. the "Agency of Roads, Bridges and Water" in the city of Hamburg.

INTERIM RESULTS

The work in StucK began in 2015 with the detailed recording of the hydrological systems in two selective model regions, Kollau and Dove-Elbe. First their usage, topography, drainage structure and control elements were analysed in detail. The Kollau model region, a relatively small catchment area (32 km²), is characterised by a large number of control elements (including 23 reservoirs). Partly dense urban development leads to a high degree of soil sealing, so the Kollau River and its tributaries respond very quickly during heavy precipitation events.

The Dove-Elbe model region is the Hamburg part of the Dove-Elbe River's catchment area (approx. 160 km²). The model region has a very complex drainage system of weirs, locks and pumping stations. Dense urban development alternates with rural settlement structures and agricultural use. The river and its tributaries respond markedly slower to precipitation events than the Kollau River does. Water levels usually rise only after several hours of heavy precipitation. The Dove-Elbe River flows into the Tide-Elbe River, natural (gravity-) drainage can occur only at low tide.

In the StucK project, the region's management is based on precipitation nowcasts which are made for a forecast period of up to 60 minutes ahead. One precipitation value is determined per grid cell (1x1 km) per minute. Radar echoes from the German Meteorological Service four radar locations in Northern Germany are combined to form a radar image, which serves as input data. The radar data is corrected online, i.e. ground clutter and calibration errors are removed. Within the framework of the StucK project, the computed nowcast is processed using the KalypsoHydrology modelling programme, among others, with the aim of determining runoff in the region from precipitation forecasts in an operational way. The processed and corrected radar data are also made available to the ReWaM project KOGGE.

Ultimately, a hydrological numerical model is created for each model region using KalypsoHydrology in order to determine the rivers' runoff and automatically incorporating the precipitation forecasts. The models are used to carry out scenario-based analyses as a starting point for better land management and to optimise the operation of storage- and retention systems. Vegetation and soil were studied in the model regions so that ecological functions could be assessed in their current status and after river management policies had changed. For example, researchers studied the potential development of vegetation in a reservoir after its retention function had been restored. The experiments show that a typically moisture-loving vegetation is likely to develop. Pedological analysis revealed that gley is the dominant soil type. There is more wet gley in damp locations and limonite gley in better-ventilated locations. Soil horizons which had been significantly disturbed, mainly through deposits and shifting, were also found. The analysis of sediments from reservoirs in the Kollau model region partly uncovered pollutant loads which prevent their unrestricted use. In order to record the *in situ* soil water budget, representative sites on the floodplain have been equipped with instruments, thus allowing the soil's water content and -tension to be measured with high temporal resolution. The soil's physical and chemical parameters are currently being analysed.

Landscape of marshes in the catchment area of the Dove-Elbe model region, Photo: www.aufwind-luftbilder.de

At the moment, economic assessments of flood management concepts are focusing on how competing usages and the scarcity of land in urban areas is evolving. For the most part, this pertains to the usage components of land used for housing developments or road construction. In the city of Hamburg this increased by 5.4% between 2000 and 2014, to a percentage of approximately 60% of the city's total surface area. Accompanied by an intensification in usage and by soil sealing, this trend is expected to strengthen, especially in the Dove-Elbe model region. Various ecosystem services such as carbon sequestration are also being identified. In this context, reference values from other studies are being collected in preparation for using the benefit transfer methodology.

OUTLOOK

The following key steps will be implemented before the completion of the project:

> Implement tidal range, regulation- and control elements in the hydrological numerical model KalypsoHydrology
> Calculate scenarios and economic/ecological assessment for optimised land management
> Analyse and evaluate German Weather precipitation forecasts, link with radar-ensemble-nowcasts which have been extended to 120 minutes
> Ensure the transferability to similar areas, practical implementation

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project duration: 01.04.2015 – 31.03.2018
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WaSiG

WaSiG – Water balance in urban areas: planning tools and management concepts Water Monitoring

WHAT TO DO WITH STORMWATER RUNOFF?

Stormwater runoff used to be drained into the sewer system, but nowadays it is preferable to let it infiltrate into the ground, to let it evaporate or to delay the drain off. This paradigm shift in water management aims at the positive effects of rainwater: it has great potential in improving urban climate as well as the cityscape itself, protecting the groundwater as well as managing stormwater runoff more efficiently. Appropriate measures for managing stormwater can include e.g. rainwater harvesting and -storage, green roofs or pervious pavements. The broad concept behind it is water sensitive urban design (WSUD), which aims to reduce runoff and peak flow and minimise drainage infrastructure and development costs.

INTERIM RESULTS

In the German cities of Freiburg, Münster and Hanover, typical districts with WSUD are chosen as study areas. Climate data, soil properties and the inflow- and runoff behaviour of stormwater have been analysed at selected sites; some of the data was continuously measured, some event-based. Data is collected on green roofs, in swales, in infiltration trenches and on pervious pavements. Swales are broad shallow channels covered by grass or other suitable vegetation in order to convey and store stormwater runoff. An infiltration trench is a swale in combination with additional subsurface storage filled with gravel or other geocellular modules, which enables the water to be stored and conveyed under the ground as well as exfiltrated into surrounding soils.

In addition to collecting data in urban districts with existing source control measures, pilot plants were constructed in the city of Münster: various set-ups of green roofs, swales, infiltration trenches and pervious pavements are analysed with evapotranspiration and the effect on urban climate as one of the main aspects of the monitoring scheme. Parameters considering evapotranspiration (rain, temperature, humidity, wind direction, wind velocity, radiation) are continuously recorded at selected sites. Furthermore, a mobile climate station was developed within WaSiG, which is recording high-resolution micro-meteorological data at different sites in the three cities. In addition to the monitoring programme, the project participants analysed already existing data on urban water balance in order to compare the hydrological scheme with the water balance of the pre-developed state. The declared goal is to maintain the urban water balance as similar as possible to the natural water balance by using appropriate measures.

At the Leonardo-Campus, Dr. Malte Henrichs and Isabel Scherer of IWARU analyse the potential for evaporation and the water storage capacity of green roofs with different types of substrate, among other things, Photo: FH Münster/Pressoffice

It is not only essential to implement measures on a technical level, but also to achieve social acceptance of WSUD in urban areas. Therefore, 18,000 questionnaires developed in correspondence with recent findings in social science were distributed in multiple districts of Freiburg, Münster and Hannover characterised by different housing schemes with varying social and economic backgrounds. With the questionnaire, the scientists try to get an insight into the level of acceptance considering positive and negative experiences of residents with stormwater control measures. An initial review of the responses, collected from the municipalities involved, indicates that WSUD planning has been implemented with varying degrees of intensity during the last decades. This is mainly due to maintenance and operational costs of

the systems, demand for land, and municipal policy requirements.

OUTLOOK

The data from Hanover, Freiburg and Münster will be managed and validated using OSCAR (Online Supervisory Control and Data Acquisition System with R) and will then be used as input data for urban hydrological models. Based on the research outcomes, the joint project partners are enhancing their simulation models to calculate the urban water balance. The aim is to provide the relevant authorities and engineering companies with effective planning instruments for WSUD.

Analysing the questionnaires from the selected districts of the three cities cooperating with the project will provide information on how the population deals with different stormwater control measures. The survey results will actively influence recent discussions in urban planning and participatory processes. In order to implement WSUD, municipalities need to know in advance what degree of planning effort and costs are associated with it.

