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Veröffentlichungen zu angewandt-wissenschaftlichen Studien mit Bezug zum Grundwasser der Schweiz

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**Ohne Gewähr / Ohne Anspruch auf Vollständigkeit
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Abstracts

Fachartikel Schweiz

1. Améliorer la gestion des ressources en eaux du karst

Le programme national de recherche PNR 61 « Gestion durable de l'eau » a pour but d'élaborer des bases pour la gestion future des ressources en eau. Il dispose d'un budget de 12 millions CHF et dure de janvier 2010 à décembre 2013. Un accent particulier est donné au savoir-faire pratique. Aqua & Gas présente ici le projet « les eaux karstiques, une ressource hydrique pour le future ? » au travers d'un dialogue entre un professionnel de l'eau et Pierre-Yves Jeannin, responsable du projet.

2. Nun ist die Politik am Zug

Gut drei Jahre nach Beginn der Forschungsarbeiten ist das Interreg-Projekt ALPEAU weitgehend abgeschlossen. Die an mehreren Standorten in Frankreich und in der Schweiz durchgeführten Untersuchungen haben die wissenschaftlichen Erkenntnisse über die effiziente Filterwirkung des Waldbodens für das Niederschlagwasser vertieft und erhärtet. Um diese wichtige Ökosystemleistung nachhaltig zu sichern, braucht es künftig mehr Investitionen in eine wasserschonende Waldbewirtschaftung. Nach der Wissenschaft ist nun also ein stärkeres Engagement der Politik gefragt, wie die Abschlussveranstaltung von ALPEAU in Evian und Lausanne gezeigt hat.

3. Goût et odeur de l'eau – Origine d'un goût de « terre moisie » apparu dans une eau de réseau

En mars 2011, un goût de terre moisie est apparu dans l'eau du réseau de la ville de la Chaux-de-Fonds et a suscité de multiples questions de la part des consommateurs. La ressource en eau responsable de ce mauvais goût a été mise à la vidange en attendant le rétablissement de la situation. Des investigations analytiques ont révélé que ce goût provenait du contact entre le chlore d'une eau traitée et l'eau d'une source suite à une fuite d'une conduite assurant le transport de l'eau traitée.

4. Grundwasserressourcen der Schweiz – Abschätzung von Kennwerten

Die Schweiz verfügt über reichhaltige Grundwasserressourcen, welche zu über 80% der öffentlichen Trinkwasserversorgung beitragen. Als Kennwerte dieser Ressource wurden zum einen das Grundwasservolumen und zum anderen das Grundwasserdargebot für die verschiedenen Grundwasserleitertypen bestimmt. Im Untergrund der Schweiz sind demnach insgesamt etwa 150 km³ Grundwasser vorhanden; davon sind gut 10% (ca. 18 km³) jährlich erneuerbar und können nachhaltig genutzt werden.

5. Anströmung von Fassungssträngen

Die Anströmung von Fassungssträngen eines sternförmigen Horizontalfilterbrunnens der Wasserversorgung Zürich wurde erstmals mittels geophysikalischer Bohrlochmessmethoden untersucht. Anhand der Messungen im Ruhezustand und im Förderbetrieb konnten die Strömungsverhältnisse im Nahbereich des Brunnens erkundet und quantifiziert werden. Für die Bewirtschaftung des Grundwasserfeldes Hardhof ergeben sich aus den Messergebnissen wichtige Grundlagen zum Aufbau eines nachhaltigen Brunnenmanagements und zur Bestimmung des aktuellen Leistungsfähigkeit sowie zur Verifizierung der hydraulischen Eigenschaften der Horizontalfilterbrunnen.

6. Ereignisbezogenes Pestizidmonitoring

Der Kanton Bern startete 2008 das Projekt „Gewässerzustand im Aaretal“ (GZA), um Fragen zum Fischrückgang zu klären und Beeinträchtigungen der Wasserqualität durch Schadstoffe wie Pestizide zu untersuchen. Die Ergebnisse des Pestizidmonitorings entsprechen für die meisten landwirtschaftlichen Pestizide den Erwartungen: Die Konzentrationen steigen während Abflussereignissen an. Allerdings zeigte sich auch, dass Biozide und Pestizide aus urbanen Quellen höhere Konzentrationsspitzen verursachen.

7. Klimaänderung und deren Auswirkungen auf die Grundwasserressourcen – Resultate des gleichnamigen Workshops

Die sich abzeichnende Klimaänderung wird sich auch auf das Grundwasser der Schweiz auswirken (BAFU 2012a). In diesem Zusammenhang organisierten die Arbeits-gruppe ‘<Klima und Grundwasser<< der Schweizerischen Gesellschaft für Hydrogeologie SGH und die Gruppe <<Grundwasserprojekte>> des Nationalen Forschungsprogramms NFP/PNR61 <<Nachhaltige Wassernutzung>> einen Workshop mit dem Titel <<Klimaänderung und deren Auswirkungen auf die Grundwasserressourcen>>. Der Workshop wurde am 11. Mai 2012 in Solothurn durchgeführt. Er hatte zum Ziel, einen Erfahrungsaustausch zwischen der Forschung und der Praxis zu ermöglichen. Das zentrale Thema war, wie im Grundwassersektor verschiedene Akteure aus Wissenschaft, Beratung, Planung, Wasserversorgung und Behörden mit den Fragen der Auswirkungen der Klimaänderung auf die Grundwasserressourcen umgehen.

8. Hydrothermal circulation systems of the Lavey-les-Bains, Saint-Gervais-les-Bains and Val d’Illiez areas associated with the Aiguilles Rouges Massif in Switzerland and France

The three studied hydrothermal systems are located around the Aiguilles Rouges Massif, one of the external crystalline massifs in the Western Alps. The general aim is to gather all the information in a paper and to provide a better description of these systems by comparison of their geological, hydrogeological, geochemical and isotopic properties. Lavey-les-Bains in Switzerland and Saint-Gervais-les-Bains in France represent the two low-elevation points of the Aiguilles Rouges basement, respectively on the north-eastern and south-western sides. The chemical and isotopic properties of these waters present similarities. The thermal component $\text{Na-SO}_4 > \text{Cl}$ for both sites was infiltrated before nuclear weapons atmospheric tests (< 1953). In contrast, Val d’Illiez in Switzerland is located out of the Aiguilles Rouges basement in a sedimentary domain belonging to the autochthonous cover outcropping along the north-western edge of the basement. The Val d’Illiez deep flow system produces a Ca-SO_4 -rich and low-Cl thermal water and its residence time is quite younger (about 5 years). For the studied thermal waters, the average elevation of the recharge zones seems to be similar, of around 1700-2100 meters, but the fluid temperatures at depth would be quite different. Indeed, the reservoir temperature would reach 100-110 °C for Lavey-les-Bains and 70-80 °C for Saint-Gervais-les-Bains, whereas it would be lower than 40 °C for Val d’Illiez.

