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Foresight Report Hydrological Research in Switzerland

Final Report

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This report is an element in the process to identify future research challenges for hydrology in Switzerland. It has been accepted in the present form by the Swiss Hydrological Commission (CHy).

CHy considers this report a suitable basis for the formulation of a roadmap for next steps in the process.

Given the complexity of the topic, the diversity of approaches, the dynamics of hydrological research, and the limited resources for the editing of this report, CHy is aware that the content of the report may not be complete and balanced in all details.

Foreword

Global change issues are debated in a number of fields in the natural sciences today. New articles are being published every day, offering scenarios for the future of our planet or of individual regions. Water – in particular water resources and flood risks – are a central element of these papers. Indeed, it is clear today that pressure on water resources, already high in many regions due to population growth and industrial needs, will significantly increase due to climate change, leading to new bottlenecks.

The degree of uncertainty that exists in such research remains very high, as the models used today are only able to capture the complexity of human–nature systems in a rudimental way. This is a major challenge for science: key to the success of research dealing with global change issues are an inter- and transdisciplinary research approach and the participation of those concerned.

In a workshop initiated and coordinated by the Swiss Hydrological Commission (CHy) and the Hydrology division of the Federal Office for the Environment in Olten, Switzerland, in autumn 2011 about thirty water researchers discussed which options were available and what kind of measures were necessary to ensure that Swiss hydrological research can efficiently take up the scientific challenges of global change. The workshop, competently moderated by Thomas Stankiewitz, was very successful. It was fascinating to see that the various groups which discussed options for improving collaboration within Swiss hydrological research made very similar suggestions.

After the Olten workshop, Pierre Walther took over the task of summarizing the essence of the workshop in a report. The titles of the chapters in the resulting volume signal how comprehensively the results of the workshop have been documented: “Context and Trends for Hydrology in Switzerland”, “Future challenges”, “The proposal of the Olten workshop” and “Programme framework”.

In 2001, CHy conducted a similar experiment. What emerged out of this first event was a vision of a “Swiss Water Foundation”. This vision became the basis for the creation of a professional agency that pushed the Swiss hydrology network into a significant growth phase, leading to a much better visibility of Swiss hydrology since then. In view of this former success story, I am convinced that the Olten workshop will be very fruitful, as well - provided hydrologists in Switzerland continue to be willing to participate in implementing the suggestions made in the present report.

My thanks go to the participants of the Olten workshop for their valuable contributions and for taking a second, critical look at the present report; to Thomas Stankiewitz and Pierre Walther for their great commitment; and to Bruno Schädler, director of CHy’s agency, for his thoughtful coordination of the whole process.

Bern, July 2013
Prof. Dr. Rolf Weingartner
President of the Swiss Hydrological Commission, SCNAT

Préface

De nombreuses disciplines des sciences naturelles sont actuellement confrontées aux questions du changement global. Chaque jour, de nouvelles publications tentent de dresser des scénarios sur l'avenir de certaines régions ou même de notre planète entière. L'eau – en particulier les ressources en eau et les risques de crues – y sont des thèmes centraux et récurrents. Ce qui est déjà sûr, c'est que le changement climatique va renforcer de manière significative la pression déjà exercée sur les ressources en eau par l'évolution démographique et l'augmentation des activités industrielles. On peut donc s'attendre à une recrudescence des situations de pénurie.

Néanmoins, les incertitudes inhérentes à ces études restent importantes. En effet, les modèles utilisés ne sont pas en mesure de considérer toute la complexité des systèmes et des interactions entre la nature et l'homme. La recherche a donc du pain sur la planche. Son succès dépendra de son orientation inter- et transdisciplinaire et de sa capacité à intégrer les personnes touchées.

A l'initiative et sous la direction de la commission d'hydrologie (CHy) et de la division Hydrologie de l'Office fédéral de l'environnement, une trentaine de chercheurs du domaine de l'eau s'est retrouvée en automne 2011 à Olten dans le cadre d'un workshop. Celui-ci devait livrer des réponses sur les options réalisables et les mesures à prendre afin de préparer la recherche hydrologique suisse aux défis du changement global. Ce workshop, animé avec compétence par Thomas Stankiewitz, fut une réussite. On a pu observer une convergence des options proposées par les différents groupes de discussion pour une meilleure collaboration de la recherche hydrologique en Suisse.

Pierre Walther a été chargé de rédiger un rapport sur les résultats du workshop. Rien que les titres des différents chapitres du présent rapport („Context and Trends for Hydrology in Switzerland", „Future challenges", „The proposal of the Olten workshop" and „Program framework") en disent déjà long sur la qualité de la documentation réalisée.

En 2011 déjà, la CHy avait mené une expérience similaire dont le résultat fut la vision «fondation suisse de l'eau ». Celle-ci conduisit à la création d'un secrétariat professionnel avec le but affiché de renforcer l'hydrologie en Suisse et d'augmenter sa visibilité. Au regard du succès de cette démarche, je suis convaincu que le workshop d'Olten lui aussi portera ses fruits, à condition que les hydrologues de Suisse prétendent à participer à la mise en œuvre des propositions contenues dans le présent rapport.

Je remercie les participantes et participants du workshop d'Olten pour leurs nombreuses et fructueuses contributions ainsi que pour la revue minutieuse du présent rapport, Thomas Stankiewitz et Pierre Walther pour leur engagement et Bruno Schädler, secrétaire de la CHy, pour la coordination engagée du processus.

Berne, en juillet 2013
Prof. Dr. Rolf Weingartner
Président de la commission suisse d'hydrologie de la SCNAT

Vorwort

Die Fragen des globalen Wandels beschäftigen verschiedenste Bereiche der Naturwissenschaften. Tagtäglich erscheinen neue Aufsätze, die szenarienhaft die Zukunft unseres Planeten oder einzelner Regionen skizzieren. Das Wasser – besonders die Wasserressourcen und die Hochwassergefahren – bildet dabei ein zentrales Element, weil jetzt schon sicher ist, dass der Klimawandel in vielen Regionen den durch das Wachstum von Bevölkerung und Industrie verursachten Druck auf die Wasserressourcen massgeblich verstärkt, was zu weiteren Engpässen führen wird.

Die bei solchen Untersuchungen bestehenden Unsicherheiten sind nach wie vor gross, weil die heute eingesetzten Modelle die Komplexität der Natur-Mensch-Systeme nur ansatzweise erfassen. Die Wissenschaft ist also gefordert. Schlüsselfaktoren für den Erfolg sind deren inter- und transdisziplinäre Ausrichtung sowie die Partizipation der Betroffenen.

Auf Initiative und unter Leitung der Hydrologischen Kommission (CHy) und der Abteilung Hydrologie des Bundesamts für Umwelt haben sich im Herbst 2011 rund dreissig Wasserforschende an einem Workshop in Olten der Frage gestellt, welche Optionen vorhanden und welche Massnahmen zu treffen sind, damit die schweizerische Hydrologie effizient auf die wissenschaftlichen Herausforderungen des globalen Wandels reagieren kann. Der Workshop, der vom Moderator Thomas Stankiewitz kompetent geleitet wurde, war sehr ergiebig. Spannend war zu sehen, dass die Diskussionsgruppen, die mögliche Optionen für eine verbesserte Zusammenarbeit in der schweizerischen Hydrologie erarbeiteten, zu sehr ähnlichen Vorschlägen gelangten.

Pierre Walther hat in der Folge die Aufgabe übernommen, die Essenz des Oltener Workshops in einem Bericht zusammenzufassen. Allein schon die Kapitelüberschriften des nun vorliegenden Berichtes „Context and Trends for Hydrology in Switzerland“, „Future challenges“, „The proposal of the Olten workshop“ oder „Program framework“ belegen, wie umfassend die Ergebnisse dokumentiert sind.

Im Jahr 2001 führte die CHy bereits ein ähnliches Experiment durch. Entstanden ist die Vision „Stiftung Wasser Schweiz“. Sie legte die Basis zur Gründung einer professionellen Geschäftsstelle, welche der hydrologischen Szene zu einem entscheidenden Schub verholfen und seither viel zur besseren Visibilität der Hydrologie beigetragen hat. Angesichts dieser Erfolgsgeschichte bin ich überzeugt, dass auch der Oltener Workshop reife Früchte tragen wird, wenn die in der Schweiz aktiven Hydrologinnen und Hydrologen auch in Zukunft bereit sind, sich an der Umsetzung der im vorliegenden Bericht skizzierten Vorschläge zu beteiligen.

Ich danke den Teilnehmern des Oltener Workshops für ihre wertvollen Beiträge und für die kritische Durchsicht des vorliegenden Berichts, Thomas Stankiewitz und Pierre Walther für ihr grosses Engagement und Bruno Schädler, dem Leiter der Geschäftsstelle der CHy, für die umsichtige Koordination des gesamten Prozesses.