Green roofs can be implemented with different substrates and plants, Photo: FH Münster/Press office

Merle Koelbing, research assistant from Freiburg University, with her mobile climate station designed specifically for WaSiG, Photo: P. Seeger

The outcomes of WaSiG can support municipalities aiming to:

- Reduce pressure on sewer systems during heavy rain events
- Improve flood safety by delaying runoff
- Increase infiltration of precipitation and thus reduce surface runoff
- Support the regeneration of groundwater
- Improve the landscape and/or cityscape through green-blue infrastructure
- Offer flora and fauna alternative habitats through green spaces
- Promote evapotranspiration to improve the microclimate due to absorbing dust, and lowering temperatures due to vegetative cooling effects
- Make water a design element of urban life

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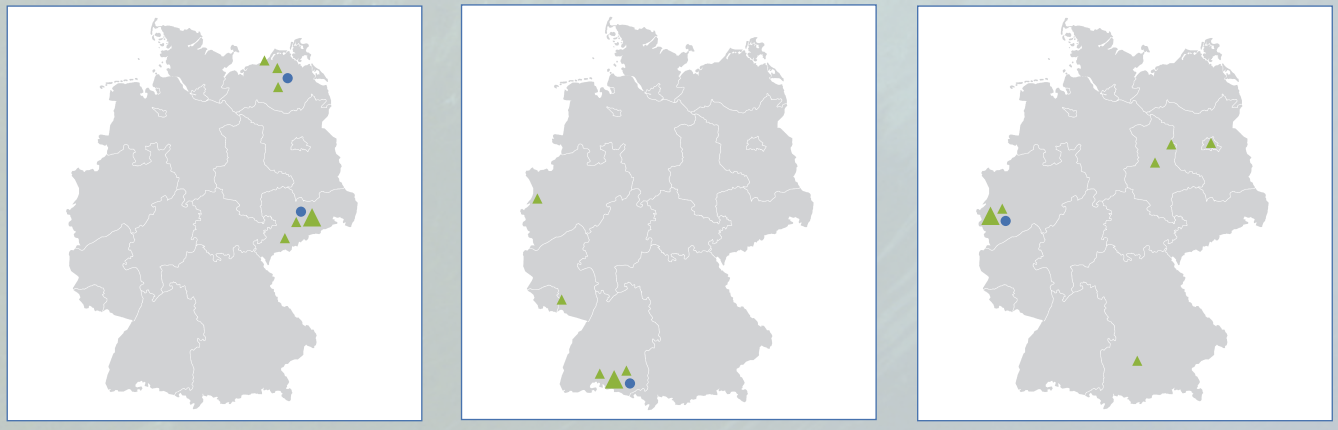
Monitoring of waters



BOOT-Monitoring – Boat-based measurement system to map the longitudinal morphometry, water quality and hydrology profiles of rivers as part of an integrated river monitoring system

Monitoring boats in use: towing convoy on the Freiberger Mulde, Photo: C. Koch, TU Dresden

Motor boat during collaborative measurement campaign, Photo: W. Klehr, University of Rostock

CONTINUOUS MONITORING OF RIVERS BY BOAT

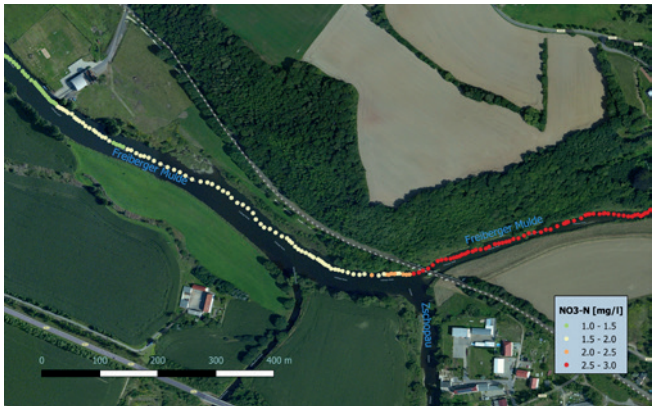
All water bodies in Europe must achieve a good environmental and chemical status by no later than 2027. That is the stated goal of the European Water Framework Directive (WFD). In order to evaluate the current status of water bodies and plan interventions, extensive measurement- and evaluation programmes are necessary. In rivers, the water quantity and -quality is measured only at specific sites which are representative for a section of the river. This data is interpolated so that a river's properties and its status between the individual measuring sites can be assessed. During this process, difficult to verify assumptions need to be made about how data values may change. The goal of the joint project BOOT-Monitoring is to describe the status of small and middle-sized streams and rivers in Germany in a more differentiated and reliable manner. A boat with online sensors continuously collects data on parameters characterising the water quality, channel morphometry and hydrology of a river along its course.

INTERIM RESULTS

During the project's initial phase, researchers developed prototypes for two different types of rivers: The team from the Technische Universität Dresden focused on a river in the uplands, while the University of Rostock team designed a monitoring system for a lowland river. In preliminary tests the project partners identified sections of the test river which were relevant and navigable by boat. A section of the Freiberger Mulde River downstream from the city of Nossen was found to be suitable. It is characterised by low water levels in some places and is not always passable due to hydropower- and industrial plants. A 28 km long section of the river Tollense between the villages of Klempenow and Demmin in the German state of Mecklenburg-Vorpommern was also selected, because it too is suitable for biological monitoring and can be navigated along its length. The Tollense River is a typical lowland river which is characterised by fairly steady water levels, low flow velocities and in some

sections dense submerged vegetation. The centrepiece of the prototype developed during the first half of the project is the Acoustic Doppler Current Profiler (ADCP); all the other online measuring equipment was assembled to its carrier boat. Together with the ADCP, an ultrasonic wedge-shaped sensor is used to determine the river's depth and flow velocity. In addition, a magnetic inductive flowmeter was used to measure the flow velocity, particularly in shallow zones. To determine the river's width, two laser distance metres are used which measure the distance between the boat and the shore line. The carrier boat also accommodates a spectrometer probe and a multi-parameter probe to record water quality parameters and is towed by a manned inflatable dinghy.

Many monitoring trips were carried out in the spring and summer of 2016. The following figure shows, for example, how nitrate levels change along an approximately 1 km long section of the Freiburger Mulde near the confluence of the river Zschopau (direction of flow NW). It is clearly evident that the recorded concentrations drop in the immediate vicinity of the river's mouth and continue to fall along the further course of the river. This indicates that the "Freiburger Mulde River" has higher levels of nitrate and highlights the usefulness of taking measurements along the length of a river, especially with regard to detecting and depicting the characteristics of mixing and turbulences.



Progression of nitrate levels in the "Freiburger Mulde River" before (right) and after the Zschopau flows into it (Bing Aerial in QGIS), Grafics: C. Koch, TU Dresden

Because some sections of the river Tollense have dense submerged vegetation, a different measuring setup was set up. A sturdy boat is used, on which few aquatic plants become entangled. The system uses a bypass system in order to avoid direct use of the monitoring equipment in the river. The instruments on board are supplied with a continuous volumetric flow from variably adjustable sampling depths.

Besides ammonium- and nitrate concentrations, the water's phosphate content can also be determined. In addition to the standard parameters, the boat can also measure the chemical oxygen demand and the turbidity. ADCP is also used on the river Tollense to measure flow velocities and -rates, with separate trips across the river at selected suitable sites proving to be more practical, however. An echo sounder was already used in the first year of the project to map the structure of the river bed.

OUTLOOK

In the next phase of the project and using the established configurations, researchers are planning to test various navigational strategies and then analyse them in terms of information retrieval. Depending on requirements which may still arise, the boats will be refined and, if necessary, supplemented by additional measuring equipment. The continuing optimisation and automation of evaluation algorithms is of key importance in this context. Researchers plan to analyse the measurement data with a particular regard to instantaneous water pollution, proposed management measures and differences between the study sites.

During different discharge situations, measurements are to be recorded in a quality which ultimately permits the creation of numerical hydrological and water quality models of the rivers. In addition to the boat trips, the use of a drone is being pursued to collect additional data.

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HyMoBioStrategie

HyMoBioStrategie – Impact of the hydromorphological changes of lakeshores (Lake Constance) on the sediment budget, submerged macrophytes and macroinvertebrate communities with the goal of optimising mitigation strategies

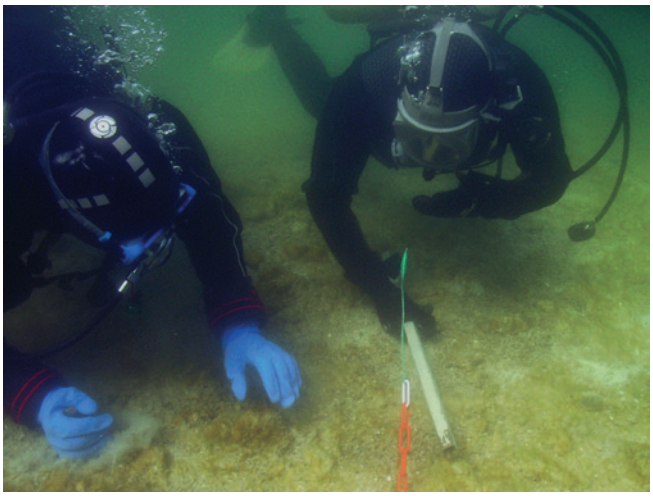
Mapping macrophyte vegetation cover by a diver and scooter, Photo: Dr. K. van de Weyer, Lanaplan

MEASURES TO PROTECT THE SHORES AND UNDERWATER MONUMENTS OF LAKE CONSTANCE

During the last decades there has been increased erosion of littoral sediments in many pre-alpine and alpine lakes. In Lake Constance this process is endangering, among other things, underwater monuments which have been designated as UNESCO World Heritage Sites. Lakes in Germany are used in a variety of different ways and suffer a significant structural impact due to shore construction, i.e. bank reinforcements or harbours, and lake uses in the form of recreational activities and ship traffic. This leads to changed hydrodynamic conditions in the littoral zone which in turn impact the transport and balance of sediments as well as aquatic plants (macrophytes) and benthic organisms (macrozoobenthos). The goal of the joint project is to study and assess anthropogenic hydromorphological changes in the littoral zone of lakes in line with the European Water Framework Directive (WFD) and to develop lake shore valorisation programmes for sustainable shore management and restoration.