9. A chromate-contaminated site in southern Switzerland - Part 1: Site characterization and the use of Cr isotopes to delineate fate and transport

The risk of groundwater contamination by chromate at a former chromite ore processing industrial site in Rivera (Switzerland) was assessed by determining subsoil Cr(VI) concentrations and tracking naturally occurring Cr(VI) reduction with Cr isotopes. Using a hot alkaline extraction procedure, a total Cr(VI) contamination of several 1000 kg was estimated. Jarosite, $KFe_3((SO_4)_x(CrO_4)_{1-x})(2)(OH)_6$, and chromatite ($CaCrO_4$) were identified as Cr(VI) bearing mineral phases using XRD, both limiting groundwater Cr(VI) concentrations. To track assumed Cr(VI) reduction at field scale delta Cr-53 values of contaminated subsoil samples in addition to groundwater delta Cr-53 data are used for the first time. The measurements showed a fractionation of groundwater delta Cr-53 values towards positive values and subsoil delta Cr-53 towards negative values confirming reduction of soluble Cr(VI) to insoluble Cr(III). Using a Rayleigh fractionation model, a current Cr(VI) reduction efficiency of approximately 31% along a 120 m long flow path was estimated at an average linear groundwater velocity of 3.3 m/d. Groundwater and subsoil delta Cr-53 values were compared with a site specific Rayleigh fractionation model proposing that subsoil delta Cr-53 values can possibly be used to track previous higher Cr(VI) reduction efficiency during the period of industrial activity. The findings strongly favor monitored natural attenuation to be part of the required site remediation measures. (C) 2011 Elsevier Ltd. All rights reserved.

10. A chromate-contaminated site in southern Switzerland - Part 2: Reactive transport modeling to optimize remediation options

A 2D horizontal reactive transport model of a chromate-contaminated site near Rivera, Switzerland, was developed using the computer code CrunchFlow to evaluate site remediation strategies. Transport processes were defined according to the results of an existing hydrological model, and the definition of geochemical (reactive) processes is based on the results of a detailed mineralogical and geochemical site characterization leading to a comprehensive conceptual site model. Kinetics of naturally occurring Cr(VI) reduction by Fe(II) and natural solid organic matter is quantified by fitting measured Cr isotope ratios to a modeled 1D section along the best constrained flow line. The simulation of Cr isotope fractionation was also incorporated into the 2D model. Simulation of the measured present day Cr(VI) plume and delta Cr-53 value distribution was used for the 2D model calibration and corresponds to a situation where only monitored natural attenuation (MNA) is occurring. Other 2D model runs simulate alternate excavation scenarios. The simulations show that with an excavation of the top 2-4 m the groundwater Cr(VI) plume can be minimized, and that a deeper excavation depth only diminishes the plume if all the contaminants can be removed. A combination of an excavation of the top 2-4 m and monitoring of the ongoing natural Cr(VI) reduction is suggested as the most ecological and economical remediation strategy, even though a remaining time period with ongoing subsoil Cr(VI) contamination in the order of 1 ka is predicted. (C) 2011 Elsevier Ltd. All rights reserved.

11. Colloid generation during water flow transients

In quasi-stagnant groundwater aquifer colloids are found to have constant concentration and size distribution under constant flow conditions. In transient conditions induced by water flow rate variations, increases of colloid concentration and size distribution are observed. The present study focuses on colloids from water of a well instrumented short bore hole in the water bearing fissure around the migration zone of the laboratory tunnel at the Grimsel Test Site, Switzerland. The low ionic strength groundwater makes the colloid suspension stable. In this system, increases in concentration and size distribution by factors of 1.5-30, according to the colloid size (50-2000 nm), are observed when the flow rate increases, as a pulse, by factors of 20-40 in 6-10 s. Colloid generation by flow transient requires a minimum impulse (threshold) that is colloid size dependant. (C) 2012 Elsevier Ltd. All rights reserved.

12. Increasing chloride concentrations in Lake Constance: characterization of sources and estimation of loads

The chloride concentration in Lake Constance, by volume the second largest lake in Europe, has increased by a factor of 2.4 during the past 40 years. Based on a chloride budget for the year 2006, we estimated total chloride imports to the catchment at 101 kt year⁻¹. Road deicing salts contributed 52%, waste water 23%, farming 11%, soil weathering 9%, precipitation and solid waste incineration 3% to this import. River monitoring programs in Switzerland, Germany, and Austria in 2006 traced an average total chloride export from the catchment into Lake Constance of almost 70 kt and an export from the lake of 56 kt. About one-third of this load to the lake originated from the Alpine Rhine catchment (Switzerland), and about 60% from various smaller tributaries in Austria and Germany. The average annual import of chloride to Lake Constance for the years 1995-2007 was 60 kt, the export almost 57 kt. This budget is in good agreement with the observed increase in the chloride content of the lake and thus confirms the appropriateness and quality of the long-term monitoring program conducted by Swiss, German and Austrian laboratories. For the year 2006, we estimated that about 65% of the chloride spread onto roads for deicing and manure on cultivated land reached the lake within the year of their application. The missing 35% remained transiently in the soil and groundwater of the catchment.

13. Occurrence of uranium in Swiss drinking water

The results of a nationwide survey of uranium in Swiss drinking water are reported. Elevated concentrations of uranium in groundwater are found mainly in the alpine regions and can be traced back to the geology of the bedrock. Water sources were systematically surveyed and analysed for the presence of Li, B, Si, Sc, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Sr, Cd, Sn, Sb, Ba, Tl, Pb and U and the results were analysed to determine if any correlation with uranium concentration was apparent. No correlation was found. The results are interpreted in relation to the current WHO guideline and those of other countries with a view to determining which areas would be affected if a maximum value were to be adopted and which areas require further investigation. Uranium content varied considerably, from below the limit of detection to almost 100µg/L⁻¹. Of the 5548 data samples, 98% are below the 2004 WHO provisional guideline value of 15µg/L⁻¹ and 99.7% below the revised (2011) value of 30µg/L⁻¹. Copyright 2011 Elsevier Ltd. All rights reserved.

14. Karstification of an aquifer along the Birs river, Switzerland - A modeling approach

The impact, caused by a construction of a dam site on the Birs river close to Basel (Switzerland), on the evolution of a gypsum-karst aquifer in the vicinity of the hydraulic building, is studied. Several sinkholes provoked subsidence of the dam and the highway nearby. Extensive technical measures had to be conducted in order to prevent further karstification. The numerous geophysical and geological field studies executed in the area, together with a 3D hydrogeological model of the aquifer, provide a very detailed information about the boundary conditions, and the local properties determining the karstification. In this work, we present a 2D karst evolution model of the aquifer in the vicinity of the dam structure. In contrast to older studies, this time the focus of the research is not the basic processes governing the karst evolution, but modeling the temporal development of the real aquifer. Using the large amount of information about the location, we demonstrate that a detailed knowledge of the local properties of the rock (hydraulic conductivity, solubility) is of crucial importance when modeling real aquifers. From a wide range of possible evolution scenarios, we deduce a warning that solutional features, such as sinkholes, can develop far away from the hydraulic structure and endanger facilities at the surface. Our model is able to reproduce and successfully explain the main geological features revealed by field studies. We suggest a workflow to combine the data from field observations, groundwater modeling, and karst evolution modeling and to study the karstification of real aquifers. We propose a scenario for the evolution of the aquifer and a reasonable range for the values of the basic parameters governing the karstification. (C) 2012 Elsevier B.V. All rights reserved.