Bern, im Juli 2013
Prof. Dr. Rolf Weingartner
Präsident der Hydrologischen Kommission SCNAT

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Abbreviations

ART	Agroscope Reckenholz Taenikon
CCES	Competence Center Environment and Sustainability of the ETH domain
CCHYDRO	FOEN Research Program about the impacts of climate change on the water
CEWAS	The International Centre for water management services
CHF	Swiss Francs
CHy	Swiss Hydrological Commission
CHYN	University of Neuchatel, Centre for hydrogeology and geothermal energy
CIP	Competitiveness and Innovation Program of the EU
CREALP	Research Center on Alpine Environment
CSD	Committee for Sustainable Development
CUHASI	Consortium of Universities for the Advancement of Hydrologic Science
CUSO	Conference of Universities of the French Speaking part of Switzerland
CZO	Critical Zone Observatory
EAWAG	Swiss Federal Institute of Aquatic Science and Technology
ECHO	Laboratory of eco-hydrology
ECV	Essential Climate Variable
EEA	European Environment Agency
EFLUM	Laboratory of fluid mechanics and hydrology
EFM	European Forum for Hydrology
EPFL	Swiss Federal Institute of Technology Lausanne
ETHZ	Swiss Federal Institute of Technology Zurich
ETP	European Technology Platform
FAO	UN Food and Agriculture Organization
FDHA	Federal Department of Home Affairs
FOEN	Federal office of the environment
GCOS	Global Climate Observing System
GFCS	Global Framework for Climate Service
GIUB	University of Berne, department of geography
GIUZ	University of Zurich, department of geography
GTN	Global Terrestrial Network
HUG	Hydrological Observation Areas of FOEN
IDANE	Inter-departmental Committee for Sustainable Development
IHP	International Hydrological Program
INBO	International Network of Basin Organizations

INTERREG	EU Interregional Cooperation Program
ISSKA	Swiss Institute for speleology and karst research
IWM	Integrated Water Management
IWRM	Integrated Water Resource Management
LIT	Literature; see annex 2
LTER	Long-term Ecological Research Network
NEON	National Ecological Observatory Network
NRP	National Research Program
NWB	Network Water of Swiss Mountain Cantons
ODA	Overseas Development Assistance
SCNAT	Swiss Academy of Sciences
SGHO	Swiss Group of Operational Hydrology
SLF	WSL Institute for snow and avalanche research
SNF	Swiss National Science Foundation
TERN	Australian Supersite network
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIBAS	University of Basle, department of environmental science
UNIL	University of Lausanne, department of geography
UVEK	Ministry of Environment, Traffic, Energy, and Communication
WEI	Water Exploitation Index
WMO	World Meteorological Organization
WSL	Swiss Federal Institute for forest, snow and landscape research

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Executive Summary

The Hydrology Division of the Federal Office for the Environment (FOEN) and the Swiss Hydrological Commission (CHy) of the Swiss Academy of Science (SCNAT) have jointly initiated a process to identify future research challenges for hydrology in Switzerland. All hydrology research groups were invited to participate.

Background: In November 2011, around 30 representatives of major Swiss hydrology research groups participated in a one-day brainstorming workshop in Olten. They concluded that the priority is the launching of a research program “long-term monitoring and research of hydrological processes in catchment areas”. The objective is “comprehensive multi-scale research, as a basis for process understanding and model development and testing”.

Mandate: To guarantee follow-up on this conclusion, FOEN mandated an independent consultant. Particular objectives of the mandate were: (a) to assess the feasibility of this proposal; (b) to further elaborate options for the implementation of the proposal.

The consultant held interviews with experts, reviewed documents and websites, and participated in synthesis sessions of large programs such as CCHYDRO. The present report is the main output of this consultancy. It provides CHy and FOEN with a basis for formulating a roadmap for the implementation of the proposal.

Context of hydrological research: This report shows that climate change and increased pressure on water resources will further increase the relevance of hydrology in the forthcoming decades. Specific expertise in mountain hydrology qualifies Switzerland to play a leading role in international initiatives. Integrated water resource management (IWRM) becomes important. Experts question whether the present, quite fragmented approach to water resource management in Switzerland, will be suitable to address the important challenges of the future.

Future challenges for hydrology: In Switzerland, hydrological research faces the following challenges: (a) to replace the present project-based funding with a program approach, needed for long-term research and monitoring of hydrological processes (>20 years); (b) to improve collaboration between research institutes which work on different hydrological systems; and (c) to achieve quantification of processes which have, till now, been described mainly in qualitative terms. The latter is needed to improve models for IWRM and forecasting.

Program framework: After having discussed the proposal of the Olten workshop with experts, the consultant proposes a program framework which builds on the strengths of hydrological research in Switzerland. Coordination with national research programs, which are coming to an end (e.g. NRP 61, CCHYDRO), will be important.

The program framework has the following components:

1. Program Design Board: The board should consist of experts. It plans and monitors the development of the program in the program design phase
2. Cooperation Mechanism: There are several options to achieve better coordination and collaboration between hydrological research institutes. Examples from US might inspire the discussion
3. Reference Centers: A number of reference centers are proposed: e.g. for sensor technology and mobile networks; for data management and meta models
4. knowledge transfer, at two levels: between research institutes; from research to practice. Existing platforms can be used more effectively
5. network of experimental catchments: Federal administration and institutes have the resources to guarantee long-term operation and maintenance of measurement

equipment. They are likely to play the leading role to define the network of experimental catchments, in which long-term monitoring and research of hydrological processes can take place. The consultant presents a long list of potentially suited areas (see annex 9).

6. process research in experimental catchments: In each Experimental Catchment there should be an area coordinator who, together with interested research teams, coordinates research
7. international component: There are several funding mechanism which can be used to complement the Swiss program with 1-2 experimental catchments abroad. Partners in developing countries can profit from being part of this program.

Organization, management, financing: Potentially interested funding partners of this program should establish a Steering Board. The Steering Board should appoint members of a Program Design Board which will help to design the program. Later, the Program Design Board is likely to be replaced by a program management unit.

Brief assessment: Long-term monitoring and research of hydrological processes which are likely to include new phenomena, is of high relevance for Switzerland. The models for water resource management have to become more integrative. The vision and objectives of the program have to be shared by the main stakeholders in the research community.

Next steps: The consultant presents recommendations for next steps. It is important that CHy formulates a management response to this report.

1
Introduction

1.1 Background

The Hydrology Division of the Federal Office for the Environment (FOEN) and the Swiss Hydrological Commission (CHy) have jointly initiated a process to identify future research challenges for hydrology in Switzerland (foresight report). CHy is a committee of the Swiss Academy of Sciences (SCNAT).

The process started with a one-day brainstorming workshop in Olten (November 2011). Around 30 representatives of major hydrology research groups participated (see list of participants in annex 1). The results of the workshops were summarized in a report[1].

The participants of the workshop found common ground that more has to be done to understand and to monitor hydrological processes, particularly at interfaces of hydrological systems., with a more programmatic approach. There was equally consensus that the new program should build on existing experiences.

1.2 Goal, mandate

To guarantee follow-up on the recommendations of this expert workshop, FOEN mandated a consultant (editor of this report). The consultant should be independent and provide an outside look (process facilitator).

Objectives of the mandate were:

1. to document the results of the workshop in Olten[2]
2. to assess the feasibility of the options which were formulated by the experts, and
3. to further elaborate the proposal.

The results of the workshop should be translated into concrete proposals which, then, could be discussed by the research community. The report should follow the methodology which is proposed by SCNAT.

1.3 Methodology

The steps in the process are presented in figure 1.

The consultant tried to make a clear distinction between the results of the discussions of the hydrology experts in the Olten workshop (November 2011), and follow-up studies and interpretations by the consultant. In practice, and because the workshop in Olten had been rather short, this was difficult.

[1] See LIT [32].

[2] See LIT [32].

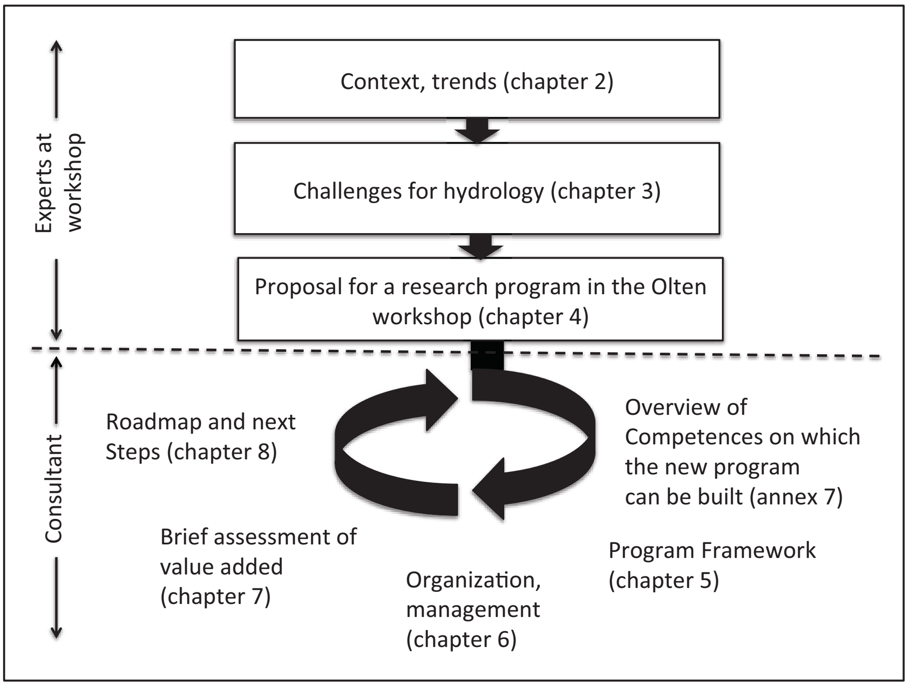

Figure 1: Steps in the process

The consultant participated in the workshop in Olten, reviewed reports, visited institues, and held interviews with a number of hydrologists. The lists of persons and of reviewed literature (LIT) are presented in annex 1 and 2.

The analysis of websites and short phone interviews to get more information from experts played an important role to put the results of the Olten workshop in a context. The National Research Program (NRP 61) carried out a quick survey among research teams to get more information on catchment areas.

The consultant had regular meetings with a Steering Group, consisting of Dominique Bérod (FOEN), Bruno Schaedler, and Rolf Weingartner (both CHy). The Swiss Hydrological Commission (CHy) approved his workplan in February 2012, and it approved the draft of this report.

1.4 Preamble

The diversity of the Swiss hydrology landscape has been described in earlier reports[3]. Interests and approaches considerably differ among the many research cells. This created a particular challenge for the consultant.

Considering this diversity, findings and recommendations presented in this report are unlikely to be shared by the whole research community. The consultant was asked to give a creative input[4], with a limited budget. His conclusions and recommendations will need discussion and approval by the concerned parties.

[3] See LIT [37].