INTERIM RESULTS

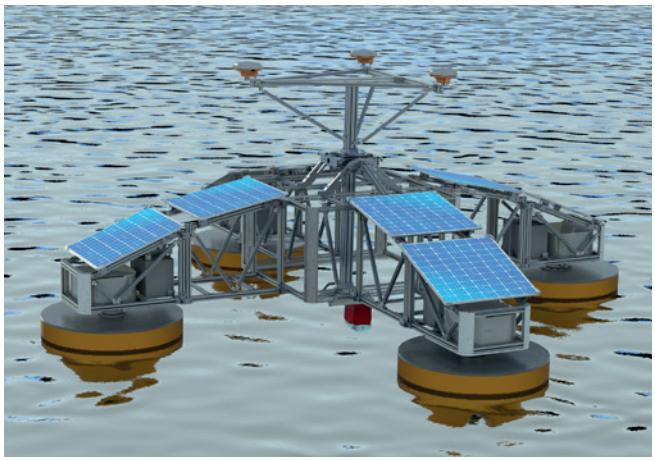
HyMoBioStrategie is based on an interdisciplinary approach in order to develop ways of achieving intact lake shores. The project initially focused on connecting researchers from various disciplines with users and operators from various federal states as well as from local communities and water authorities, on informing these players about the project's topics, and on discussing the requirements for the applicability of the project's outcomes. This took place e.g. within the framework of events chaired by the Advisory Council of the International Water Protection Commission for Lake Constance, by the "Round Table Renaturation" network, by the LAWA Expert Committee for Lakes and by the National UNESCO World Heritage Day.



Monitoring underwater UNESCO World Heritage monuments with low-cost erosion markers, Photo: Dr. M. Mainberger, UWARC

After an initial review of the six areas being studied on the northern shore of Lake Constance, a comprehensive monitoring programme was launched. Since then data on hydro- and morphodynamics (surface waves, currents, erosion/accumulation) are continuously being recorded in the littoral zone of Lake Constance. This data is being supplemented by spatially resolved campaigns to characterise the properties of the sediment and the biocoenosis, with a particular focus on the macrozooben-

thos and macrophytes. In addition, first process-based studies were conducted to describe the complex relationships and their interactions which become effective under natural conditions and/or when lake shores are anthropogenically modified.



Latest stage in the development of the Hydrocrawler monitoring vehicle which operates autonomously and scans the sediment surface of Lake Constance with various sensors, Fig.: C. Degel, Fraunhofer IBMT

The hydro- and morphodynamics in the littoral zone of the six study areas are affected to varying degrees by wind- and ship waves. Wind waves dominate the wave field in terms of energy. In the summer months, ship waves can account for up to 40% of the energy input into the littoral zone. Wind waves occur sporadically, while ship waves are periodical. The pattern and dynamics of the resuspension of particles on the sediment surface follow the properties of the wave field and depend on water depth. Initial measurements with acoustic erosion markers have shown that the net sediment transport in the littoral zone is very small. During strong wind events, up to 2 cm of the surface sediments are mobilised, usually transported parallel to the shore and redeposited again. Numerical experiments with 3D-models are being carried out together with the empirical experiments in order to spatially quantify the transfer of sediment considering water level fluctuations.

Both relevant quality components of the WFD, the macrozoobenthos and macrophytes, were sampled spatially resolved in all study areas. First results suggest that the diversity and abundance of the macrozoobenthos and macrophytes are less affected by the shore structure itself than by the properties of the available substrate (sediment structure and grain size) and the occurring water level fluctuations. Renatured sections of the shoreline and areas with erosion shelter structures to protect the UNESCO World Heritage site are rapidly recolonised by the macrozoobenthos, while macrophytes recolonise them only reluctantly due to the lack of fine sediment.

In the course of the project, the HyMoBioStrategie partners have already developed and tested the first new techniques to measure suspended sediment and bead-load transport, the erosion- and/or accumulation behaviour of the surface sediments as well as for acoustic methods. Among other objectives, these are used in combination with the monitoring vehicle “Hydrocrawler” that allows precise, spatially resolved surveys of the lake bottom topography and sediment stratigraphy. Highly accurate digital elevation models (based on LIDAR measurements) are available as references for the measurements with the Hydrocrawler.

OUTLOOK

The outcomes of HyMoBioStrategie play a key role for the evaluation of hydromorphological changes on lake shores in line with the WFD and for the development of future lake shore valorisation programmes at larger lakes in Germany under consideration of the preservation needs of historical monuments. Furthermore, innovative technical solutions are being developed and tested, i.e. the Hydrocrawler, boulder- and gravel tracers, inexpensive erosion markers and numerical models. At the end of the project, these will be available to use as monitoring or forecast tools by the institutions (e.g. the state authorities and municipalities) supporting and conducting the measures. The focus of the joint project HyMoBioStrategie is to develop, together with the institutions supporting the measures, solutions and recommendations for sustainable lake shore design and management under consideration of the existing usage claims and sustainability conflicts.

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Project duration: 01.04.2015 – 31.03.2018
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RiverView – River status monitoring and management

REMOTE-CONTROLLED BOAT MONITORS STREAMS AND RIVERS

Extreme events, disasters, and dynamic changes in rivers as a result of intensive farming, multiple pollutant entry and climate change – the challenges water management faces are manifold. But these phenomena and changes all have one thing in common: They generate a need for river data which has high temporal and spatial resolution and is available at short notice. These data are relevant for describing and evaluating river dynamics, for regional water resources management, and for identifying sustainable measures. RiverView aims to develop new and innovative solutions for river management which substantially contribute to the collection, visualisation and analysis of data – above and under water. This offers targeted support for specialised planners and water managers in fulfilling their numerous tasks.

Flow measurement with the ADCP metre, Photo: R. Engels, FiW

INTERIM RESULTS

With RiverView, a holistic approach is being developed for monitoring and managing rivers based on their status. Monitoring centres on the RiverBoat which can navigate small- and medium-sized rivers remotely. The challenge at the beginning of the project was to build a very small and manoeuvrable boat to safely navigate even in small rivers. At the same time the boat needed to be able to carry a large amount of measuring equipment for collecting data above and under water, record all the data and make it available in real-time when necessary.

The boat also needed to maintain its ability to navigate and manoeuver while integrating the monitoring technology into the boat's technology. In the meantime the RiverBoat is fully equipped, ready for monitoring and is navigating the rivers in the Emscher and the Lippe river basins as well as the rivers in the Rur river basin. During the initial test period the primary focus lay on the boat's practical suitability, but rivers and river sections' navigability was also carefully studied. Researchers were able to choose both from developed, easily accessible river sections and from natural rivers which were shallow and, in some cases, difficult to access.

The boat records parameters such as oxygen content, pH, conductivity or temperature with a multi-parameter sensor. The so-called INN sensor enables the composition of the river bed/substrate to be analysed, while the ADCP provides information on the discharge and flow. In the project's initial phase, work was carried out to integrate the majority of the sensors directly into the boat. This work was always done in close collaboration with the water management associations to ensure that the instruments provide realistic results. RiverView's approach offers a new perspective on rivers. A 360° panoramic camera was integrated for this purpose, enabling pictures to be taken directly from the RiverBoat. Together with sonar technology, this thus allows the river's structure to be mapped above and under water completely and seamlessly along the course of the river, and the watercourse as a whole can be surveyed. All pictures are stamped with time- and GPS data in order to spatially and temporally record the measured parameters and the photos. This gives complete insight into all river-relevant data, thus allowing interdependencies to be identified quickly and cost-effectively.

The solution has many potential uses: for example, the images can be used by water- and nature conservation associations to extrapolate key data such as shading,

Using the multi-parameter sensor, Photo: S. Tabatabaei, FiW

tributaries or vegetation. But these images can also be used to provide added value for local residents or other interested parties such as fishing associations or canoe clubs, i.e. by enabling them to experience the river in a virtual way and to improve their river trip planning. The data which has been collected is fed into a database which allows it to be centrally managed and, at the same time, accessed by interested users. This is where the data is managed, checked, processed and prepared for a web portal. The web portal provides different data to different user groups. The user has the option of deciding which parameters will be displayed so that they can be contextualised and assessed. This enables the river's status to be evaluated in a high-resolution manner directly in the web portal.