15. Temperature-driven meltwater production and hydrochemical variations at a glaciated alpine karst aquifer: implication for the atmospheric CO₂ sink under global warming

About two hydrological years of continuous data of discharge, temperature, electrical conductivity and pH have been recorded at the Glarey spring in the Tsanfleuron glaciated karst area in the Swiss Alps, to understand how glaciated karst aquifer systems respond hydrochemically to diurnal and seasonal recharge variations, and how calcite dissolution by glacial meltwater contributes to

the atmospheric CO₂ sink. A thermodynamic model was used to link the continuous data to monthly water quality data allowing the calculation of CO₂ partial pressures and calcite saturation indexes. The results show diurnal and seasonal hydrochemical variations controlled chiefly by air temperature, the latter influencing karst aquifer recharge by ice and snowmelt. Karst process-related atmospheric CO₂ sinks were more than four times higher in the melting season than those in the freezing season. This finding has implication for understanding the atmospheric CO₂ sink in glaciated carbonate rock terrains: the carbon sink will increase with increasing runoff caused by global warming, i.e., carbonate weathering provides a negative feedback for anthropogenic CO₂ release. However, this is a transient regulation effect that is most efficient when glacial meltwater production is highest, which in turn depends on the future climatic evolution.

16. Membrane Inlet Mass Spectrometer for the Quasi-Continuous On-Site Analysis of Dissolved Gases in Groundwater

We developed a stand-alone system based on a membrane inlet mass spectrometer (MIMS) for measuring dissolved gas concentrations in groundwater under field conditions. The system permits the concentrations of dissolved gases (He, Ar, Kr, N₂, and O₂) in groundwater to be determined quasi-continuously (every 12 min) with a precision of better than 4% for He and Kr, and with a precision of 1% for Ar, N₂, and O₂ in air-saturated water. The detection limits are below 3×10^{-9} cmSTP μ g for the noble gases and below 400×10^{-9} cmSTP μ g for N₂ and O₂. The results of a first deployment of the system in the field indicate that changes in the concentration of Ar that result from diel fluctuations of 3 °C in the river water temperature were still able to be resolved in groundwater, although the corresponding temperature signal almost vanished.

17. Intensified organic carbon dynamics in the ground water of a restored riparian zone

1. River restoration projects usually aim at improving the physical habitat for aquatic organisms. The extent to which biogeochemical processes and microbial activities are intensified in restored river reaches remains uncertain. 2. Here, we investigated the relationships between the distribution and composition of organic carbon (OC), bacterial secondary carbon production and extracellular enzymatic activity (EEA) in the ground water below a restored riparian section of the River Thur, Switzerland, relative to a channelised section. The spatiotemporal variability in the stable C isotopic ratio, dissolved OC polydispersity (the distribution of molecular mass in a mixture of molecules) as well as bacterial abundance, EEA and secondary production were investigated in different process zones. 3. At high river discharge, humic as well as low molecular weight amphiphilic substances infiltrated into the subsurface in a zone dominated by the pioneer plants *Salix viminalis* (willow bush). Concurrently, bacterial abundance, EEA and secondary carbon production increased at this location. 4. The willow plants leached bioavailable substrates into the ground water when the water table was high. The flood-driven soilgroundwater coupling stimulated EEA and bacterial secondary production of the suspended groundwater bacterial community. 5. Establishing riparian habitat diversity adds hot spots of OC inputs during flood events, potentially providing valuable ecosystem services (e.g. degradation of organic pollutants) that accompany.

18. Equilibrium Helium Partitioning in the Rock-Water System: New Prospects for Dating Ancient Groundwater

The estimation of the mobility of ancient groundwater provides clues to a number of fundamental and applied problems. The U(Th)-He system is a promising tool for dating ancient waters. This study focused on the recently proposed method of the reconstruction of helium concentration in groundwater. The method is based on equilibrium in the mineral-water system which allows us to avoid direct sampling of water from boreholes. Some minerals contain excess helium migrating from the ambient groundwater into the internal helium-accessible volume (HAV) of grains. For this study, quartz was sampled from the sandstones of the 1000-m-thick Permian-Carboniferous sedimentary sequence of the Molasse Basin in northern Switzerland. The HAV of the quartz concentrate was determined via helium saturation of samples under controlled conditions and subsequent helium analysis as 0.066 +/- 0.037% of the bulk sample volume (hereafter, mean values for the sequence are given). The measurement of helium concentration in initial samples allowed us to determine the partial pressure of helium in the gas phase of HAV as 0.47 +/- 0.16 atm; the concentration of helium in the pore water was calculated as the product of pressure and the Henry solubility constant corresponding to the conditions of natural rock occurrence: 0.0036 +/- 0.0016 cm³ STP (He)/cm³ (H₂O). This estimate based on mineral-water equilibrium is in good agreement with the results of direct measurements of helium content in water from the two aquifers

of the Permian-Carboniferous sequence of the Molasse Basin, where helium concentrations were found to be 0.0045 and 0.0016 cm³ STP (He)/cm³ (H₂O). The obtained results validated the method. A necessary prerequisite for its application is the equilibrium of helium concentrations in the water-HAV system. The investigation of helium mobility in quartz grains (through the measurement of helium release rates from the grains under isothermal heating at different temperatures) allowed us to estimate the time of equilibration as approximately 103 yr, which is much shorter than the helium residence time in the Permian-Carboniferous sequence of the basin (more than 107 yr). Using quartz grains as detectors of helium concentration in pore waters, it was shown that the waters of the whole sequence are stagnant, and the sequence is appropriate for the disposal of high-level radioactive wastes.

19. Estimating traveltimes and groundwater flow patterns using 3D time-lapse crosshole ERT imaging of electrical resistivity fluctuations induced by infiltrating river water

The infiltration of river water into aquifers is of high relevance to drinking-water production and is a key driver of biogeochemical processes in the hyporheic and riparian zone, but the distribution and quantification of the infiltrating water are difficult to determine using conventional hydrological methods (e.g., borehole logging and tracer tests). By time-lapse inverting crosshole ERT (electrical resistivity tomography) monitoring data, we imaged groundwater flow patterns driven by river water infiltrating a perialpine gravel aquifer in northeastern Switzerland. This was possible because the electrical resistivity of the infiltrating water changed during rainfall-runoff events. Our time-lapse resistivity models indicated rather complex flow patterns as a result of spatially heterogeneous bank filtration and aquifer heterogeneity. The upper part of the aquifer was most affected by the river infiltrate, and the highest groundwater velocities and possible preferential flow occurred at shallow to intermediate depths. Time series of the reconstructed resistivity models matched groundwater electrical resistivity data recorded on borehole loggers in the upper and middle parts of the aquifer, whereas the resistivity models displayed smaller variations and delayed responses with respect to the logging data in the lower part. This study demonstrated that crosshole ERT monitoring of natural electrical resistivity variations of river infiltrate could be used to image and quantify 3D bank filtration and aquifer dynamics at a high spatial resolution.