[4] E.g. synthesis of NRP 61; implementation of the FOEN research plan 2013-2016; LIT [3].

2

Context and Trends for Hydrology in Switzerland

This chapter summarizes facts and trends, which are likely to form the context of hydrological research in the forthcoming years. Part of this analysis relates to results of the workshop in Olten (November 2011).

2.1 Relevance of hydrology

Switzerland is a country with a long history of hydrology, water infrastructure development, and water economy[5]. Hydrological research has been nourished from different groups, leading to a complex landscape of competent research institutes. The thematic orientation of Federal Research Institutes represents the different challenges in the management of water resources over time[6].

Climate change and increased pressure on water resources puts hydrology at the center of interest. The fact that the conference for the presentation of the results of CC HYDRO (June 2012) mobilized 230 persons from politics, research, public administration, private sector, tourism, infrastructure planning, and media, is clear evidence that the issues on which hydrologists are working are highly relevant.

2.2 Criteria for research funding

FOEN[7] gives a good overview about funding of environmental research in Switzerland. From 2004 to 2008, there has been an increase from 519 million CHF (2004) to 738 million CHF (2008). Hydrology is part of this budget.

Different stakeholders and sources are involved: the private sector (262 million), the Federal Research institutes of the ETH (157.9 million), ETH and EPFL (127,4 million) and cantonal universities (121,5 million)[8].

Regarding research funding, hydrology stays in competition with other sciences. Funding agencies like the SNF are obliged to use “scientific excellency” as the most important criteria to assess research proposals. This is increasingly becoming an obstacle for the funding of longer-term process studies and monitoring of hydrological parameters.

Switzerland is a good place to do innovative science in hydrology. It has a vibrant water sector. And it is a high-tech country with excellent infrastructure and conditions for the development of new technologies and methods. Hydrological research can benefit from this (e.g. micro sensor technology; telematics)[9].

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5 See LIT [14].

6 Flood protection (VAW, WSL), water power (VAW), water quality (EAWAG), etc.

7 FOEN research program 2013-2016; see LIT [3].

8 Figures for 2008.

9 See LIT [15].

2.3 International context and hotspots

Water is an issue not only in Switzerland but, even more, at the global level and in international platforms and in the UN institutions. Swiss hydrology is part of this arena.

The global water crisis: Globally, risks related to water (scarcity) are increasing. Till 2025, 50% of the world population could live in areas with water scarcity. This can have direct impacts on the world economy and on poverty, and it could lead to conflicts.

Global leaders are alerted by these challenges. The 6th World Water Forum in Marseille in March 2012 gathered around 15,000 people. Alliances or partnership for water are established in all parts of the world[10]. The World Economic Forum in Davos 2013 identified water as the top problem of the future.

More than 80% of the water footprint of Switzerland is located abroad, often in countries with water scarcity. To some extent, the supply chains of firms and our wealth depend on the availability and the proper management of water.

Urbanization and mega cities: Mega-cities in Asia, Latin America, and Africa are rapidly growing. There is a new need to further invest in water supply and sanitation. Design of artificial river systems (natural drainage), to transport water out of the cities, becomes an issue. The ETHZ is involved in a number of interesting projects.

The effects of climate change: The reality of climate change has drastically increased the relevance of hydrological research. International organizations such as UNEP, UNESCO, the European Environment Agency (EEA) consider climate change, natural disasters and conflicts, ecosystem management etc. as the main issues for the future[11].

Swiss hydrology is playing an important role in research in this area. Effects and options to deal with the consequences of climate change are studied in research programs which have been initiated in the past five years, such as CC HYDRO, NRP 61, CC Waterpower, and others.

Switzerland is the focal point for the Mountain Agenda of the Global Commission for Sustainable Development (CSD). Mountains are among the most affected by climate change[12]. Publication shows that impacts will be far beyond the role of mountains as water towers (e.g. glacier melting) or the increase of natural hazards. Issues are e.g. effects on biodiversity, food security and migration.

International processes: The Swiss Government, represented by FOEN, is playing an active role in international platforms. WMO is the lead agency for water monitoring[13]. UNESCO coordinates research. The International Hydrological Program (IHP) of UNESCO has recently elaborated an action plan. FOEN also cooperates closely with the European Forum for Hydrology (EFH). The International Network of Basin Organizations (INBO) is another example where Switzerland is involved.

2.4 Global monitoring of Essential Climate Variables (ECV)

Partly related to global risks related to climate change, monitoring of hydrological parameters has become of international concern. The focus is more and more on Essential Climate Variables (ECV).

The importance of such international collaborations is increasing. In Switzerland, MeteoSwiss has a mandate of the Swiss Government to make follow-up. Regarding water, it coordinates with FOEN, the main authority for water.

Global Climate Observing Systems (GCOS): This program focuses on three systems: ocean, atmosphere, terrestrial. Switzerland is one of the leading countries in the development of the terrestrial component[14].

[10] E.g. the Netherlands, France, Germany, Corea, the EU.

[11] See LIT [3], [30].

[12] See LIT [6].

[13] See section 2.4.

[14] Other leading countries are: Germany, the Netherlands, Irland, France, the US, Australia China.

The Swiss Government endorsed the GCOS implementation plan in 2004, and it has denominated MeteoSwiss as the focal point for GCOS. At present, there are 23 national GCOS offices. Only China, Switzerland and Germany have an office with an infrastructure.

The GCOS report of Switzerland[15] describes variables which are regularly monitored, in a comprehensive way: e.g. with legal basis, measurement points in Switzerland (map), resources required. Many of the variables are relevant for hydrology and are included in the list.

GCOS has budget to support organizations which collect important ECV but are too weak to guarantee sustainable data collection.

Global Terrestrial Network (GTN): The Global Terrestrial Network (GTN) is coordinated by FAO. It also invests in monitoring of hydrological parameters. Switzerland is leading GTN-G (glaciers) and very actively involved in GTN-P (mountain permafrost).

Global Framework for Climate Services (GFCS): The World Meteorological Organization (WMO) is focal point. It has also an important component on water.

Climate Change Initiative (CCI) of the European Space Agency (ESA): As part of this project, long-term remote sensing based records of ECV are currently being collected. IAC of ETHZ is involved.

2.5 International initiatives

Partly related to the reality of climate change, there is an increasing number of international initiatives in which Switzerland has an active role, and which are likely to be important for hydrological research in the future.

Remote sensing technology: Innovations are the result of international collaboration. At present, there is significant progress in the launching of a satellite which has the capacity to measure soil moisture, at least in the top layers (a few centimeters). Capacity to visualize could lead to progress in hydrological research.

Networks of research sites: Partly related to the demand for studies to understand the effects of climate change, there are a number of programs which establish networks of research catchments and sites. Hydrology plays a leading role, either as lead science or as discipline for ecological research.

Some good examples are described in annex 3, many of them from the US. The list includes networks such as Critical Zone Observatories (CZO), SoilTrec, the Long Term Ecological Network (LTER), the National Observatory Network (NEON), WATERSNET, or the Australian Supersite Network (TERN)[16].

WATERSNET has a thematic focus exclusively on hydrology. The other networks use a more comprehensive model of ecology as starting point. The Consortium of Universities for the Advancement of Hydrologic Science (CUHASI) in the US also started with an initiative to coordinate hydrological research in basins.

A relatively new trend is the establishment of artificial catchment areas, to study processes in the different phases of ecosystem development. Examples are found e.g. in Germany (Chicken Creek) and in China.

Other initiatives: Other international trends around water resources and the role of hydrology are described in the literature (see annex 2).

2.6 Switzerland: pressure on water resources

Switzerland is relatively rich in water resources. If all the water stored in Switzerland would be put into a lake of the surface of Switzerland, the depth of this lake would be 5 meters[17]. The

[15] See LIT [19].

[16] Supersites measure 10-200 km2 and are, hereby, considerably smaller than LTER sites.

[17] Calculation of David Volken, FOEN; presented at the CC HYDRO.

Water Exploitation Index (WEI)[18] of Switzerland is much lower than in most parts of the world (0-9,9%)[19].

Partly due to this richness of water resources, management of water infrastructure and water resources was accomplished largely without integration across sectors[20]. Limitation of this approach become, however, visible if pressure on water resources will further increase, what is generally expected.

The thematic synthesis 2 of NRP 61 identifies hotspots where water is already scarce. CC HYDRO has identified underlying trends: dry periods in summer; increasing risk for flooding; snow line will be much higher; increasing temperature will have an impact on water quality.

Pressure will be felt mainly in dry regions. There are already sources drying out during dry seasons. Beside increases in water uses, climate change is another factor[21]. In dry seasons, the demand for irrigation water will be increasing[22]. In mountain areas, 19% of ski slopes are watered (production of artificial snow)[23]. This can be a problem in dry inner-alpine valleys with a lot of pressure from tourism (e.g. Montana).

Water demands from neighboring countries are likely to increase significantly in the forthcoming decades. Switzerland will be under pressure to respond to international obligations as water castle of Europe.

Cantons will have – or are already – to move towards a more integral management of water resources (see canton of Berne). The objective is to achieve a good balancing of water uses, sustainable water supply, and the protection of water resources.

In areas where water is scarce, there is a need to define priorities as not all demands for water can be satisfied. Politically, this will be a difficult process. Hard facts are needed from hydrology research.

2.7 Fragmentation of the institutional context

Compared to other countries, the institutional context of the water sector is still quite fragmented in Switzerland. This relates to water management as well as to research. Three examples:

1. roles and responsibilities for water are shared between the federal level, the cantons, and the municipalities
2. responsibilities and budgets for data collection, monitoring, and research are split: Meteorology, hydrology, and snow monitoring are split into different departments of the federal administration (FDHA, UVEK)[24]. There is a risk for parallel activities
3. at the federal level (e.g. within FOEN), responsibilities for the water sector are shared among different divisions: ground water, water quality, prevention of floods, river forecasting.