To ensure that this system is geared to the needs of the users, the project partners contacted further parties like the regional water authorities at an early stage of the project. Two regional workshops are also being planned during which the demands made on the web portal will be assessed and user feedback will be collected. Beyond the target groups which have practical and scientific relevance, low-threshold communication via Facebook and Twitter was set up to reach the general public. This is where, for example, information about upcoming river monitoring trips and public events is disseminated.

OUTLOOK

At the beginning of the second half of the project period, the focus is on extensive open water tests and the implementation of river tests together with the practice partners. The emphasis is on practical applicability with regard to the recording and accuracy of the collected data compared to classic methods. The speed at which data can be collected and evaluated will also be examined, i.e. how much time passes between the collection of data and its availability in the web portal. Based on this, fields of application for the RiverView system will be identified, tested and evaluated, with the automation or partial automation of data processing playing a more significant role.

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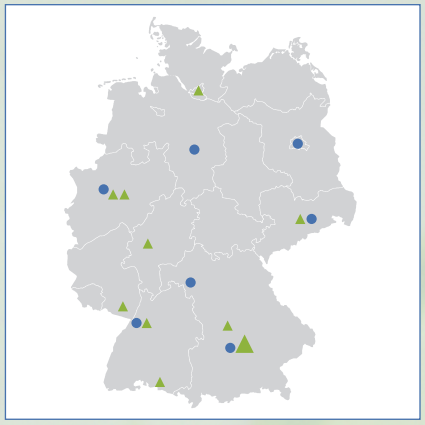
Assessment Methods for Aquatic Ecosystems

30 GroundCare



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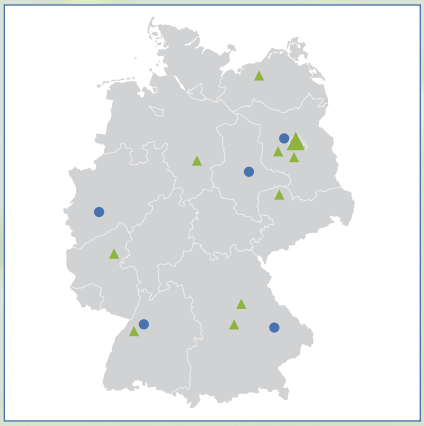

▲ Project coordination ▲ Joint project partners ● Model regions

GroundCare – Parameterisation and quantification of ecosystem services as a basis for sustainable groundwater management

NEW BIOINDICATORS AND TOOLS FOR GROUNDWATER ECOSYSTEM ASSESSMENT

Groundwater is Germany's most important resource for drinking water. However, pollution, extreme weather events, accidents and land-use change compromise its quality. To date, there are no standardised indicators and methods for the assessment of the ecological status and stress tolerance of groundwater ecosystems. Therefore, the main objectives of GroundCare are to evaluate the functional capacity and integrity of groundwater ecosystems and to identify appropriate ecological criteria that can be applied as indicators. In addition, a set of application-oriented, biological/ecological criteria and methods for an integrated groundwater monitoring are developed, with the goal of subsequently making these tools available to the environmental authorities and water managers. Herein, the focus lies on the functional diversity of microbial and faunistic communities, as well as on important services that are being provided by groundwater ecosystems.

The newly developed gastight, sterilisable sampling system (BGD ECOSAX GmbH). a) Removal of a sample vessel from the gastight sampling system. b) Close-up of the gastight sample vessel, Photo: F. Kurzius, BGD GmbH

INTERIM RESULTS

Representative sampling is a key prerequisite in order to obtain reliable information about the quality of groundwater and the groundwater ecosystem. Currently, validated methods and binding guidelines for sampling are lacking in water management practice. Consequently, based on related, existing norms and regulations, as well as taking into account the project partners' experience in this field, a guidance document for the planning and performance of groundwater sampling for microbiological and molecular analyses was developed. Moreover, several technical aspects that are of relevance to groundwater sampling were optimised. For example, BGD ECOSAX GmbH Dresden (formerly BGD GmbH), in collaboration with Umwelt- und Ingenieurtechnik GmbH Dresden, refined a gastight, sterilisable sampling system which maintains the existing environmental conditions in the sampling vessel until analysis and minimises contaminations of the sample with microorganisms that do not naturally occur in groundwater. The DVGW Research Centre TUHH developed specifically adapted techniques for sampling and analysis of anoxic groundwater – a condition frequently found in German aquifers.

To obtain groundwater fauna, a so-called phreatic net sampler is lowered to the bottom of a groundwater monitoring well with a winch, Photo: IGÖ GmbH

For the assessment of physicochemical, biological and hygienically-relevant parameters in groundwater, the GroundCare consortium evaluates the currently available analytical methods in terms of practicability and works towards their standardisation. To this end, a series of ring trials are performed. In a first trial, under the participation

of five project partners (BGD ECOSAX, HMGU, TUHH, TZW, WWU), different methods for the determination of bacterial cell numbers in groundwater were compared. The comparison showed that depending on the method used, the results can vary considerably, and emphasised the urgent need for standardisation of procedures in order to make them ready-to-use in water management practice.

In search for ecological parameters that can be used as reliable indicators for the ecological status of groundwater ecosystems, the GroundCare consortium examines seven model sites throughout Germany that are subject to different types of usage and anthropogenic pressures. The aspects investigated include the structural and functional diversity of the biocoenoses, the chemical-physical conditions, the carbon sources, the nitrogen turnover processes, and the occurrence and biological transformation of micropollutants. The species composition of the groundwater fauna is being studied by the Institute for Groundwater Ecology (IGÖ GmbH), with a focus on the question whether genetic analysis delivers results that are comparable with the findings from a traditional, organism-based environmental assessment of groundwater status. Another key aspect is the self-purification potential of groundwater ecosystems with respect to micropollutants. In collaboration with the Bavarian State Office for the Environment, the Helmholtz Centre Munich investigates to what extent micropollutants are being degraded by microorganisms along a river bank filtration route.

Whenever pollutants enter an aquifer, the groundwater organisms are negatively impacted. However, so far there are no standardised test methods for the evaluation of pollutant toxicity towards groundwater organisms. To this end, LimCo International GmbH developed a Microimpedance Sensor System (MSS) that allows a continuous monitoring of meiofauna behaviour. Not only acute and chronic ecotoxicity tests can be carried out with this testing system, but also continuous, real-time monitoring of groundwater quality. First experiments with the MSS examined the toxicity of the plasticiser bisphenol A on various groundwater crustaceans. Being a component of many plastic products of every-day domestic use and food packaging, bisphenol A is assumed to disturb the hormone balance of organisms. The crustaceans in the test showed significant changes in their movement activity – the larger, ground-dwelling species reduced their activity; the small, planktonic ones, increased it.

A sufficient number of groundwater organisms need to be available at any time for ecotoxicological studies to be routinely carried out in practice. To this end, the Justus Liebig University of Giessen develops a method for the rearing of selected groundwater organisms in the lab. This poses considerable challenges, since so far, little is known about these organisms' optimum living conditions. The project partners have, however, already succeeded in developing a special, mixed plant-animal diet which is being readily accepted even for long periods of time by all the groundwater species that have been studied so far.

A cave amphipod *(Niphargus aquilex)* seizes a worm *(Enchytraeidae)* that it has been offered as a food source, Photo: N. Rütz, University of Gießen

OUTLOOK

GroundCare contributes to the identification of reliable indicators for the assessment of the ecological status of groundwater ecosystems. At the end of the project, a selection of practicable, proven and standardised groundwater monitoring methods will be delivered to the authorities and water managers. In addition, GroundCare performs comprehensive laboratory and field studies. Hereby, key processes and groundwater ecosystem services are assessed, with a focus on the prevailing nutrient turnover processes, the biodegradation of contaminants, as well as the stress tolerance of groundwater communities.