20. Imaging and quantifying salt-tracer transport in a riparian groundwater system by means of 3D ERT monitoring

Determining groundwater flow paths of infiltrated river water is necessary for studying biochemical processes in the riparian zone, but their characterization is complicated by strong temporal and spatial heterogeneity. We investigated to what extent repeat 3D surface electrical resistance tomography (ERT) can be used to monitor transport of a salt-tracer plume under close to natural gradient conditions. The aim is to estimate groundwater flow velocities and pathways at a site located within a riparian groundwater system adjacent to the perialpine Thur River in northeastern Switzerland. Our ERT time-lapse images provide constraints on the plume's shape, flow direction, and velocity. These images allow the movement of the plume to be followed for 35 m. Although the hydraulic gradient is only 1.43 parts per thousand, the ERT time-lapse images demonstrate that the plume's center of mass and its front propagate with velocities of 2×10^{-4} m/s and 5×10^{-4} m/s, respectively. These velocities are compatible with groundwater resistivity monitoring data in two observation wells 5 m from the injection well. Five additional sensors in the 5-30 m distance range did not detect the plume. Comparison of the ERT time-lapse images with a groundwater transport model and time-lapse inversions of synthetic ERT data indicate that the movement of the plume can be described for the first 6 h after injection by a uniform transport model. Subsurface heterogeneity causes a change of the plume's direction and velocity at later times. Our results demonstrate the effectiveness of using time-lapse 3D surface ERT to monitor flow pathways in a challenging perialpine environment over larger scales than is practically possible with crosshole 3D ERT.

21. Reversible rock-slope deformations caused by cyclic water-table fluctuations in mountain slopes of the Central Alps, Switzerland

Within the framework of the Gotthard Base Tunnel Project in the Central Alps, Switzerland, geodetic monitoring networks were installed above the tunnel trajectory in alpine valleys. Natural ground-surface deformation recorded in the years prior to the tunneling excavation was seen to contain an unexpectedly large cyclical component of horizontal strain across the valleys, which was seasonal and appeared to be due to elastic processes. The strain is strongly correlated with snow

melt and rainstorm precipitation, suggesting the implied rock-mass deformation is driven by changes in water-table elevation within adjacent mountain slopes. The horizontal strains are of the order of $1-2 \cdot 10^{-5}$, which is close to the design limits that can be accommodated by hydropower arch dams in the study area. This study investigates these processes in detail and describes a new mathematical model (REROD), which is able to accurately reproduce and predict such natural rock-slope displacements. The model implements a transfer-function approach to predict the valley-crossing strains from rainfall and winter snow height data recorded at nearby meteorological stations. It has been used to estimate and remove the natural strain signal from the net recorded deformation so as to resolve the component due to tunneling.

22. Mixing law versus discharge and electrical conductivity relationships: application to an alpine proglacial stream

Mixing laws have been used in hydrogeology for decades. In glacial hydrology, they are used to determine the contributions of the different reservoirs supplying the proglacial stream. However, some assumptions about discharge-solute matter and discharge-electrical conductivity (EC) relationships have led to erroneous conclusions. Analysis of a theoretical example indicated a hyperbolic relationship between discharge and solute matter concentration/EC for two reservoirs. We applied this approach to experimental data from the Baounet Glacier (Savoie, France), assuming that the proglacial stream is provided by a combination of watershed groundwater flow (diurnally stable and with high EC) and quick drainage from the glacier (low EC and discharge that change very quickly). Applying mixing laws allowed us to characterise these two flows and to separate the quick flows (glacial ablation and rainfalls). Copyright (c) 2011 John Wiley & Sons, Ltd.

23. Investigating riparian groundwater flow close to a losing river using diurnal temperature oscillations at high vertical resolution

River-water infiltration is of high relevance for hyporheic and riparian groundwater ecology as well as for drinking water supply by river-bank filtration. Heat has become a popular natural tracer to estimate exchange rates between rivers and groundwater. However, quantifying flow patterns and velocities is impeded by spatial and temporal variations of exchange fluxes, insufficient sensors spacing during field investigations, or simplifying assumptions for analysis or modeling such as uniform flow. The objective of this study is to investigate lateral shallow groundwater flow upon river-water infiltration at the shoreline of the riverbed and in the adjacent riparian zone of the River Thur in northeast Switzerland. Here we have applied distributed temperature sensing (DTS) along optical fibers wrapped around tubes to measure high-resolution vertical temperature profiles of the unsaturated zone and shallow riparian groundwater. Diurnal temperature oscillations were tracked in the subsurface and analyzed by means of dynamic harmonic regression to extract amplitudes and phase angles. Subsequent calculations of amplitude attenuation and time shift relative to the river signal show in detail vertical and temporal variations of heat transport in shallow riparian groundwater. In addition, we apply a numerical two-dimensional heat transport model for the unsaturated zone and shallow groundwater to obtain a better understanding of the observed heat transport processes in shallow riparian groundwater and to estimate the groundwater flow velocity. Our results show that the observed riparian groundwater temperature distribution cannot be described by uniform flow, but rather by horizontal groundwater flow velocities varying over depth. In addition, heat transfer of diurnal temperature oscillations from the losing river through shallow groundwater is influenced by thermal exchange with the unsaturated zone. Neglecting the influence of the unsaturated zone would cause biased interpretation and underestimation of groundwater flow velocities. The combination of high resolution field data and modeling shows the complex hydraulic and thermal processes occurring in shallow riparian groundwater close to losing river sections as well as potential errors sources for interpreting diurnal temperature oscillations in such environments.

24. Measurement of spatial and temporal fine sediment dynamics in a small river

Empirical measurements on fine sediment dynamics and fine sediment infiltration and accumulation have been conducted worldwide, but it is difficult to compare the results because the applied methods differ widely. We compared common methods to capture temporal and spatial dynamics of suspended sediment (SS), fine sediment infiltration and accumulation and tested them for their suitability in a small, canalized river of the Swiss Plateau. Measurement suitability was assessed by data comparison, relation to hydrological data and in the context of previously published data. SS concentration and load were assessed by optical backscatter (OBS) sensors

and SS samplers. The former exhibit a better temporal resolution, but were associated with calibration problems. Due to the relatively low cost and easy mounting of SS samplers, they can provide a higher spatial distribution in the river's cross section. The latter resulted in a better correlation between sediment infiltration and SS load assessed by SS samplers than SS concentrations measured with OBS sensors. Sediment infiltration baskets and bedload traps capture the temporal and spatial distribution of fine sediment infiltration. Data obtained by both methods were positively correlated with water level and SS. In contrast, accumulation baskets do not assess the temporal behaviour of fine sediment, but the net accumulation over a certain time period. Less fine sediment accumulated in upwelling zones and within areas of higher mean water level due to scouring of fine sediments. Even though SS and sediment infiltration assessed with the bedload traps increased from up- to downstream, less fine sediment accumulated downstream. This is probably also attributable to more scouring downstream.