Fragmentation can limit the capacity for Integrated Water Resource Management (IWRM). From time to time, there are attempts to rationalize this institutional set-up. Progress is, however, slow as there are multiple interests involved (e.g. water economy; regional interests) and constitutional barriers.

There are a number of (temporary) platforms and initiatives which try to increase coordination in the water sector (see also annex 4):

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[18] Water consumption of a country, in percentage of renewable water resources.

[19] In Switzerland, water consumption is around 5% of the run-off. In Italy (35%) or Germany (48%) it is much higher (LIT Worldbank, Freiburghaus 2009).

[20] See Hering et al., LIT [14].

[21] See CCHYDRO, LIT [4].

[22] See GCOS report, LIT [19].

[23] Around 10,225 litres per year and per km ski slope is used.

[24] Cooperation and coordination is not always optimal; e.g. different snow monitoring systems; interface between atmospheric models and forecasting of floods.

1. coordination platforms in the Federal administration: Inter-departemental Sustainable Development Committee (IDANE), Swiss Group of Operational Hydrology (SGHO)
2. coordination platforms in Research: Swiss Geoscience, The Hydrological Commission (CHY), The Swiss Society for Hydrology and Limnology (SGHL), National Research Program (NRP) 61, Competence Center Environment and Sustainability of the ETH Domain (CCES)
3. others: Water Agenda 21, Network Water of Swiss Mountain Cantons (NWB), Conference of Universities in the French part of Switzerland (CUSO), etc.

To achieve a more integrated management of water resources (IWRM), it will be important to reduce the fragmentation of roles and responsibilities, particularly in the areas which are most affected.

2.8 Funding of hydrological research

An important share is applied research. In this area, annual budget figures are difficult to estimate and are also not necessarily representative[25].

Regular budgets over a longer period of time, necessary for long-term process research and monitoring, can be provided mainly by FOEN, the cantons, Federal Research Institutes, and the ETH domain.

Swiss National Research Foundation (SNF): Expenditures for hydrology projects in regular budgets have increased from CHF 1,770,590 (2002) to CHF 5,789,199 (2011). On top of that, the NRP 61 has been launched.

Regarding hydrology, a programmatic approach would be most welcome by the SNF; e.g. to bundle catchment area research into larger programs in which research institutes collaborate, on an agreed framework of issues and research questions.

The SNF is not particularly keen to fund equipment, infrastructure, monitoring, and data management.

SYNERGIA: This is a new program of the SNF. The idea is that 3-5 research groups collaborate on a topic for 4-8 years. Proposals can be submitted each year by mid January, and they may include joint costs. A main criteria for the evaluation of proposals is the value added by the collaboration.

National Research Program (NRP) 61: NRP 61 is funded by the SNF. It focuses on “sustainable water use and management”[26]. The program started in mid 2009 and will end in late 2014. It has a budget of CHF 12 million. Synthesis work started in mid 2012.

Swiss Government Adaptation Strategy to Climate Change: The proposal for funding has been submitted to the Swiss Government.

FOEN Applied Research: Two large programs – “impacts of climate change on water resources” (CCHYDRO)[27]; and “Impacts of climate change on the water power sector”[28], confinanced by the Swiss Federal Office of Energy – have come to an end. The synthesis reports are published.

The Swiss Parliament has decided to channel research funding mainly through universities and the SNF. Consequently, the research budget of FOEN has been reduced to around CHF 6 million per year. Research mandates of FOEN are granted according the rules of public procurement.

FOEN applied research is expected to focus on areas which are important for carrying out the core tasks of FOEN (e.g. preparation of policies and laws).

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[25] An important source is the project data base of the SNF: http://p3.snf.ch.

[26] See www.nfp61.ch.

[27] LIT [4].

[28] LIT [2].

The FOEN master plan for research 2013-2016 is a key document[29]: Water plays a prominent role in the following priority areas: action for conservation and design of intact environment (priority 1); sustainable use of natural resources (priority 3); control and management of climate change (priority 4); integral risk management (priority 5).

Regarding the water agenda, five priorities are identified: hydrological process understanding, hydrological modeling, micro pollutants, revitalization, policy options water quality and management of surface and ground water.

The first two priorities are described as follows:

1. hydrological process understanding: (a) improved understanding of systems, in particular with regard to the generation of run-off (border processes, climate change); (b) improved knowledge about process chains (mass transport); (c) further development of methods for monitoring of bed load, run-off in case of floods, and water quality
2. hydrological modeling: (a) improvement of operational models and forecasting, particularly in floods, mass transport, temperature; (b) modeling of processes for the generation of groundwater.

Water is key in many other areas of the research plan of FOEN:

1. management of climate change, primarily in the area of climate change adaptation (topic 3.2.1): criteria for priority setting; estimation of follow-up costs of climate change; better knowledge about effects of climate change concerned sectors, like agriculture, water economy, forest, tourism, natural hazards, energy, etc.
2. management of natural hazards and technical risks (topic 3.2.18): better knowledge about hazards and risks; better models; integral planning of hazard prevention (forest, water); better forecasting.

Cantonal administrations: Some cantons have capacity to contribute with infrastructure to hydrology research programs, but only in areas which are relevant to their interests[30]. Contributions are e.g. the construction of infrastructure, the provision of electricity. Expenses can be justified with the mandates of the cantonal offices, e.g. to regulate water.

Overseas Development Assistance (ODA): In 2009, the Swiss Agency for Development and Cooperation (SDC) has established two global programs: on climate, and on water. They develop and fund projects. The Swiss Parliament has granted a special credit[31].

In June 2012, SDC and SNF launched a new instrument (Research for Development) through calls for proposals[32]. The program has five thematic programs (modules), each of them with around CHF 14 million. Water will play a role in two of the modules, social conflicts (water) and ecosystems (content not yet defined).

In this program, projects should run over 6 years and include two research institutes from the target countries of SDC (South, transition countries). They can have budgets of up to 3 million. Like in NRP, there will be two steps in the submission of proposals (project idea; project proposal).

EC funding: The FOEN research plan 2013-2016 gives a good overview about priorities of research programs at European level:

1. the 6th Framework research program led to technology platforms (ETPs) which play an important role in research funding. Water supply and sanitation is one of these platforms
2. competitiveness and innovation program (CIP): This is a new program to increase competitiveness of Europe, promotion of innovation, in particular eco innovations. The program started in 2007

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[29] See LIT [3].

[30] E.g. Berne, Zuerich.

[31] CHF 60 million, till December 2014, coordinated by SDC.

[32] Research for development; see www.r4d.ch.

3. After 2014-2020: the European Commission proposes to integrate framework research programs and CIP into a more comprehensive program "Horizon 2020".

International programs: Examples are the European Forum for Hydrology (EFH), UNESCP-IHP, INTERREG, or INBO. Funding is available for specific programs and actions.

2.9 Conclusions

Main conclusions of this context analysis are:

1. water is an important issue on the international and the national agenda. Mainly related to climate change and the impacts of pressure for additional uses, there are many issues and environmental risks which have to be addressed firmly
2. internationally, demand for hydrology is increasing, at multiple levels: e.g. to understand processes, to monitor Essential Climate Variables (ECV), and to develop models for Integrated Water Resource Management (IWRM)
3. in Switzerland, the larger research programs such as CCHYDRO or NRP 61 will soon come to an end. These programs will define new priorities for research, which can eventually form the basis of a new program
4. if there are no incentives, the institutional context for water management and coordination of hydrological research in Switzerland is likely to remain fragmented
5. Switzerland has important obligations in international platforms such as the UNESCO International Hydrology Program (IHP)
6. there are many opportunities for research funding. Funding, however, becomes more and more competitive, at the basis of scientific criteria, basically favoring short-term research
7. research on long-term trends and processes - observation of trends over 20 or more years - becomes important in in the water sector. There is a risk that this type of research is not funded adequately.

3

Future Challenges for Hydrology in Switzerland

This chapter summarizes research challenges for hydrology in Switzerland. Each of the national research programs (e.g. CC HYDRO, NRP 61) will present an agenda. The following chapter was edited at the basis of the results of the brainstorming workshop in the Olten (November 2011) and of the expert interviews.

3.1 General

Each of the larger national research programs (e.g. NRP 61, CCHYDRO, Climate change and Water and Energy Production) will submit a detailed list of future research challenges for hydrology in Switzerland. Globally, the challenges are well known[33].

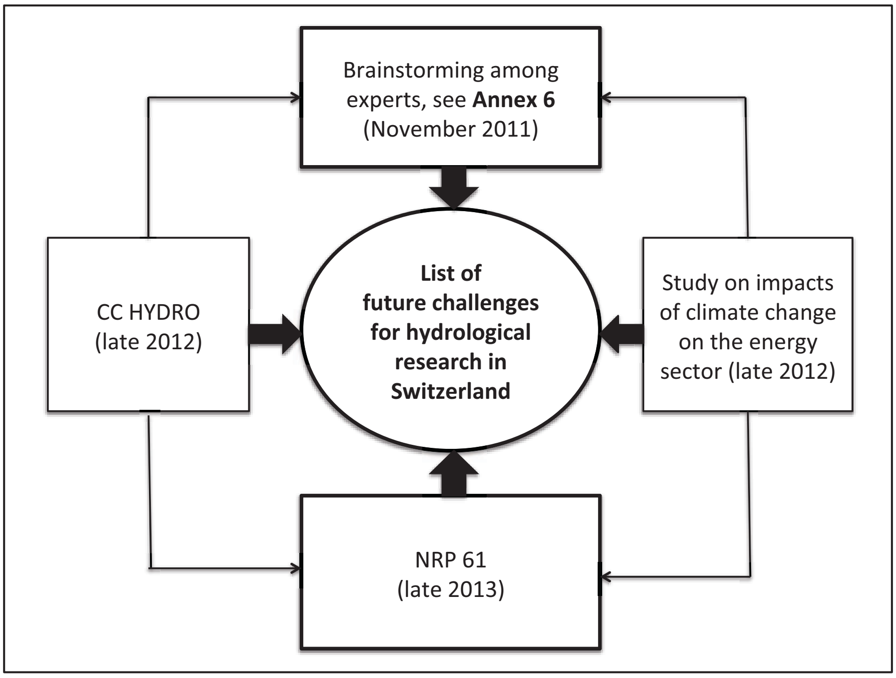

Figure 2: Sources for identifying future research themes

The results of the expert workshop which was organized in Olten (November 2011) can merely complement but not substitute the conclusions and recommendations of national research programs. The list of future hydrology research problems which is presented in annex 5 has to be seen in this context.