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RESI – River Ecosystem Service Index

ANALYSIS AND EVALUATION OF ECOSYSTEM SERVICES IN RIVER LANDSCAPES

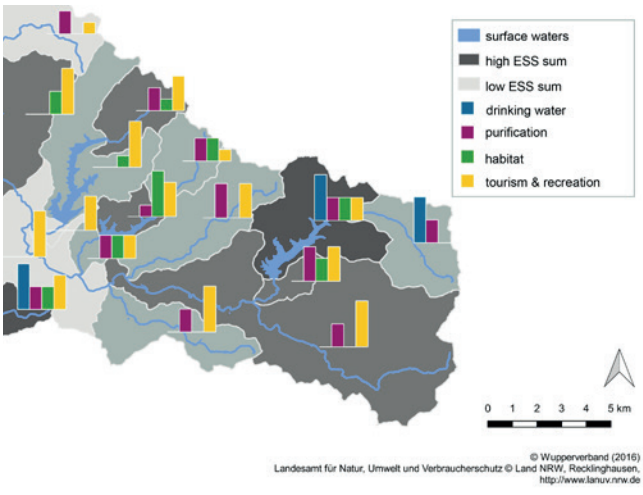
In many places today, rivers and their floodplains are being used intensively for hydropower generation, navigation, agriculture and forestry, or for various recreational activities. At the same time, rivers and their remaining floodplains are spatially interconnected systems and represent particularly valuable refuges for nature. This has often led to conflicts of interest with regard to their use. Currently, the management of rivers and floodplains is mainly done taking a sectoral approach, with different federal- and state institutions involved. The institutions are obliged to follow numerous directives, such as the EU Water Framework Directive and the EU Flood Risk Management Directive. The resulting complex problems and conflicts of interest between different uses thus represent a challenge for implementation in administrative practice. The goal of the joint project RESI is to develop the integrative „River Ecosystem Service Index“ (RESI) which complements the current state-based assessment methods by a functional assessment based on ecosystem services and enables the visualisation of interactions between uses.

INTERIM RESULTS

The objective of the first phase of the RESI project was to determine the relevant ecosystem services in rivers and floodplains, to adapt the ecosystem service approach for use in river corridors and to identify suitable data sources and indicators and/or models. Based on the literature, an overview of different ecosystem service classifications was prepared. The list was evaluated in terms of the applicability of the individual ecosystem services in the context of rivers and floodplains, while ensuring the compatibility with the ”Common International Classification of Ecosystem Services” (CICES). As a result 27 ecosystem services were identified. In contrast to other studies, the RESI project covers ecosystem services of all three main groups, i.e. eight provisioning, eight cultural and eleven regulating ecosystem services (including habitat provision). It is acknowledged that habitat provision represents a special case as it forms the basis for biodiversity and thus for many other ecosystem services, too. In addition, the group basic ecosystem functions was defined, which relates to the basic structures and functions of ecosystems. During the ecosystem service assessment we differentiate between the offered ecosystem services (provided by nature) and used ecosystem services (under additional human influence). Against this background, indicators and complex models for ecosystem service assessment are developed. To exemplify, the yield of agricultural crops depends on the natural fertility of the soil as well as on additional labour, capital, fertiliser and pesticide input. Whereas recreational bathing as a water-related activity can be defined as a function of the state of the river bank, the velocity, the water quality as well as the existing infrastructure.

Many institutions which play a key role in river- and floodplain management are active in RESI. These numerous partners ensure a high degree of practical relevance in the project. In close cooperation with the practice partners, various options for the field test of RESI were discussed for the river corridor model regions in Germany.

The different quantification methods for the individual ecosystem services are currently being tested in the



Use-profiles of four selected ecosystem services (ESS) at water body sections in the catchment area of the river Wupper (excerpt). The shade of grey of the colouring of the associated subcatchment shows the respective sum of the ecosystem services used, Graphics: A. Kaiser

Rivers and their wetlands render essential ecosystem services for society, Photo: M. Pusch, IGB

Flooding on the river Spree in 2010, Photo: M. Pusch, IGB

model regions with regard to data availability, data processing challenges and model validation. In this regard, an initial analysis of some ecosystem services was carried out in the "Wupper" model region, for example. The results show that stretches of river in that region are used in various and quite different ways, which means that the sum of the ecosystem services can vary considerably. The analyses revealed synergies between drinking water provision and nature conservation on the one hand and improvements in the availability of ecosystem services through targeted reductions in environmental pollution on the other hand.

OUTLOOK

Spatially explicit maps for ecosystem services in the model regions will be created during the next phase of the project. Simultaneously, the visualisation and methodology of the multi-criteria analysis will be developed in order to prepare the synthesis of the RESI. When thematic maps have been drawn up accordingly, the various forms of ecosystem services can be quantified for the status quo and for an alternative management scenario, respectively. The visualisation of the overall assessment through the RESI highlights the synergies and trade-offs between the individual uses. RESI thus represents the multi-disciplinary information platform for practitioners in water management, environmental planning and nature conservation. It enables the evaluation and optimisation of management scenarios in terms of a multiple use of river landscapes considering the respective political targets. Ultimately a cross-sectoral management of rivers and floodplains can be developed.

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Project duration: 01.06.2015 – 31.05.2018
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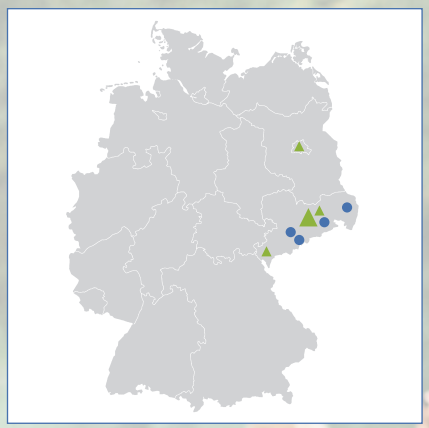
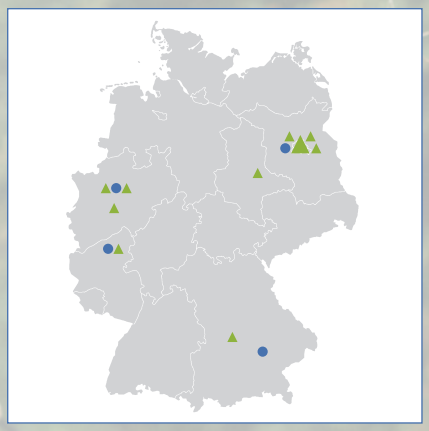
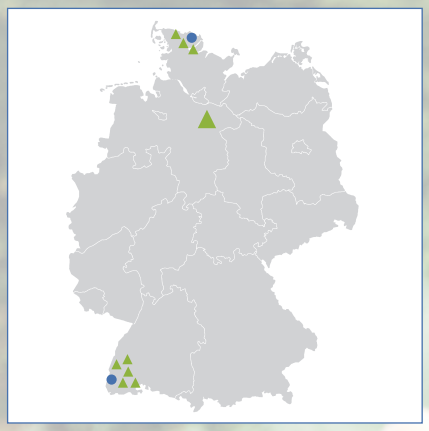
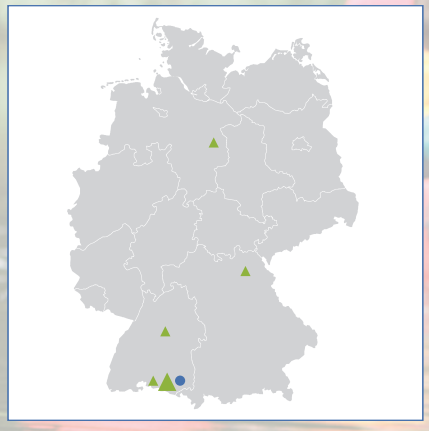
Water Quality Management









▲ Project coordination ▲ Joint project partners ● Model regions

CYAQUATA – Study of the interrelation between toxin-producing cyanobacteria and water quality in reservoirs and development of a sustainable management strategy

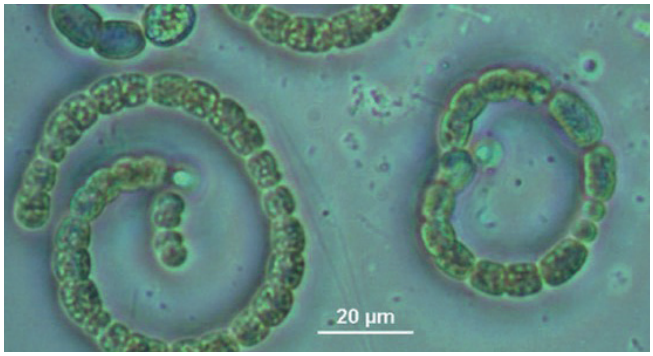
RESEARCH ON THE GROWTH OF CYANOBACTERIA IN RESERVOIRS

The concentration and taxonomic composition of phytoplankton are key indicators for assessing water quality in standing water bodies such as reservoirs or lakes. Specific groups of phytoplankton like cyanobacteria can benefit from climate change. Due to their potential for forming mass developments and their capacity for producing toxins, the occurrence of cyanobacteria can impact the use of water bodies, e.g. for the production of process- or drinking water. CYAQUATA thus aims to gain a better understanding of the occurrence of cyanobacteria and their toxins. The goal is to identify key factors for cyanobacteria development and toxin production and to test and enhance monitoring tools. Using the findings which have been gained and the methods which have been developed, mass developments of cyanobacteria with toxin-producing potential are to be detected at an early stage and long-term solutions for controlling the cyanobacteria problem are to be developed.