25. Spatial variability of herbicide mobilisation and transport at catchment scale: insights from a field experiment

During rain events, herbicides can be transported from their point of application to surface waters, where they may harm aquatic organisms. Since the spatial pattern of mobilisation and transport is heterogeneous, the contributions of different fields to the herbicide load in the stream may vary considerably within one catchment. Therefore, the prediction of contributing areas could help to target mitigation measures efficiently to those locations where they reduce herbicide pollution the most. Such spatial predictions require sufficient insight into the underlying transport processes. To improve the understanding of the process chain of herbicide mobilisation on the field and the subsequent transport through the catchment to the stream, we performed a controlled herbicide application on corn fields in a small agricultural catchment (ca. 1 km²) with intensive crop production in the Swiss Plateau. Water samples were collected at different locations in the catchment (overland flow, tile drains and open channel) for two months after application in 2009, with a high temporal resolution during rain events. We also analysed soil samples from the experimental fields and measured discharge, groundwater level, soil moisture and the occurrence of overland flow at several locations. Several rain events with varying intensities and magnitudes occurred during the study period. Overland flow and erosion were frequently observed in the entire catchment. Infiltration excess and saturation excess overland flow were both observed. However, the main herbicide loss event was dominated by infiltration excess. Despite the frequent and widespread occurrence of overland flow, most of this water did not reach the channel directly, but was retained in small depressions in the catchment. From there, it reached the stream via macropores and tile drains. Manholes of the drainage system and storm drains for road and farmyard runoff acted as additional shortcuts to the stream. Although fast flow processes such as overland and macropore flow reduce the influence of the herbicide's chemical properties on transport due to short travel times, sorption properties influenced the herbicide transfer from ponding overland flow to tile drains (macropore flow). However, no influence of sorption was observed during the mobilisation of the herbicides from soil to overland flow. These observations on the role of herbicide properties contradict previous findings to some degree. Furthermore, they demonstrate that valuable insight can be gained by making spatially detailed observations along the flow paths.

26. Geophysical imaging of shallow subsurface topography and its implication for shallow landslide susceptibility in the Urseren Valley, Switzerland

Landslides and soil erosion are an ever present threat to water management, building construction, vegetation formation and biodiversity in the Swiss Alps. Improved understanding of the mechanics and causative factors of soil erosion is a key factor in mitigation of damage to Alpine natural resources. Recently, much progress has been achieved in the forecasting of landslides on Alpine slopes with a new generation of shallow landslide models. These models perform well in spatial predictions, but temporal control on the occurrence of shallow landslides is less successful. Realistic soil composition and geometry of interfaces are necessary input for better predictions. Geophysical methods have so far not been widely considered to obtain these parameters, in spite of their ability to cover much ground with high-resolution. In this study we successfully use such methods to derive adequate subsurface topography as input to dynamic spatially distributed hydrological and soil mechanical models. Trench, GPS, electrical resistivity tomography and ground penetrating radar data were collected, resulting in revealing images of the composition and geometry of past and future landslides. A conceptual model for the occurrence of local shallow landslides is derived, spanning from block-wise steady creep of detaching soil units to rapid sliding and downslope deposition of soil units via varying sliding planes. Significant topography was

observed in the soil interfaces acting as sliding planes, leading to a more complex role of groundwater flow in the initiation of shallow landslides. Hydrogeologic models should be revised accordingly. (c) 2012 Elsevier B.V. All rights reserved.

27. A laboratory experiment for determining both the hydraulic and diffusive properties and the initial pore-water composition of an argillaceous rock sample: A test with the Opalinus clay (Mont Terri, Switzerland)

Argillaceous formations are thought to be suitable natural barriers to the release of radionuclides from a radioactive waste repository. However, the safety assessment of a waste repository hosted by an argillaceous rock requires knowledge of several properties of the host rock such as the hydraulic conductivity, diffusion properties and the pore water composition. This paper presents an experimental design that allows the determination of these three types of parameters on the same cylindrical rock sample. The reliability of this method was evaluated using a core sample from a well-investigated indurated argillaceous formation, the Opalinus Clay from the Mont Terri Underground Research Laboratory (URL) (Switzerland). In this test, deuterium- and oxygen-18-depleted water, bromide and caesium were injected as tracer pulses in a reservoir drilled in the centre of a cylindrical core sample. The evolution of these tracers was monitored by means of samplers included in a circulation circuit for a period of 204 days. Then, a hydraulic test (pulse-test type) was performed. Finally, the core sample was dismantled and analysed to determine tracer profiles. Diffusion parameters determined for the four tracers are consistent with those previously obtained from laboratory through-diffusion and in-situ diffusion experiments. The reconstructed initial pore-water composition (chloride and water stable-isotope concentrations) was also consistent with those previously reported. In addition, the hydraulic test led to an estimate of hydraulic conductivity in good agreement with that obtained from in-situ tests. (C) 2011 Elsevier B.V. All rights reserved.

28. Assessing the Cr(VI) reduction efficiency of a permeable reactive barrier using Cr isotope measurements and 2D reactive transport modeling

In Thun, Switzerland, a permeable reactive barrier (PRB) for Cr(VI) reduction by gray cast iron was installed in May 2008. The PRB is composed of a double array of vertical piles containing iron shavings and gravel. The aquifer in Thun is almost saturated with dissolved oxygen and the groundwater flow velocities are ca. 10–15 m/day. Two years after PRB installation Cr(VI) concentrations still permanently exceed the Swiss threshold value for contaminated sites downstream of the barrier at selected localities. Groundwater $\delta^{53/52}\text{Cr}_{\text{SRM979}}$ measurements were used to track Cr(VI) reduction induced by the PRB. $\delta^{53/52}\text{Cr}_{\text{SRM979}}$ values of two samples downstream of the PRB showed a clear fractionation towards more positive values compared to four samples from the hotspot, which is clear evidence of Cr(VI) reduction induced by the PRB. Another downstream sample did not show a shift to more positive $\delta^{53/52}\text{Cr}_{\text{SRM979}}$ values. Because this latter location correlates with the highest downstream Cr(VI) concentration it is proposed that a part of the Cr(VI) plume is bypassing the barrier. Using a Rayleigh fractionation model a minimum present-day overall Cr(VI) reduction efficiency of ca. 15% was estimated. A series of 2D model simulations, including the fractionation of Cr isotopes, confirm that only a PRB bypass of parts of the Cr(VI) plume can lead to the observed values. Additionally, the simulations revealed that the proposed bypass occurs due to an insufficient permeability of the individual PRB piles. It is concluded that with this type of PRB a complete and long-lasting Cr(VI) reduction is extremely difficult to achieve for Cr(VI) contaminations located in nearly oxygen and calcium carbonate saturated aquifer in a regime of high groundwater velocities. Additional remediation action would limit the environmental impact and allow to reach target concentrations. (C) 2012 Elsevier B.V. All rights reserved.

29. A comparison study of two different control criteria for the real-time management of urban groundwater works

We present the comparison of two control criteria for the real-time management of a water well field. The criteria were used to simulate the operation of the Hardhof well field in the city of Zurich, Switzerland. This well field is threatened by diffuse pollution in the subsurface of the surrounding city area. The risk of attracting pollutants is higher if the pumping rates in four horizontal wells are increased, and can be reduced by increasing artificial recharge in several recharge basins and infiltration wells or by modifying the artificial recharge distribution. A three-dimensional finite

elements flow model was built for the Hardhof site. The first control criterion used hydraulic head differences (Delta h-criterion) to control the management of the well field and the second criterion used a path line method (%s-criterion) to control the percentage of inflowing water from the city area. Both control methods adapt the allocation of artificial recharge (AR) for given pumping rates in time. The simulation results show that (1) historical management decisions were less effective compared to the optimal control according to the two different criteria and (2) the distribution of artificial recharge calculated with the two control criteria also differ from each other with the %s-criterion giving better results compared to the Delta h-criterion. The recharge management with the %s-criterion requires a smaller amount of water to be recharged. The ratio between average artificial recharge and average abstraction is 1.7 for the Delta h-criterion and 1.5 for the %s-criterion. Both criteria were tested online. The methodologies were extended to a real-time control method using the Ensemble Kalman Filter method for assimilating 87 online available groundwater head measurements to update the model in real-time. The results of the operational implementation are also satisfying in regard of a reduced risk of well contamination. (C) 2012 Elsevier Ltd. All rights reserved.