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[33] See e.g. reports of UNEP, LIT [30].

3.2 Climate change and new phenomena

Partly related to climate change, there will be an increase of unexpected, rapid changes and new phenomena in the water cycle, particularly in high mountain regions. The degree of freedom in the systems is decreasing. Characteristics will be: changing conditions; stochastic and cumulative effects; seasonality of run-off; need to integrate simple and complex models; short-term conflicts.

The impacts of climate change can be described quite precisely: an increase in temperature in all seasons; a clear decrease of precipitation (N) in summer till 2100; in other seasons slight increase of N; the duration of snow cover till 2100 will be up to 8 weeks shorter than today; the regions up to 3500 are in summer without snow; many glaciers (around 75%) are till 2100 disappeared; a shift of seasonal run-off maximum towards spring in high altitudes; the water volume may increase, also with less annual run-off[34].

According to CC HYDRO, effects are likely to be: extreme discharge minima in summer; months-long low-discharge periods; reduced flow velocities; less power production; increased water temperatures; deeper groundwater/lake levels; perturbed aquatic ecosystems; floods in summer. Complex, non-linear impact chains, including various processes, will become likely.

The increase of water temperature in rivers could have the following effects:

1. effects in the river ecosystems; e.g. there will be e.g. increase of illnesses in the fish population
2. higher groundwater temperature could lead to increased micro-biotic activities, resulting in decrease of O2 content, increased formation of F and Mg, leading to serious problems for many of the more than 3000 water supplies in Switzerland
3. the cooling effect of river water for nuclear power plants will be lower than anticipated when the plants were planned.

Whether the hydrologic situation can be analyzed in 2030 with the same assumptions and models as in the past, is questioned in the research community. Socio-economic and environmental parameters are changing rapidly.

Water infrastructure (e.g. flood protection, waste water treatment plants) has to be rehabilitated in the forthcoming decades. The planners need reliable hydrological forecasts. An understanding of the processes could be key, to provide this information in rapidly changing contexts (planning in moving targets)[35].

3.3 Priority fields for research

In the past, hydrologists have described phenomena and processes mainly in qualitative terms. The challenge is to move from this qualitative approach to quantification, achieving an integration of data acquisition, monitoring and modeling (multi-scale), and taking spatial and temporal variability into account.

In this context, priority fields are:

1. research and modeling of hydrological processes: e.g. interfaces of hydrological systems; impacts of climate change
2. development of new approaches to water management
3. new sensor systems and their potential to generate hydrological data
4. data management, meta-models.

An extended version of this list which was edited at the basis of results of brainstorming and expert interviews in this study (e.g. interviews, Olten workshop, literature review), is presented in annex 5.

New phenomena such as shifts in seasonal availability of water, increase of water temperature, increased risks for flooding during a longer period, periods of water scarcity, increased demand for irrigation water etc. present challenges.

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[34] See LIT [2].

[35] See Hering et al., LIT [14].

3.4 Conceptual and methodological challenges

There are a number of conceptual issues and methodological challenges to which hydrology has to respond, and which create new opportunities for research. The following is a selective list.

Move to long-term monitoring and research of processes: Hydrology research studies normally last a few years. Then, catchments are abandoned. What is increasingly needed to understand effects of e.g. climate change, is monitoring and research of hydrological processes over a longer period of time (e.g. 20 years).

Collaboration with neighboring sciences is important for IWRM: The definition of thresholds and targets for water management needs a close collaboration of hydrology with neighboring sciences such as plant ecology, zoology, soil sciences, or economy. Practical problems can only be solved with a more integrative, ecological approach.

Hydrology's role in ecological monitoring: Hydrology plays a significant role as partner for long-term ecological monitoring. Many sub-systems are interacting with the water cycle. Processes that shape the earth surface are studied in an integrative way. Little is known about how these processes are coupled, e.g. at what temporal and spatial scales.

Need to better calibrate hydrological models: Hydrologists have developed excellent models. However, many of them run on relatively poor data. Calibration is needed, particularly, when working at smaller scales (smaller catchments) and in alpine areas where there is little data available.

Quality of data is a problem. Run-off data e.g. is very good, at least for large catchments (e.g. river systems). Evaporation is, however, already an estimate. The lack of soil moisture information is a problem, and precipitation data in high altitudes are broad estimates.

With the present field data, it is difficult to parameterize the models in a satisfactory way.

The traveling science show - how to integrate results of short-term studies? Applied research normally starts by studying a concrete problem. Examples are: (a) In the near future, 100 waste water treatment plants will be equipped with new technology. What are the impacts? (b) Revitalization of rivers: what are their impacts on hydrological systems and processes?

There will be a large number of such studies. The question is how to translate these results into formats which lead to a deeper understanding of hydrological processes in Switzerland. The results of these studies need to be generalized. Meta-models are of great use.

3.5 Strengthening of hydrology as a discipline

The fragmentation of the institutional context of hydrology has been described in section 2.7. Regarding research, this fragmentation further increased since 2001[36], and this can weaken hydrology as a discipline.

The challenges are[37]:

1. move from a project to a program approach: Long-term monitoring and research on hydrological processes, looking also at the interfaces between hydrological systems, will be increasingly important
2. better integration of research about different hydrological systems (e.g. snow, glaciers, ground water, surface water, water in the atmosphere): At present, there is relatively little interaction and coordination. This can lead to gaps in process research, particular with focus on the interfaces in the hydrological systems
3. improve the flow of information among the research cells: Research cells should become better informed about the activities of others

[36] See LIT [37].

[37] See also results of the workshop in Olten; LIT [32].

4. swiss hydrology has to have a stronger voice in international processes. Coordination platforms need to be strengthened (mandate)
5. a widening gap between research and practitioners who have the legal obligation but little capacity to respond to recommendations of the research community: There are few platforms for this dialogue. Research follows its own dynamic and agenda.

4

The Proposal of the Olten Workshop (November 2011)

To foster the challenge of moving to a program approach, CHy and FOEN invited around 30 hydrologists to a workshop in Olten (November 2011). The objective was to identify and to discuss elements of a future research program which could help to address a number of the challenges described. This chapter summarizes main conclusions of this workshop.

4.1 General

All Swiss institutes with hydrology research cells were invited to this workshop. A large number participated (see annex 1). At the end of the workshop, there was a strong will to enter into a dialogue and to look for synergies.

Five groups discussed in parallel. Surprisingly, they came up with quite similar proposals[38]. This was an unexpected result. In the synthesis discussion, the five proposals could be integrated into a single proposal which is described in this chapter.

> **The proposal was named as follows:** Comprehensive multi scale research, as a basis for process chain understanding and model development and testing.

Participants of the workshop agreed that such a research program is a necessary and proactive step, to achieve long-term monitoring and research of hydrological processes, hereby generating knowledge how to face the forthcoming challenges in water resource management, likely to dominate the water agenda in the forthcoming decades.

Research over a longer period of time (> 20 years), and in the same catchment areas, is needed to define the right strategies for Integrated Water Resource Management (IWRM) at the federal and at the cantonal level.

The proposal addresses all of the four priority areas identified in section 3.3. It sets a clear priority on research for a better understanding of hydrological processes in defined representative catchment areas.

[38] See LIT [32].

4.2 Vision

The vision was described as follows:

Hydrologists work in interdisciplinary teams and during several decades in 4-7 catchment areas, which represent the main hydrological regimes and forthcoming challenges for water resourced management in Switzerland.

In each catchment (50-250 km2), there is a regional component (e.g. research management, modeling, tool development) and a network of sub-catchments for more detailed process research.

Collaboration between research groups will be key to achieve quantification and modeling as well as long-term monitoring of hydrological processes. Understanding of interfaces between hydrological systems (e.g. atmosphere, soil, groundwater, surface water) will be substantially improved (integration of models).

Ideally, the new program succeeds to use existing resources (e.g. know-how and expertise, achievements of earlier research programs) in an optimal way. Research teams in these catchments will be supported by national reference centers, e.g. in the areas of standard definition, research design, data acquisition methodology, data management, and meta-modeling. The results of the program will be translated into tools for water management.

1-2 catchment areas could also be located in other countries (e.g. alps, mountains in developing countries).

4.3 Two levels: national, catchment

The participants of the Olten workshop proposed to make a clear distinction between the following two levels: (a) national support team; (b) research teams in catchments.

National support team: National expert teams should support the research teams working in catchments. Specific tasks are e.g.:

1. program design and development: Communication and knowledge exchange is also an important task
2. data acquisition methodology: definition of standards and methodologies for data acquisition; support to research teams in sensor technology; infrastructure for monitoring
3. data integration, meta models: support to the teams.

Research teams in catchments: Monitoring and research on hydrological processes will be done in long-term research (observatories) in a number of hydrological catchments in which changes due to e.g. climate change are likely to become visible soon. Research teams should comprise scientists from different fields (e.g. snow, glacier, atmosphere). Catchment might be organized in two levels: (a) regional (50-250 km2); (b) sub-catchments for detailed process research.

Specific tasks are e.g.:

1. interdisciplinary process research: The catchments should be long-term observatories of hydrological processes. Preferably, the program can be linked to international programs of monitoring of super sites[39]
2. development of options for water management to meet future challenges: The results should be concepts and tools. Collaboration with the federal and cantonal authorities would be important.