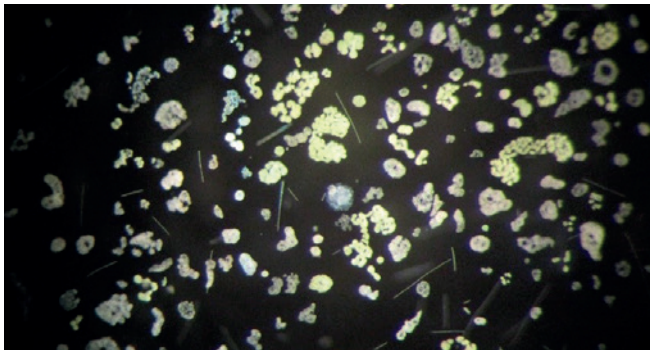
INTERIM RESULTS

CYAQUATA regularly takes samples from five reservoirs in the German state of Saxony. The composition of the phytoplankton is recorded directly on site with a FluoroProbe sensor, which can differentiate and quantify phytoplankton groups. Recent enhancements of this technology are being tested in the project and, with flow cytometry, another method for the fast differentiation and quantification of phytoplankton groups is being applied. Additionally, cyanobacteria from the reservoirs under investigation are being cultivated and gene sequences for the production of cyanotoxins are being detected using molecular biology methods (PCR). The established multiplex PCR method quickly and effectively verifies the genetic potential for the production of various toxins. The extra- and intracellular concentration of different cyanotoxins is also determined in the samples from the reservoirs using various analytical methods concurrently, e.g. immunoassays (ELISA) and modern LC-MS/MS methods. In addition, a test strategy for the toxicological assessment of toxin-producing cyanobacteria is being developed and used both for water samples and for the cyanotoxins' pure substances. Field studies with enclosures are also being carried out in the Saidenbach Reservoir. The enclosures are used to isolate sections of the reservoir

Mass development of cyanobacteria in the Radeburg II Reservoir on July 18th 2016, Photo: K. Zoschke, TU Dresden



Fluorescence microscopic image of a cyanobacterium *(Anabaenopsis elenkinii)*, sample from the reservoir Radeburg II, Photo: A. Hartmann, LfULG



Microscopic image (1,6x magnification) of cyanobacteria (*Microcystis* sp. (colonies) and *Anabaena* sp. (filaments), Surface sample from the Saidenbach Reservoir, Photo: H. Beesk, TU Dresden

to selectively study which reservoir- and sediment areas play a key role in the spread and mass development of cyanobacteria. Moreover, the different methods are being studied with regard to their suitability as an early warning system for the occurrence of mass developments of toxic cyanobacteria. Interim results show that the temporal development of cyanobacteria in a body of water can be tracked effectively using the FluoroProbe and flow cytometry. Particularly in nutrient-rich (eutrophic) shallow lakes like the reservoirs Quitzdorf and Radeburg II, a mass occurrence of cyanobacteria is to be expected.

The Quitzdorf Reservoir was colonised mainly by the cyanobacterium *Microcystis aeruginosa*, whereas various cyanobacterial species dominated the phytoplankton in the Radeburg II Reservoir. In contrast, the biovolume and the proportion of cyanobacteria relative to the phytoplankton were lower in the nutrient-poor reservoirs that were studied. According to the predominance of cyanobacteria, high toxin concentrations were detected temporarily in the nutrient-rich process water reservoirs. It also became apparent that the toxins were stored mainly in the cells and were rarely actively released into the water. The immunoassay ELISA which was used provides a total value of the cyanotoxin concentration within a short time frame, thus making it a suitable screening method. On the other hand, single substances can only be analysed using LC-MS/MS. The comparison of the results of both analytical methods showed that there was usually a mixture of different toxins and that not all existing toxins were detectable using single substance analysis (due to non-availability of standards). In order to close this gap, the project partner Cyano Biotech GmbH is working on the establishment of new analytical standards. During a mass occurrence of cyanobacteria, toxicological testing of the water samples was also carried out. Furthermore, cyanobacteria are also cultured from all of the water bodies being studied in order to obtain cultures, which contain only a single cyanobacterial species. Using both molecular biology and laboratory tests with varying conditions, these cultures can help to determine the potential for toxin production and the toxicological effect can be analysed.

OUTLOOK

The interim results show that a broad spectrum of cyanobacteria and cyanotoxins can be found in the reservoirs with varying trophic status that were studied. This diversity is a good basis for culturing the cyanobacteria whose strains are characterised physiologically and in terms of toxin production. The thus obtained key factors for cyanobacterial development, along with the findings from field experiments on their propagation within a body of water, can be used for the early detection of cyanobacteria blooms. In conjunction with the results from toxicological tests, this can help to improve risk assessments of cyanobacteria in reservoirs.

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FLUSSHYGIENE – Hygienically relevant microorganisms and pathogens in multi-functional rivers and water cycles – sustainable management of different types of rivers in Germany

‚Island of youth' in Berlin's suburban Spree River: Model region to study different implementation strategies for opening new river bathing areas, Photo: Kompetenzzentrum Wasser Berlin gGmbH

RESEARCH FOR CLEAN BATHING WATERS

Good water quality and high standards of hygiene in watercourses are key prerequisites for public health. In order to ensure a high level of protection, the revised EU Bathing Water Directive of 2006 (2006/7/EG) calls for the systematic collection of information on the sources of hygienic pollution and for the realisation of appropriate management measures. For rivers, however, methods for reliably predicting microbial pollution are still lacking. The goal of the joint project FLUSSHYGIENE is to develop tools which help the responsible local authorities manage complex, multi-functional rivers so they ensure the highest possible level of health protection. In addition, guidelines, risk-based prediction models as well as sustainable management strategies with regard to hygienic loads in rivers are to be developed and made available to the responsible authorities.

INTERIM RESULTS

The project's initial phase served to record the entry paths of hygienic loads, identify and quantify the degradation processes in rivers and determine potential obstacles arising from the usage claims of various stakeholders with regard to bathing in rivers. To this end, river monitoring programmes were planned and implemented in four model regions: the Spree-Havel-system in Berlin, the Ruhr in North Rhine-Westphalia, the Rhine/Moselle in Rhineland-Palatinate and the Isar/Ilz in Bavaria. In the model region of Berlin's suburban Spree River, the urban planning and planning framework as well as environmental aspects were analysed with a view to assessing its potential as a river for bathing. Through interviews and in collaboration with state- and district authorities as well as local stakeholders and citizens, researchers were able to identify typical constellations which might ensue if a new bathing river was opened for public use. In July 2016, an event was held with approximately 100 interested citizens and representatives from local administration on the topic "Bathing in the suburban Spree". As part of a planning game, the participants identified inviting bathing sites and engaged in a lively discussion about their wishes and concerns. In order to determine the loads caused by heavy rainfall events, event-based sampling was carried out in all the model regions. Samples were taken at rain overflow basins, rainwater sewers, sewage treatment plants, tributaries and

combined sewer overflows. Heavy rainfall events often impair the water quality of rivers. To find out where these loads originate, DNA sequences found specifically in the faeces of warm-blooded animals were detected in the rivers Isar and Ilz. This allows researchers to determine whether faecal pollution originates in residential- or agricultural areas and/or whether several entry paths play a role. Faulty and incorrect sewage connections in urban neighbourhoods with a separate rainwater drainage system can also be sources of pollution. These faulty and incorrect connections were localised in Berlin and their significance as an entry path for hygienic loads is being assessed in the project. In addition to the indicator organisms *E. coli* and *intestinal enterococci*, levels of viral and parasitic pathogens (adenoviruses, noroviruses, *giardia spp., cryptosporidium parvum)* were measured to determine the actual risk of infection. Furthermore, on the days after rain events, samples were taken with automatic samplers at specific sites at current and potential bathing waters in the Unterhavel in Berlin, at the suburban Spree River and at the river Ruhr. In addition to documentation of the entry paths, analysis of the degradation processes played a significant role. In Berlin, flow-time conform sampling was implemented during two combined sewer overflow events in order to determine the degradation rate in the river.

Measuring site with automatic samplers in Berlin's Unterhavel River for event-specific sampling after heavy rainfall events, Photo: Kompetenzzentrum Wasser Berlin gGmbH

The load was monitored through a combination of online monitoring in the sewer system, a flow measurement at the discharge point, hydraulic modelling of the Spree River and the online monitoring of conductivity and oxygen in the river. The composition of the microzooplankton (heterotrophic flagellates and ciliates) was analysed regularly in all model regions to determine the reduction of pathogens through grazing. Researchers were able to gauge the elimination capacity of the microzooplankton by combining studies on the intake of pathogens and virus-like particles in the laboratory as well as directly on the rivers being studied.