30. Bioavailability and diagenetic state of dissolved organic matter in riparian groundwater

Riparian groundwater can exhibit considerable patchiness in the concentration and reactivity of dissolved organic matter (DOM), which ultimately shapes subsurface biogeochemical transformations. Free and combined amino acids are bioavailable constituents of DOM, and their concentration and composition can provide valuable information about the diagenetic state of DOM. Based on riparian groundwater samples and relevant DOM end-member samples, we adapted the amino-acid-based marine DOM degradation index (DI) to groundwater. The groundwater DI was applied to evaluate the spatial and temporal variability in the bioavailability and diagenetic state of riparian DOM in a restored and a channelized section of the River Thur, Switzerland. Among different indicators for DOM diagenetic state (total hydrolysable amino acid concentrations, C-normalized yields, and the contribution of nonprotein amino acids), the groundwater DI correlated best with the activity of the enzyme leucine-aminopeptidase and bacterial secondary production in riparian groundwater. The "freshest" DOM was consistently found in the channel and during high-flow conditions in the groundwater of the restored riparian section and was spatially constrained to a zone inhabited by a dense willow population. The use of amino acid data and the newly developed DI for DOM in groundwater is a promising approach for characterizing the spatial and temporal dynamics of DOM reactivity and diagenesis within riparian groundwater.

31. Diurnal fluctuations of electrical conductivity in a pre-alpine river: Effects of photosynthesis and groundwater exchange

Diurnal fluctuations of dissolved oxygen (DO) concentration and pH due to photosynthesis and respiration are commonly observed in rivers that support periphyton growth. Diurnal fluctuations of electrical conductivity (EC) in connection with photosynthesis have also been reported, but mostly in small, first-order streams or in streams fed by karst springs. The objective of this study is to examine the diurnal EC fluctuations in a large river and understand biological, chemical, and hydrological processes controlling the fluctuations, using long-term archived data, focused field monitoring, and laboratory experiments. The study was conducted in the Thur River draining a 1700 km² catchment in northeastern Switzerland. The river showed distinct diurnal fluctuations of DO and pH caused by photosynthesis and respiration except during December and part of January. Fluctuations were frequently disrupted by spates with peak discharge exceeding 150 m³ s⁻¹, which removed biofilm and periphyton. During a period of low flow (12 m³ s⁻¹) and clear sky, photosynthesis released O₂ and consumed CO₂ in water during the daytime, thereby increasing pH and the saturation index of calcite. This caused calcite to precipitate and removed Ca and alkalinity from water, and reduced EC. Laboratory experiments showed that the increase in pH and the saturation index alone cannot cause calcite precipitation without the presence of periphyton. It is likely that the precipitation occurs in the microenvironment in the close vicinity of photosynthesizing cells, where the pH and the calcite saturation index are much higher than in the bulk river water. Calcite precipitation stopped during the nighttime despite supersaturated conditions, and EC gradually increased presumably due to the input of Ca and alkalinity by groundwater exchange. The study clearly showed that photosynthesis and calcite precipitation have a strong influence on the chemistry of the large river, and pointed out the need for future research examining the biogeochemical processes in the microenvironment surrounding periphyton, and the roles of river-groundwater exchange processes. (c) 2012 Elsevier B.V. All

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32. Karstification beneath the Birs weir in Basel/Switzerland: A 3D modeling approach

We present a three-dimensional model describing the evolution of a gypsum karst aquifer along the Birs river near Basel in Switzerland. Here, a small dam-site was built in 1890 to generate hydroelectric power. After subsidence of a nearby highway, geophysical and geological field studies have been carried out and a detailed hydrogeological model has been developed. These observations identified a karstified weathered zone as the reason for the subsidence. To prevent any further damage, remedial construction measures have been carried out. We employ our numerical model KARSTQUIFIER, which simulates the temporal evolution of a karst system by dissolution, increasing the porosity in the aquifer. We used results from geological and geophysical investigations as a priori information for implementing the initial boundary conditions into our three-dimensional numerical model. Our model accounts for topography, precipitation and geology and especially for the anisotropy of the local bedrock. It can successfully reproduce the weathered zone in its current horizontal and vertical extent. We can also simulate the possible evolution of the aquifer following a remedial construction phase. Therefore, taken together with the geophysical and geological observations and the groundwater model, our three-dimensional karst aquifer evolution model enhances the understanding of the development of this heterogeneous karst aquifer system. (C) 2012 Elsevier B.V. All rights reserved.

33. Principal component analysis of time series for identifying indicator variables for riverine groundwater extraction management

Although alluvial aquifers connected to rivers can be a rich source of drinking water, they are susceptible to contamination by infiltrating river water. The processes governing river-groundwater interaction are variable in time and space. Natural filtration mechanisms are often not sufficient during high discharge events in the river. To capture the dynamics of river-groundwater interaction, indicator parameters that can serve as proxies for river water infiltration need to be derived. Principal component analysis of continuously measured time series was used to identify indicator wells and derive indicator parameters for a study area in NW Switzerland. The results showed different sources of variation in the parameters, including river stage fluctuations. The multivariate approach highlighted differences between observation wells based on the response of the measured parameters to effects of damping and delay of the input signals. Three observation wells were shown to be representative of river-groundwater interaction dynamics in the study area. Of the three parameters analysed, groundwater head and electrical conductivity are recommended as a combined proxy for river water infiltration in the study area. In contrast, temperature proved not to be a reliable indicator. (C) 2012 Elsevier B.V. All rights reserved.

34. Arsenic sequestration by organic sulphur in peat

Wetlands cover more than 6% of the global ice-free land area, and have been recognized as important sinks for arsenic. Wetland soils and sediments are subject to frequent changes in redox conditions, driven by fluctuations in the water table and shifts in biological activity. Under oxic conditions, natural organic matter promotes arsenic release from metal-(hydr)oxides, thereby enhancing arsenic mobility. Under strongly reducing conditions, however, organic matter triggers the formation of arsenic-sequestering sulphides, leading to a reduction in arsenic mobility. Furthermore, the sorption of arsenic to natural organic matter is increasingly thought to suppress arsenic mobility, but the binding mechanisms have remained elusive. Here we use X-ray absorption spectroscopy to analyse the speciation of solid-phase arsenic in peat samples collected from a naturally arsenic-enriched peatland in Switzerland. We show that natural organic matter can completely sequester arsenic through the formation of covalent bonds between trivalent arsenic and organic sulphur groups, which have an average arsenic-sulphur bond distance of 2.26 angstrom. We suggest that by binding arsenic in this way, natural organic matter plays an active role in arsenic immobilization in sulphur-enriched, anoxic wetlands.