Research in the catchments should be multi-scale (in terms of space and time), multi-sensor (in terms of measurements), and multi-variable (in terms of understanding links between quality, quantity, and ecology). Specific issues are:

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[39] See section 2.4.

1. to identify key variables of models (experiments to understand what processes matter)
2. the experimental validation of models
3. to understand what is causal and what are the causal elements (very critical issues); understanding causality across causal elements
4. to form chains of causality; propagation of signals across chains and scales.

4.4 Characteristics of the proposal

The workshop in Olten implied a number of strategic choices which were not further discussed in the workshop.

Focus on Experimental Catchments: The experts in Olten confirmed the need for research in defined hydrological catchments (hydrological observatories). The basins should become an opportunity for collaboration in data acquisition, in modeling, and in developing water resource management tools.

Water cycle at the center: Ecological aspects (e.g. fauna, flora, soils) should be included where they are important, e.g. to define parameters for water management (e.g. thresholds). The program should, however, not be an ecological program, including e.g. extended research on the impacts of changes in the water regimes on e.g. the fauna, the flora; in the sense of ecological or critical zone observatories[40].

4.5 Results of specific discussions

Selection of experimental catchment areas: The experts gathering in Olten did not yet succeed to determine catchments which will be included in the future program. They agreed that (a) the catchments should represent different process regimes in Switzerland, (b) parameters could be hypsometry, soil, geology, or phenology, (c) regional catchment (50-250 km2) should comprise sub-catchments for more detailed process research.

Data acquisition, monitoring: In each catchment, there should be long-term time series of data on hydrological parameters available (e.g. FOEN, MeteoSwiss). It was proposed to design data acquisition at two levels:

1. permanent units: anchor measurements (mobile stations) on long-term measurement points of FOEN etc.
2. mobile units: more measurement points (mobile stations, wireless networks).

Sharing of data: Data should be freely available to all research groups which participate in the program. Rules need to be formulated.

Modeling: The idea is to create a modeling environment which allows to compare different modeling approaches, e.g. with a universal modeling language, representing atmosphere, storage, surface, groundwater, water uses, and other elements of the hydrological system.

Research groups working on specific issues, would contribute with components (models), using e.g. universal modeling language,. The models should be process-based, conceptual and quantitative, explicit, and parsimonious.

Tools for IWRM: There is a need to formulate integrated water resource management tools which allow to calculate scenarios, or to assess options for water resources management (see figure 3). Quantification of processes in the experimental catchments will provide the necessary basis.

[40] To some extent contradictory to trends described in annex 3, such as the establishment of Critical Zone Observatories.

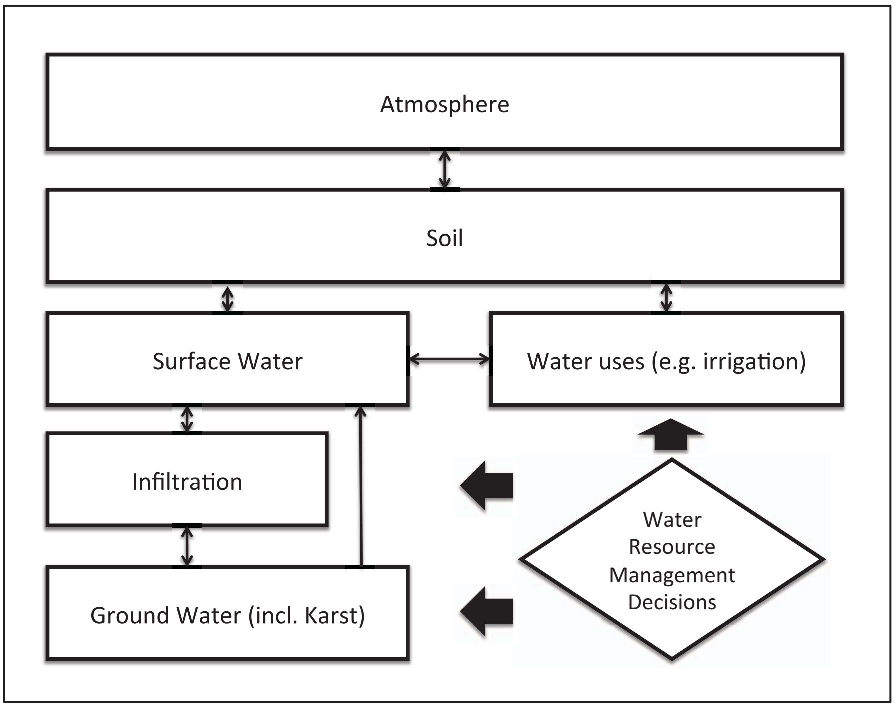

Figure 3: Elements of a water management tool (Olten workshop)

Program organization and management: Among the experts present in Olten, there was consensus that NRP 61 was a good experience on which it is possible to build. What would be needed is to determine focal points for the design of the program, for data exchange, for communication, and for knowledge transfer.

There was agreement that a collaborative approach could succeed to place special emphasis on the spatial and temporal dynamics of both structures and accompanying processes and their interactions.

4.6 Expected benefits

The hydrology experts who participated in the workshop in Olten, expressed that such a program could have direct benefits, at various levels:

1. with a program approach it will be significantly easier to leverage funds from different sources[41]
2. there will be less duplication of research, better sharing of research infrastructure, and a more efficient use of research funds
3. the research catchment areas could become areas for training and education
4. some of these research catchments might become part of international monitoring programs (e.g. supersites of GCOS)
5. the program will lead to a solid database, resulting from a better integration of networks for monitoring: e.g. biodiversity monitoring; water quality monitoring; monitoring of hydrological parameters
6. there will be more interaction and collaboration between research groups and teams which work on different hydrological systems
7. the potential to couple models increases: e.g. environmental models; meteorological forecasting models; hydrological run-off models; diffusion models
8. effective models and approaches for integrated water resource management can be developed. These will help to address the challenges which are likely to increase in a few decades.

[41] See section 2.8.

5
Program Framework (Proposal of the Consultant)

Taking the proposal of the workshop in Olten, the following two chapters 5 and 6 describe a possible framework for the future program. The proposal of the consultant builds on an analysis of competences and assets of the hydrological research landscape in Switzerland (see annex 6).

5.1 General

Considering the significant challenges for water management in the coming decades, there is agreement that hydrology has to become more pro-active. The future generation of hydrologists is challenged to take the lead, to conquer unknown territories of water management issues which are likely to become very relevant in the near future.

The vision described in section 4.2 is a good starting point. To transform this vision into action, a program framework is needed. The program should create an enabling environment for hydrology research groups, drawing on their particular strengths and interests, to develop research projects which serve the overall interest.

The following is a realistic proposal, taking the context (chapter 2), the proposal of the workshop in Olten (chapter 4), and the resources of on-going initiatives (annex 6) into account. The framework can set direction for achieving the goals which have been defined in the workshop in Olten[42].

Elements of the proposal have been discussed with selected experts[43] to get an understanding of what is feasible and what are specific interests. If resources[44] are bundled, such a program can become reality.

5.2 Program architecture

The program architecture is presented in figure 4 below. It identifies 7 components. Work in the different components can progress independently of each other, at different speeds. This makes implementation flexible.

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[42] As seen in section 2.8, funding is available from different sources. The program framework helps to avoid duplication.

[43] See annex 1.

[44] FOEN, cantons, SNF, federal research institutes, etc.

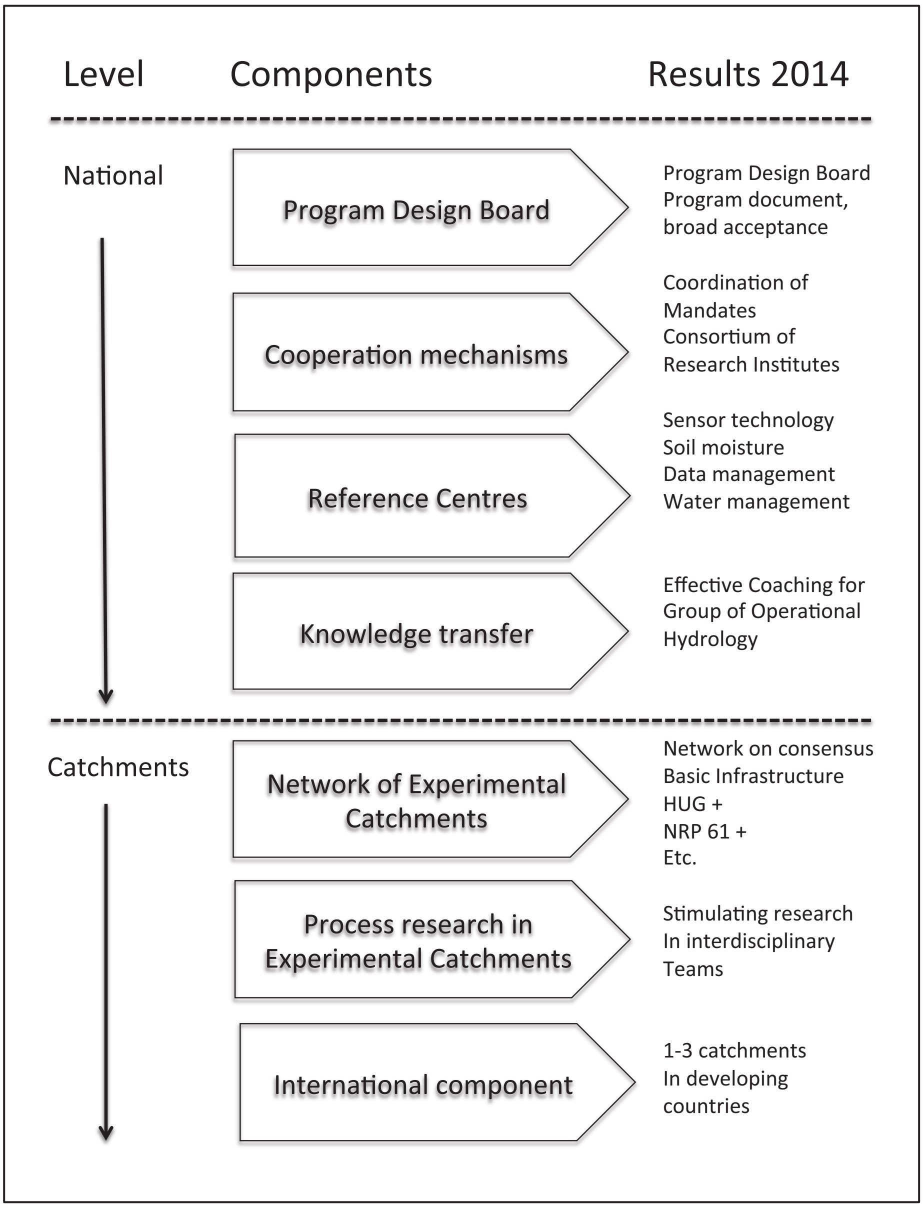

Figure 4: Program framework

Important: To put this into practice, it is important that potentially interested funding partners (e.g. FOEN, SNF CCES) take the lead. Together, they have to nominate a Program Steering Board (see chapter 6) which has the capacity to guide the process and to supervise and to monitor progress in the different components.