OUTLOOK

Using the data from the monitoring phase, various prediction models will be set up and calibrated as the project progresses. These are to be used firstly to predict periods of increased hygienic loads at short notice, and secondly to evaluate jointly established options for taking action for the selected river sections. Among others, this will be reified in an exemplary fashion on the suburban Spree in Berlin and on the Ruhr River. Beginning with the Spree it will be determined what measures are essential for creating a status suitable for bathing and how high the ensuing costs are. Subsequently and immediately before the start of the 2017 bathing season, a representative phone survey is to determine the willingness of citizens in Berlin to pay for the realisation of a bathing area on the river – so that, in addition to the cost side, the benefit side is also monetised. The early warning system developed on the Ruhr River will be used at its newly created bathing area during the 2017 bathing season. When a river bathing area is opened for the first time, the results of the cost-benefit analysis and the conflict- and constellation analysis, together with the scientific findings on the dynamics of hygienic loads, will be summarised in a checklist. A guideline for dealing with short-term pollution events will also be created from the findings of the four different model areas.

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MUTReWa – Measures for a more sustainable management of pesticides and their transformation products in regional water management

LONG-TERM PROTECTION OF WATER BODIES FROM PESTICIDES

In recent years, policy makers, water management organisations, academia and society took various steps to improve the ecological status of ground- and surface waters. However, the increasing mobilisation of trace organic compounds and in particular of their transformation products has been neglected so far when water protection measures are assessed. The joint project MUTReWa aims to close this knowledge gap by investigations of mobilisation- and transformation processes of pesticides from intensive agriculture and biocides from urban areas. Thereby, the project partners intend to assess the effectiveness and sustainability of selected water management measures to improve the ecological status of ground- and surface water. In collaboration with water managers, recommendations derived from the project results shall then be integrated into regional water management strategies.

INTERIM RESULTS

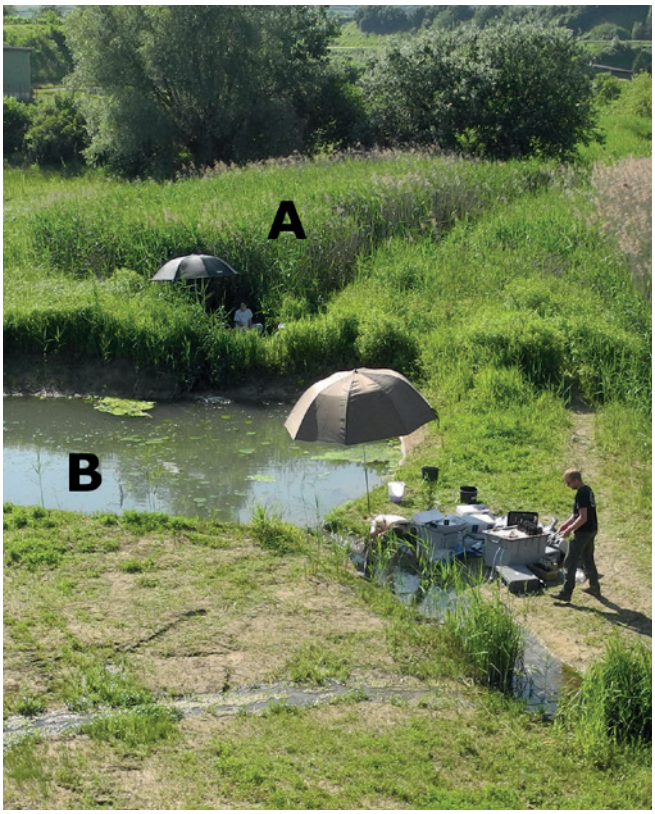
The degradability of selected biocides and pesticides through sunlight and microorganisms was analysed during the first half of the project. Initial outcomes show that the degradation of various sample substances was not complete, but that these substances were transformed into transformation products (TPs). Studies performed in the laboratory also provided new insights into the formation and properties of the TPs, some of which were previously unknown. Compared to the parent compound, individual TPs which formed through exposure to light showed a better biodegradability, but at the same time higher toxicity was also observed in some TPs. Furthermore, only minor effects of pesticides on domestic macrophyte species were found by field mapping and toxicity tests. Preliminary experiments with fluorescence tracers show that pH, organic matter and clay content impact sorption and that plants impact the biodegradation of these fluorescence tracers.

In the Kielstau study area and in close collaboration with local farmers, different water bodies were sampled for three months in the autumn of 2015 after the herbicides metazachlor and flufenacet had been applied. The results show that TPs of both herbicides from the previous year were detectable in surface waters and inside the drainage system. Since concentration peaks of parent compounds and their TPs occurred at the same time in the water bodies, it is assumed that the transport pathways are similar. In two of five raw-/ drinking water wells, TP concentrations were quantified in low concentrations. These results reveal that wells with a thin conveying layer are more prone to contaminations than those with a thick one. At some groundwater monitoring sites the presence of the parent compounds and their associated TPs were detected. The studies show that land management such as crop rotation in the inflow area of the groundwater wells and the soil type at the site significantly affect the concentrations of the target compounds. The outcomes of the monitoring were presented to local farmers from the catchment area of the Kielstau within the framework of the practical application- and expert councils.

In the Mühlbach (Freiburg) study area samples were taken from the inflow to urban rainwater percolation facilities. Initial results from analysis show positive findings for the selected biocides, with biocide concentrations in urban storm water similar to those of other cities. This is particularly alarming because in a study carried out with hydrological tracers, a rapid breakthrough within a percolation trench system was documented. It thus seems likely that urban storm water seepage via these kinds of percolation systems poses a threat to groundwater.

In an intensively cultivated wine-growing area in the Kaiserstuhl region (South Baden), a stream was restructured with the support of the municipality of Eichstetten. It now consists of two wetlands in a row which both retain pesticides: a densely vegetated reed bed (A) and an open water body (B). Both wetlands are characterised by high biological activity, but their light, oxygen- and temperature dynamics differ.

This leads to different degradation- and transformation mechanisms, which was demonstrated using fluorescence tracers and solute transport modelling. Because high levels of pesticides were applied in the study area due to wet weather conditions in early summer of 2016,



A multi-tracer test demonstrates the positive effect of a vegetated wetland (A) and an open water body (B) on the water quality of a stream in the wine-growing region of the Kaiserstuhl, Eichstetten, Photo: Jens Lange, Albert-Ludwigs-Universität Freiburg

Implementation of stakeholder workshops and communications activities in the form of an expert council meeting, Photo: O. Olsson, INUC

elevated concentrations of fungicides and herbicides were measured in the stream. The combination of wetlands (A and B) was able to markedly lower these levels. Pesticide export from the upstream catchment was successfully simulated using the ZIN-AgriTra model, confirming concentration dynamics before and after pesticide application, as well as the impact of rainfall events on pesticide export. Model simulations show that pesticides accumulated on road surfaces are immediately washed into the streams with discharge pathways varying according to the chemical properties of the different compounds.

OUTLOOK

Until the end of the project more research on the potential risks of TPs, process studies of hydrological tracers and pesticides in relevant turnover areas and further improvements of the existing simulation models will be carried out. The latter will permit reliable model scenarios enabling the assessment of water management measures. Moreover, they will be used as a communication tool. The communications concepts in the study areas will continue to be implemented. They support the transfer of new project findings on the fate of pesticides and TPs in the environment, on potential risks posed by TPs, and on the implementation of sustainable water management measures into regional water management.

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PHOSWAM
Von der Quelle bis ins Meer

PhosWaM – Phosphorus from source to sea – Integrated phosphorus and water resources management for sustainable water protection

Sampling with the research vessel ‚Klaashahn' in the coastal waters of the Baltic Sea, Photo: H. Posselt, IOW

REDUCING CRITICAL LEVELS OF PHOSPHORUS IN AQUATIC ENVIRONMENTS

Next to nitrogen, phosphorus (P) is one of the essential nutrients for aquatic and terrestrial plant growth. While many aquatic ecosystems have a surplus of phosphorus (here and forthwith meaning "total phosphorus") which leads to eutrophication, land used for agriculture is often phosphorus-deficient due to the extraction of biomass. As a result, farmers use phosphate as fertiliser on their land to promote plant growth. Not just agriculture, but industrial and sewage treatment plants also release phosphorus compounds into the environment. Via various routes – such as lakes, rivers and estuaries – a large percentage of these compounds reach the sea. Large amounts of phosphorus pose a significant problem for aquatic ecosystems. In aquatic environments, an over-abundance of plant nutrients leads to the excessive growth of phytoplankton and other aquatic plants. This leads to turbid water, toxic algal blooms, oxygen deficiency and a loss of biodiversity. The goal of the researchers and practice partners involved in the joint project PhosWaM is to identify and characterise emission sources and to develop effective measures to reduce the P-levels in aquatic environments.