35. Implementing an effective finite difference formulation for borehole heat exchangers into a heat and mass transport code

We present an effective finite difference formulation for implementing and modeling multiple borehole heat exchangers (SHE) in the general 3-D coupled heat and flow transport code SHEMAT. The BHE with arbitrary length can be either coaxial or double U-shaped. It is particularly

suitable for modeling deep BHEs which contain varying pipe diameters and materials. Usually, in numerical simulations, a fine discretization of the BHE assemblage is required, due to the large geometric aspect ratios involved. This yields large models and long simulation times. The approach avoids this problem by considering heat transport between fluid and the soil through pipes and grout via thermal resistances. Therefore, the simulation time can be significantly reduced.

The coupling with SHEMAT is realized by introducing an effective heat generation. Due to this connection, it is possible to consider heterogeneous geological models, as well as the influence of groundwater flow. This is particularly interesting when studying the long term behavior of a single BHE or a SHE field. Heating and cooling loads can enter the model with an arbitrary interval, e.g. from hourly to monthly values. When dealing with large BHE fields, computing times can be further significantly reduced by focusing on the temperature field around the BHEs, without explicitly modeling inlet and outlet temperatures. This allows to determine the possible migration of cold and warm plumes due to groundwater flow, which is of particular importance in urban areas with a high BHE installation density.

The model is validated against the existing BHE modeling codes EWS and EED. A comparison with monitoring data from a deep BHE in Switzerland shows a good agreement. Synthetic examples demonstrate the field of application of this model. (C) 2012 Elsevier Ltd. All rights reserved.

36. Swiss prealpine Rietholzbach research catchment and lysimeter: 32 year time series and 2003 drought event

The prealpine Rietholzbach research catchment provides long-term continuous hydroclimatological measurements in northeastern Switzerland, including lysimeter evapotranspiration measurements since 1976, and soil moisture measurements since 1994. We analyze here the monthly data record over 32 years (1976-2007), with a focus on the extreme 2003 European drought. In particular, we assess whether the well-established hypothesis that the 2003 event was due to spring precipitation deficits is valid at the site. The Rietholzbach measurements are found to be internally consistent and representative for a larger region in Switzerland. Despite the scale discrepancy (3.14 m²) versus 3.31 km²), the lysimeter seepage and catchment-wide streamflow show similar monthly dynamics. High correlations are further found with other streamflow measurements within the Thur river basin (1750 km²) and-for interannual anomalies-also in most of northern Switzerland. Analyses for 2003 confirm the occurrence of extreme heat and drought conditions at Rietholzbach. However, unlike findings from regional-scale modeling studies, they reveal a late onset of the soil moisture deficit (from June onward), despite large precipitation deficits from mid-February to mid-April. These early spring deficits were mostly compensated for by decreased runoff during this period and excess precipitation in the preceding weeks to months (including in the 2002 fall). Our results show that evapotranspiration excess in June 2003 was the main driver initiating the 2003 summer drought conditions in Rietholzbach, contributing 60% of the June 2003 water storage deficit. Finally, long-lasting drought effects on the lysimeter water storage due to rewetting inhibition were recorded until spring 2004.

37. Temperature dynamics of a proglacial stream: Identifying dominant energy balance components and inferring spatially integrated hydraulic geometry

Proglacial fields typically have complex topography and heterogeneous sediments, resulting in highly variable flow and temperature regimes in surface runoff and groundwater. Using data from the Damma glacier forefield (Switzerland), we examined how longitudinal stream temperature changes can be used to infer reach-averaged hydrological and thermal processes in proglacial riparian zones. A simple energy balance showed that (1) radiative forcing and frictional warming largely explained the observed temperature patterns in three stream reaches, and that (2) groundwater inflow and/or hyporheic exchange appear to influence stream warming along a fourth reach. Daytime stream warming depends on channel width, and here we show that stream temperature measurements can be used to infer reach-averaged hydraulic geometry relationships between stream width and discharge, which are normally difficult to obtain by other methods in braided gravel bed streams. Our results illustrate how proglacial stream temperatures can yield spatially integrated information about hydrological and thermal processes in glacial forefields, where extreme spatial heterogeneity makes conventional methods difficult to apply.

Übersichtspublikationen

38. Umgang mit lokaler Wasserknappheit in der Schweiz - Bericht des Bundesrates zum Postulat „Wasser und Landwirtschaft. Zukünftige Herausforderungen“

Der Bundesrat erfüllt mit diesem Bericht das Postulat 10.3533 „Wasser und Landwirtschaft. Zukünftige Herausforderungen“ von Nationalrat Hansjörg Walter. Das Postulat fordert einen Bericht. Dieser soll Handlungs- und Lösungsansätze einerseits für „kurzfristige Ereignisse wie z. B. einen lokalen, vorübergehenden Wassermangel“ beinhalten, andererseits soll er „langfristige Perspektiven aufzeigen, wie der Bundesrat mit einer generellen Wasserverknappung, z. B. infolge Klimawandel umzugehen gedenkt.“

Die zuständigen Stellen des Bundes haben die Situation eingehend analysiert und dabei auch Fachleute der Kantone, der Fachverbände und der Wissenschaft beigezogen.

Der Bericht konzentriert sich auf den Umgang mit Wasserknappheit und Trockenheit und die entsprechenden Konflikte, Versorgungsprobleme und Lösungsansätze. Er ist abgestimmt auf andere Strategien (wie z.B. die Klimaanpassungsstrategie, die Biodiversitätsstrategie, die Wasserkraftstrategie). Hingegen werden der Hochwasserschutz und die Siedlungsentwässerung nur soweit behandelt, als dies für das Phänomen Wasserknappheit relevant ist.

39. Grundwasserschutzzonen bei Lockergesteinen / Zones de protection des eaux souterraines en roches meubles. Un module de l'aide à l'exécution protection des eaux souterraines.

Dieses Modul der Vollzugshilfe Grundwasserschutz zeigt die Vorgehensweise bei der Ausscheidung von Grundwasserschutzzonen in Lockergesteinen auf. Der Verfahrensablauf sieht ein schrittweises Vorgehen vor: Die Feststellung der Zweckmässigkeit eines Fassungsstandortes durch eine Eignungsprüfung bildet die Voraussetzung, um die Untersuchungen zur Dimensionierung der Schutzzonen einzuleiten. Ein besonderes Augenmerk wird auf die Aufzeichnung und Beurteilung des Gefährdungspotenzials gelegt. Zur Bemessung der Schutzzonen und insbesondere zur Bestimmung der 10-Tages- Isochrone sind die gängigen hydrogeologischen Methoden aufgeführt. Die Vollzugshilfe richtet sich primär an die Vollzugsbehörden sowie an die Wasserversorgungen und an beratende Geologinnen und Geologen.

Ce module présente la marche à suivre pour délimiter les zones de protection des eaux souterraines en roches meubles. La procédure prévue se déroule par étapes: les investigations pour délimiter les zones de protection nécessitent tout d'abord un contrôle d'adéquation destiné à déterminer l'utilité d'un emplacement de captage. Il convient d'accorder une attention particulière à l'identification et à l'évaluation du danger potentiel. Les méthodes hydrogéologiques ordinaires servent à délimiter les zones de protection et notamment à déterminer l'isochrone 10 jours. L'aide à l'exécution s'adresse en premier lieu aux autorités d'exécution ainsi qu'aux services des eaux et aux géologues consultants.