5.3 Program Design Board

The new program has to be designed by experts (Program Design Board), under the leadership of the funding partners (Steering Committee). The design of the new program and the synthesis phase of NRP 61 will run largely in parallel in 2013.

Specific tasks of the Program Design Board include: drafting of a program documents; annual planning and reporting of activities in the components; monitoring. The present report can be used as a starting point.

Regarding nomination of this Board, there are several alternatives:

1. the Swiss Hydrological Commission (CHy)[45] is the platform in which the main actors (FOEN, federal research institutes, cantons, universities) are represented. Therefore,

[45] Representing SCNAT.

it could take the lead as the Program Design Board of the new program, either as a commission (CHy) or by nominating a technical committee under its leadership

2. the Committee of NRP 61 is another option. It has some disadvantage that NRP 61 does not include the whole research community, and that the Committee will be burdened with a lot of work in the synthesis phase
3. a new consortium, see section 5.4, open to all interested parties (e.g. universities, ETH domain) qualifies for this role
4. the Steering Committee appoints members individually.

Representation of the cantons and of the private sector is important to achieve a balanced program. Institutes with specific competence (e.g. modeling, sensor technology, data warehouse), the young generation, and NRP 61 should have a voice in this Board.

The Program Design Board needs a budget, e.g. to cover costs of meetings, or to organized roundtables in the different components, or to discuss the program proposals with the concerned partners (e.g. water economy, agriculture, ecology).

Whether the Program Design Board will play a role also in managing the new program, has to be decided later. It will also depend on the progress in the component “cooperation mechanisms” (see section 5.4).

Coordinator, responsible for next steps: Funding partners

Recommended next steps:

1. the funding partners (e.g. FOEN, SNF) form a Steering Board
2. the Steering Board finalizes Terms of Reference (TOR) for the Program Design Board
3. it appoints the Board
4. the Program Design Board formulates an action plan for the next steps to be achieved in all components. It regularly reports to the Steering Board.

5.4 Cooperation mechanisms

Moving to the program approach needs willingness to define mechanism which foster collaboration among hydrologists. This was a clear message of the participants of the Olten workshop (November 2011).

Options to achieve this cooperation are:

1. a more binding consortium of hydrology research institutes in Switzerland takes the lead, following e.g. the model of CUHASI in the US[46]
2. steering by the funding agency: Research teams are asked to submit joint proposals; similarly as in NRP 61
3. a joint program of various research institutes: e.g. following the model of SwissEx, financed by CCES.

Each of these models is suitable to achieve the objectives of the program. Each of them have specific advantages and disadvantages.

An association or consortium of hydrology research institutes: Institutes which have the same objective (e.g. collaboration in a program; the promotion of hydrological research) form a more binding association or a consortium which fosters collaboration beyond the envisaged program.

CUHASI and LTER are interesting models (see boxes below) because there are quite some similarities with the envisaged new program.

[46] See annex 3; and below.

Consortium for the Advancement of Hydrologic Science (CUHASI) in the US: The mission of CUHASI is to enable the US water science community to advance understanding of the central role of water to life, earth, and society. The consortium supports the community to advance water science and to improve society well being by developing, supporting and operating research infrastructure; improving access to data, information and models; facilitating interactions among the diverse water research community.

CUHASI has also mobile equipment. Members can rent equipment such as mobile X-band radars. It also becomes involved in developing observatory networks and catchment comparison exercises (2010), Webinars). It runs a Hydrological Information System (HIS) for the sharing of information.

CUHASI has a board of directors, an executive committee, several standing committees, and special committees. Member institutions are non-profit educational and research institutions (e.g. universities). There is a one time USD 2000 initiation fee; plus annual dues of USD 200. In 2011, the total annual budget was 1,146,000 USD. 27% of the budget was for the operation of the CUHASI data federation.

Long-term Ecological Network (LTER) in the US: The LTER network consists of 26 sites, spanning a wide range of ecosystem types. Each site develops individual research programs in areas which are defined by the program management board.

The network is governed by an elected chair and an executive board, comprised of nine rotating site representatives and one member selected to provide expertise on information management. There are eight standing committees; a network office; a science council with a representative from each site, establishes the scientific direction and vision of the LTER Network. The Science council reserves ultimate authority for decisions affecting the Network.

The network research agenda is supported by a coordinated program of information management that involves data managers from each site, common metadata standards and a centralized information architecture that provides access to site data.

The LTER office has following duties: (a) facilitate communication among the LTER sites and between the LTER program and other scientific communities; (a) support the planning and conduct of collaborative research efforts, including providion of technical support services; (c) facilitating inter-site scientific activities, including national and international meetings; (d) providing a focal point and collective representation of the LTER Network in its external relations.

The main advantage of this approach is that it would have a long-term perspective which is needed to achieve the objectives of the program: long-term monitoring and research on hydrological processes.

Steering by the funding agency: Research teams collaborate in short- (e.g. projects) or long-term agreements. NRP 61 used this approach, and this experience was received positively participating hydrologists. In NRP 61, the research community was forced to submit joint proposals. Some of the teams are likely to continue also after the closing of the program.

Joint program: Researchers from different institutes (lead, partners) design and submit a joint program for funding. A good example is SwissEx which was submitted to CCES for funding of phase 1.

Coordinator, responsible for next steps: Program Design Board.

Recommended next steps:

1. study the CUHASI model; and, if found suitable, decide whether a similar consortium should be formed which becomes the main platform for the planning and the implementation of the new program
2. in case that this approach is not feasible, decide for another model.

5.5 Reference centers

Many Swiss hydrology institutes have developed specific, internationally recognized expertise in a particular field, which the Program Design Board may use to define standards, to provide conceptual or methodological inputs, or for peer reviews in in the program (see annex 6). Some examples:

Sensor technology, mobile networks: EPFL has developed international expertise in this area (e.g. mobile sensor networks; optical fibre; LIDAR). This expertise, including parts of the infrastructure, can be used in other catchments.

Data management, meta-models: SwissExperiment and/or SensorScope of the CCES have specific know-how.

Soil moisture: ETHZ (IAC-ETHZ) is leading a national soil moisture network in collaboration with Agroscope, WSL and MeteoSwiss (SwissMEX). Collaboration is established also with FOEN.

Glaciers: GIUZ, Geographic Institute of the University of Fribourg, VAW.

Snow: SLF is an international reference center.

Water management: The initiative to establish a PHD course in water management under the framework of CUSO could be the starting point for the development of a reference center on water management. GIUB has also a lot of expertise (NRP 61).

Groundwater: The University of Neuchatel, together with the UNIBAS.

Karst hydrology: ISSKA.

Coordinator, recommendation for next steps: Program Design Board.

Recommended next steps:

1. the Program Design Board will invite candidates to present their ideas and possible involvement in the future program
2. if feasible and found interesting: draft Terms of Reference (TOR) and/or assign roles and mandates.

5.6 Knowledge transfer platforms

Knowledge transfer is needed at two levels: (a) among hydrologists; (b) between research and application.

Knowledge transfer among hydrologists: The Swiss Society for Hydrology and Limnology (SGHL) or CHy will continue to play an important role. The approach to gather all research teams regularly in round tables, can be continued.

If the program materializes, knowledge transfer will be likely to become more intensive, also related to the establishment of the reference centers. SwissEx (data exchange) is likely to play an important role.

Knowledge transfer between research and application: The Group of Operational Hydrology (GOH) which is coordinated by FOEN, can play an important role in the promotion and implementation of this transfer.

It is important to intensify this dialogue in the new program. Cantonal offices will increasingly be faced with water resource management problems to which the new program is expected to give answers.

Coordinator, responsible for next steps: CHy, FOEN, SGHL.

Recommended next steps:

1. strengthen the presence of cantons in CHy
2. regularly invite representatives of the new program, to participate in meetings of the GOH as resource persons.

5.7 Network of Experimental Catchments

The Program Design Board, together with FOEN, NRP 61 and other interested parties[47], may develop a network of 4-7 experimental catchments in which a certain infrastructure for long-term process research and monitoring can be guaranteed (>20 years), and in which there is high motivation from the research community to become engaged.

Each catchment should consist of sub-catchments which are apt for a variety of more detailed process studies. Results of this research should feed into models at the regional level (50-250 km2).

This report presents an overview of presently used experimental catchments (see annex 7) as well as a proposal for a long list (see annex 8). Figure 5 is a summary of these annexes.