GOALS

The project's overarching goal is to grow the knowledge base with regard to the sources, transport routes and transformation processes of phosphorus compounds in water bodies by studying processes and using models. Researchers plan to use the outcomes of these studies, together with the results of studies of exemplary measures i.e. controlled drainage, filter systems in small sewage treatment plants and opening culverted watercourses, to draw up proposals for optimising the monitoring plans and action programmes in line with the EU Water Framework Directive (WFD) and the EC Marine Strategy Framework Directive (MSFD).

Other project goals:

- Use modelling to determine the percentages of individual phosphorus sources i.e. drainage-, groundwater- and erosion paths as well as selective emissions from small sewage treatment plants
- Model the impact of measures and altered hydrological conditions on phosphorus losses
- For various arable crops, assess the risk of agricultural

phosphorus losses into water bodies by means of field trials and by using an application-oriented phosphorus index
> Examine how various phosphorus fractions contribute to water pollution and how they change along the course of a waterway
> Develop and test measures to reduce phosphorus inputs and/or control phosphorus retention
> Develop an overall concept for improving phosphorusretention
> Develop recommendations for regional and national planning authorities

IMPLEMENTATION

PhosWaM's implementation plan includes a variety of measures to transfer the project results into practice and ensure their continued use. The State Office of Agriculture and the Environment Mittleres Mecklenburg will cooperate closely with the other project partners during the implementation phase. The project results will be discussed in terms of their feasibility for the management planning process as laid out by the WFD and MSFD, and a catalogue of measures for reducing phosphorus levels will be developed. The measurements and analysis methods used will be aligned with existing measurement programmes. Together with the staff of the State Office of Agriculture and the Environment Mittleres Mecklenburg, a workshop will also be implemented for regional and local governmental decision makers, state offices, farmers, as well as water- and soil associations.

MODEL REGION

The studies focus on the catchment area of the river Warnow, the estuary Unterwarnow and the adjacent coastal waters of the Baltic Sea. At 3,324 km², the Warnow and Unterwarnow constitute the second largest German catchment area that drains into the Baltic Sea. The region is mainly agricultural and its hydrologic balance has been strongly altered by anthropogenic influences, particularly by agricultural drainage measures (drains).

OUTLOOK

A promising series of measurements will be secured through the intensified cooperation of the individual project partners on joint procedures and measuring points from the phosphorus sources to the sea. This will ensure the comparability of the results obtained from the various work packages along the entire gradient with the authorities' existing monitoring data. Measurements are now ongoing and analyses can begin as soon as the first data series are available.

Analysis of the nutrient inputs from drainage- and stream water at the Dummerstorf site. Removal of the samples from the autosampler, Photo: S. Jahn, IOW

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SeeZeichen

SEEZEICHEN – Tracer methods to identify groundwater- and inflow stratification and its impact on water quality and drinking water production

GETTING TO THE BOTTOM OF LAKE CONSTANCE

Maintaining a high water quality in Lake Constance is vitally important, particularly with regard to the long-term protection of drinking water quality and sustainable water pollution control. Achieving this goal poses a challenge, however, because the third-largest inland lake in Central Europe is subject to strong anthropogenic influences. In addition to the direct inflow of substances into the lake (e.g. the discharge of waste water), pollutants also enter the lake indirectly via various inflow routes, e.g. groundwater inflows, river water plumes and the atmosphere. The overarching goals of the SEEZEICHEN project are therefore to describe the inflow routes and their impact zones in the lake and to assess the impact of indirect inflows on the entire lake. The working hypothesis of the project states that each inflow route differs biologically, chemically, and physically from the lake water, i.e. that each has a specific water body signature or "fingerprint". The goal is to use these specific signatures to describe the interaction between the lake and the various inflow routes.

INTERIM RESULTS

In the "Tiefenschärfe" project (ISF, 2013 - 2016) topographic structures at the bottom of Lake Constance were localised which indicate the potential inflow of groundwater. In the SEEZEICHEN project, these sites are the focal points for studying the impact of groundwater on the water quality of Lake Constance. During the first half of the project, a study of the species composition of ostracods at the sediment-water interface provided evidence of groundwater exfiltration. At three sites (Mehrerau, Birnau, Überlingen) researchers came across groundwater-indicating species which were not found at other structures. In Mehrerau, water samples taken directly above the lake sediment also had typical groundwater signatures of stable isotopes (hydrogen and oxygen) and radon. It became evident, however, that the underground inflow is subject to seasonal fluctuations so all the relevant sites were sampled on a quarterly basis. Water samples were also analysed for other chemical parameters (cations, anions, hardness, rare earths) so that inflowing groundwater could be characterised more comprehensively. A new method for the two-dimensional mapping of

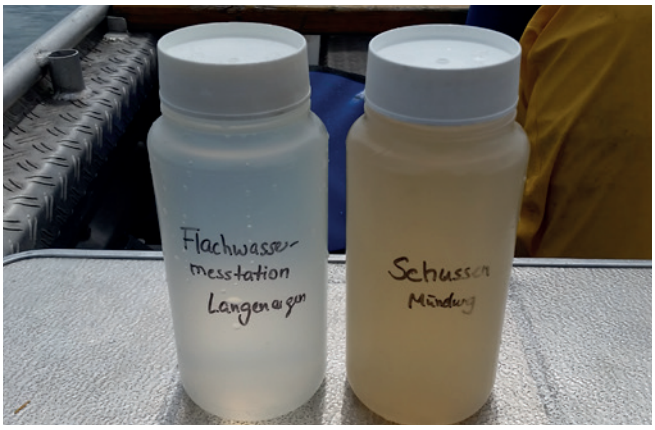
Series of measurements near the river plume of the Schussen River, Photo: LUBW

temperature anomalies on the lake bottom - the thermal mapping system - was also developed, tested and successfully implemented. Based on the hypothesis that the temperature of groundwater is constant all year round but that the temperature of seawater is subject to seasonal fluctuations, the temperatures at sites where there is groundwater exfiltration into the lake should differ from those around them. Targeted searches of the lake bed for areas with increased underground inflow were performed, and more qualitative and quantitative data was gathered and analysed at these sites. In addition to the lake-based studies, researchers began developing a numerical groundwater model which should allow a quantitative assessment of the long-time mean groundwater inflow into Lake Constance.

This is based on developing a conceptual hydrogeological model of the area around Lake Constance in which all system-relevant hydrogeological parameters are recorded and characterised. Surface inflows are the main sources of water- and substance loads into Lake Constance. Due to the different characteristics of their catchment areas with regard to flow dynamics, geology and anthropogenic impact, each river has a distinct signature which differs from that of the lake. Five representative tributaries (Alpenrhein, Bregenzer Ach, Argen, Schussen, Seefelder Aach) were sampled quarterly with regard to temperature, conductivity, an- and cations, hardness, nutrients, rare earths and isotopes. This is designed to identify the seasonal dynamics and to determine the combination of parameters which are best suited to describe the diffusion area of various rivers in the lake. On the Schussen River, the area where there is a river-lake interaction is also being studied directly.

The river was chosen because it flows into a shallow water zone which, compared to the rest of Lake Constance, is extensive and has been heavily anthropogenically impacted. Using a fixed measurement grid, temperature- and conductivity-depth profiles were determined once a month. Then this data was spatially interpolated for different depths in order to depict the spread of the river water. Based on the measurements on the Schussen River, a numerical pilot model was implemented which makes it possible to describe the ongoing distribution of the river water plume.

A three-dimensional hydrodynamic model of Lake Constance was also drawn up which looks at the tributaries and meteorological control variables in different spatial and temporal resolution. In a comprehensive sensitivity study the results of different model runs were compared with the water levels and temperatures which had been measured. This not only provides a tool for long-term simulations, but the retention times can also be determined and the spreading patterns of substance inflows from the river- and groundwater can be identified.



Water samples from Lake Constance and the river plume of the Schussen River, Photo: LUBW

OUTLOOK

The seasonal sampling of Lake Constance and of the groundwater inflows will continue and the scope of procedures will be expanded (e.g. through isotope online screening in Lake Constance, pore water sampling) as the project progresses. In addition, the collected data will be amalgamated and analysed using multi-parametric statistical methods which also serve to optimise and refine the models. The methods for detecting sources of pollution and transport processes are currently being tested and established at other lakes (e.g. Steißlinger See).

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