Fachartikel SGM 2012

40. Assessing controls on cold-season recharge: The Vers Chez Les Brandt study site in the Swiss Jura Mountains

The scientific community has ubiquitously acknowledged that climate change could shift the volume and temporal distribution of groundwater recharge, particular in cold-regions, drastically altering available groundwater resources. As seasonal snow pack plays a significant role in storage and redistribution of water, many studies have addressed recharge and runoff processes attributed to spring onset snowmelt. However, previous work has failed to identify inter-cold-season recharge processes and their relationships to climatic conditions prior to spring snowmelt, particularly in low alpine, karstic environments. If cold-region aquifers are to be sustainable and effectively managed,

the dependency of winter recharge on climatic conditions should be identified and their relationships quantified. The Vers Chez les Brandt test site, where water infiltrating from a zone of approximately 2500m² drains towards a single water arrival point in a cave 53m below its recharge zone, is an ideal location to study unsaturated recharge processes. A weather station and snow depth sensor were installed within the site's recharge area while the upper meter of soil-water was vertically profiled for physical parameters including water content, electrical conductivity, and temperature. Vadose water draining into the karst cavity was assessed for discharge, electrical conductivity, and temperature. Through time-series analysis and bivariate statistical regression of climatic data with that of soil and unsaturated zone waters, we derive the relative impacts of climatic variables on infiltration throughout winter months, thereby shedding light on the information gap concerning inter-cold-season recharge. This detailed approach revealed that, even with a shallow soil frost and an established meter thick snowpack, air temperature strictly governs infiltration; with positive air temperatures of even just 1°C resulting in observable increases in soil water content and vadose zone outflow. Results imply that equal consideration should be given to winter recharge as is afforded to that historically given to spring on-set snowmelt within groundwater modeling applications and management practices. Additionally, temporally detailed site temperature data is crucial for accurate assessments of recharge within the winter months.

41. Application of stable isotopes of water to evaluate tributary mixing and micropollutant fate in Swiss lakes

The isotope network of Switzerland (ISOT) is regularly measuring the isotope compositions of surface water, precipitation and groundwater at 23 sampling locations (BAFU 2009). This provides a large data base and wide range of applications. In the framework of this study ISOT data were used in combination with stable isotope compositions of water, obtained from depth profiles taken throughout Lake Geneva. The overall research goal was to study the hydrodynamics of the lake and evaluate micropollutant transport. In principal the research idea is based upon the fact that rivers, which originate from high altitude, do have a distinct oxygen and hydrogen isotopic compositions compared to a lake, which is also fed by other water sources with a watershed at lower altitude. The presented method may therefore be applicable for several peri-alpine lakes in Switzerland and elsewhere.

42. Investigating spatial and temporal runoff generation mechanisms in a Swiss pre-alpine catchment

Spatial and temporal rainfall and runoff data of mountainous catchments are generally sparse and even when they exist, more detailed information such as groundwater levels or isotopic data are usually lacking. This makes difficult to identify runoff generation processes and system conditions. Here we present first results from a new data set collected during three years of measurements in the Zwäckentobel, a 4.3 km² Swiss pre-alpine catchment in the Alptal. The high annual precipitation input, flashy character of stream flow dominant wet conditions and the existence of long-term data for one sub-catchment make this catchment an exciting study area for investigating rainfall-runoff processes. An open challenge is the runoff contribution of sub-catchments and the response of individual streams to storm flow in space and time ...

43. Mountains – Up and Down: the Role of Groundwater Pressure

In fractured and granular porous aquifers a change in groundwater pressure results in a modification of the effective stress state. Decreasing groundwater pressures can result in a consolidation of the porous media, increasing groundwater pressures in an expansion. This coupled hydromechanical process named fluid-to-solid, i.e., a change in fluid pressure results in a change of the porous volume, has been observed also in the crystalline fractured rock of the Gotthard Massif (Hansmann et al, 2012). Increasing/decreasing water pressures during groundwater recharge/discharge periods lead to cyclical expansions/compressions of the fractured rock mass resulting in a subtle mountain “up and down”. ...

44. NRP61/SWISSKARST Project. Mapping karst water resources using KARSYS approach. Application to the Bernese Jura (BE, Switzerland)

Karst hydrogeological systems and aquifers have been represented by a large type of hydrogeological maps in the past. The use of the full 3D approach KARSYS (Jeannin et al. in press) reveals that none of these representations are really adequate to depict specificities of

recharge and flow organization in karst. In the frame of the Swisskarst project – part of the NRP61 - and thank to additional funding provided by the Amt für Wasser und Abfall des Kantons Bern, a new concept of karst hydrogeological map has been developed along with a study of groundwater resources in the Bernese Jura. Result seems satisfying, reproducible and usable. The map includes the following indications: catchment boundaries, specific recharge modalities (autochthonous, allochthonous or mixed), specific flow mechanisms (diffluence/convergence), specific 3D geometry of main flow paths and the location of confined/unconfined saturated part(s) of the aquifer. It also introduces the concept of sub-catchment units which refers to an area with a uniform type of recharge and uniform flow properties at the considered scale.

45. Permeable Fault Detection in Deep Geothermal Aquifer Exploration by Soil Gas Measurement

The two key focus points in the exploration for deep geothermal fluids are the inferred temperature and productivity. These two parameters define whether the resource will be economic or not. The productivity is dependent on the permeability of the reservoir, and turns out to be the main factor limiting the number of fully successful geothermal projects in deep aquifers of Switzerland. To improve the capacity to exploit the resources available under our feet, the exploration campaigns aim at localizing fault zones, in which the fracture density naturally enhances the circulation of water. However, traditional methods used to detect fractured zones, either geological or geophysical, give no information on the permeability of the fractures. ...

46. Solid-rock surface model of the Rhine and Seez valley

The elevation and morphology of the solid-rock surface and the associated thickness and distribution of Quaternary deposits are of practical and scientific interest. They provide opportunities for studying subglacial erosion and other glacial processes at the glacier bed and provide boundary conditions for geo-engineering tasks, groundwater resource management and the siting of deep geological repositories for radioactive waste. ...

47. The application of optically stimulated luminescence to overdeepened valleys in northern Switzerland

Overdeepened valleys and basins are commonly found below the present landscape surface in the North of the Alps, and the major control for their development is ascribed to glacial processes during the Quaternary. The extent of these troughs and their sedimentary fillings is an important aspect of applied geology with regard to the geotechnics of deep foundations and tunnelling, and groundwater resource management. Moreover, the sites under investigation for the installation of deep geological repositories for radioactive waste are located in the vicinity of some of these troughs. With the need for them to remain stable for up to 1 Ma, both the timing and nature of the overdeepening processes are being investigated. ...

48. The 3D-model Basel region – a planning tool

In 2008 started the EU project “GeORG” (www.geopotenziale.eu) with the idea to establish a tool for space planning of the subsurface across political boundaries along the Upper Rhine Graben. The project partners are the Applied and Environmental Geology Group of the University of Basel and the geological surveys of France (BRGM), Baden-Württemberg (RPF-LGRB) and Rheinland-Pfalz (LGB). The aim of the project was the development of a geological 3D model between Basel and Mannheim (D), which can be used as a tool for evaluation of the possibilities and risks of the deeper underground. The geological 3D-model of the Basel region (600 km²) was established as the Swiss contribution to the “GeORG”-project. 12 geological horizons between the Quaternary and the crystalline basement were modelled and joint with the rest of the GeORG model. ...