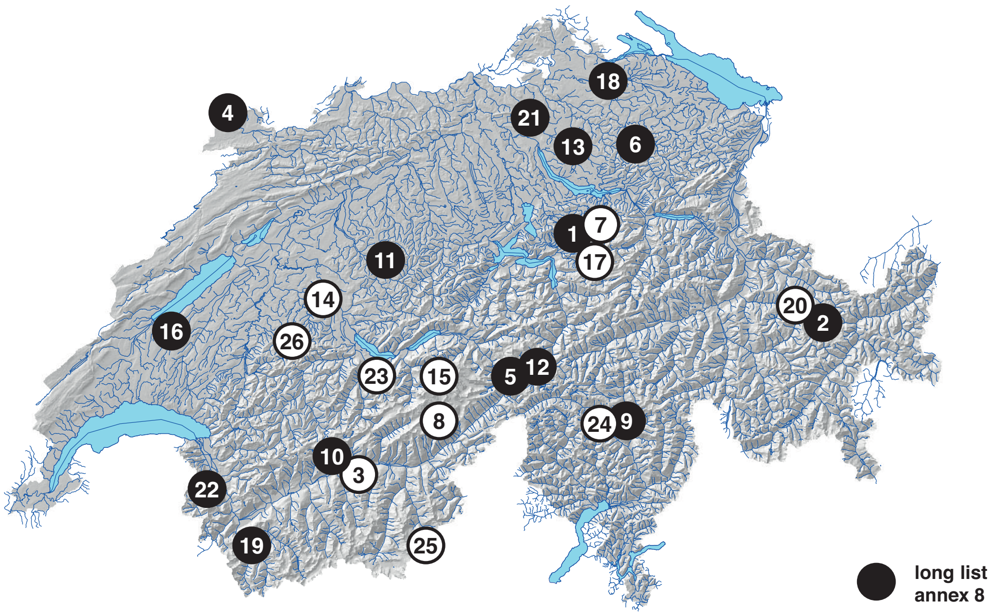

Figure 5: Summary Map of Experimental Catchments (legend see annex 7)

The research community could be invited to propose sites. And the final selection is likely to be made by the Program Design Board, at the basis of agreed criteria (see annex 9) or the mapping of hydrological similar units[48].

In the above selection, catchments in Alpine areas appear to be slightly over-represented. In a program focusing on impacts of climate change and pressure on water, the “Mittelland” and the Jura need to be adequately represented.

[47] Participating institutes should have the capacity to guarantee long-term engagement (regular budgets); e.g. Federal Research Institutes.

[48] See e.g. the approach of Kasey et al., LIT [17] of mapping Human Influenced Water Environmental Classes (HIWECS), with the aim to determine hydrologically similar units; using parameters such as: average soil permeability, bedrock permeability, terrain, land use type.

Infrastructure: Each Experimental Catchment could be equipped (a) with a permanent standard equipment, and (b) mobile devices. Information on which parameters are measured in Critical Zone Observatory (CZO)[49] sites could be a useful input before deciding on the standard to be achieved.

Recommendations for the implementation: The network of Experimental Catchments can be developed step by step (from year to year), to cover as many costs as possible from ordinary budgets:

1. upgrade already existing and well recognized experimental catchments which have a record of research and are likely to meet the criteria: e.g. Rietholzbach (IACETH), Alptal (WSL)
2. review experimental catchments of NRP 61: Some areas might be well suited to be developed into experimental catchments (e.g. Montana)
3. Hydrological Observation Areas (HUG) of FOEN: Long time series, basic infrastructure and background data[50] are available. Run-off measurement stations are checked by FOEN staff regularly. Some of the HUG could be selected as reference areas; to collect relevant spatial data (e.g. terrain models, soil moisture) and to present it in as GIS data to interested research groups.

For each experimental catchment area, there will be a coordinator (institute) who is responsible for coordination of research activities (e.g. planning, reporting), in close collaboration with the management of the program (see section 6.3).

Most likely, there will be a negotiation process between FOEN, cantons and interested institutes, represented by an area coordinator. For each catchment, a particular contract has to be elaborated specifying roles and responsibilities.

FOEN has to establish the link of these Experimental Catchments to national (e.g. HUG+) or international monitoring programs (e.g. GCOS supersites).

Coordinator, responsible for next steps: Program Design Board, in close collaboration with FOEN, NRP 61, research institutes, and the cantons.

Recommended next steps:

1. the Program Design Board agrees on goals, objectives of the program, and on criteria (see annex 9)
2. it invites research institutes to submit proposals. Based on that it proposes a shortlist of 4-7 experimental catchments
3. the Program Design Board develops standards, rules and models for equipping and defining roles and responsibilities for long-term operation of these experimental catchments
4. implementation step by step, opportunity driven, and taking specific offers (e.g. of the cantons, of FOEN, of institutes) into account.

5.8 Process Research in Experimental Catchments

Planning of research in the experimental catchments should be bottom-up, with involvement of interested research institutes, under the responsibility of the lead institutes (area coordinators). Criteria will have to be defined also at the national level.

In principle, the research infrastructure should be accessible for all interested research teams which present good proposals to the area coordinator and meet criteria such as e.g. quality of the proposal, contribution to the objectives of the program, guaranteed funding, feasibility with the research plan.

[49] See annex 3, as well as LIT [7] and [45].

[50] FOEN plans to prepare a GIS for each HUG, e.g. with terrain model, land-use data, soil moisture data, etc.

Funding of this research will probably be organized individually by each research team. To develop a regular funding mechanism (e.g. a fund, providing incentives for the research community) would be advisable[51].

Coordinator, responsible for next steps: Research teams (area coordinators).

Recommended next steps:

1. formulate research plans (milestones) for each of the experimental catchments as an instrument for steering
2. approval of the plans by the program coordination unit (see section 6.3).

5.9 International component

The program might be complemented with an international component (e.g. 1-2 catchments in mountains in the South). A particular focus on water management is recommendable[52].

To be compatible with criteria of the new SNF/SDC funding mechanism, collaboration with hydrologists and university institutes in developing countries will have to be put high on the agenda. Thus, exchange of researchers for training and capacity building could be part of this component.

SDC and SECO are engaged in a number of projects which aim at strengthening water management in selected countries and river basins[53]. The international component could draw on these experiences. Training of water resource management specialists from developing and transition countries could be one element of this component.

Coordinator, responsible for next steps: Program Design Board, together with interested partners (e.g. SDC, SECO, CUSO).

Recommended next step:

1. explore collaboration with the envisaged PHD school on water management of CUSO or with the new program of SDC/SNF.

[51] E.g. Co-funding, if the project is of interest for long-term process monitoring.

[52] Collaboration with the planned CUSO PHD school on water management would be an attractive option.

[53] E.g. on the Balcans, in Macedonia, in Kosovo, in Bosnia-Herzegovina.

6
Organization, Management, Financing

6.1 General

The proposed program will be a collaboration of various entities which share a vision and are ready to contribute with their resources over a longer period of time (> 20 years). The funding partners are in the lead.

Steering board (SC): It should consist mainly of representatives of entities which are committed to contribute with regular and long-term financing to the program, e.g. as they have a direct benefit from the program. Candidates are likely to be: FOEN, SNF, SCNAT, ETH domain, CCES, cantons.

The SC can determine the Terms of Reference (TOR) for the Program Design Board, and assign this role to an organization (e.g. CHY) or appoint the members. Afterwards, it is likely to meet 2-3 times per year, e.g. to approve strategies, plans and reports which are elaborated by the Program Design Board.

Phasing: Concerning organization, management, and financing of the program, it is important to distinguish between the two phases:

1. program design phase: 2012-2014
2. operational phase: after 2015.

6.2 Program design phase

The Program Design Board will work under the strategic leadership of the Steering Board, consisting of the financing organizations. It will plan and coordinate the development of the new program, also at the operational level.

Budgets will be assigned directly to the units which will assume responsibilities in the components of the future program (e.g. contracts between financing organizations like FOEN and reference centers).

The Program Design Board has more a coordination role (e.g. planning, monitoring, reporting, technical decisions). This report – in particular chapter 5 – can be taken as a starting point for the development of the program.

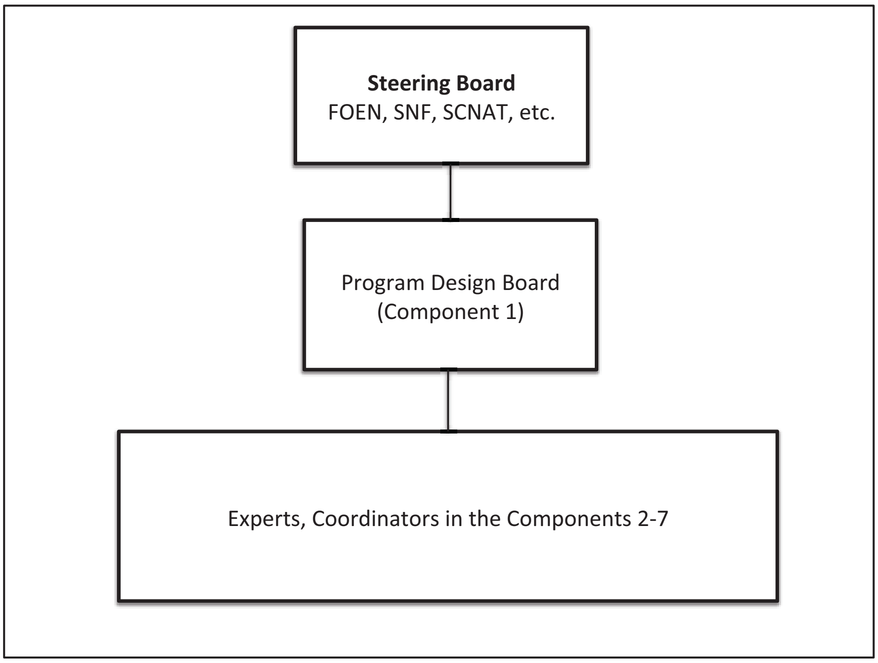

Figure 6: Organization in the design phase

6.3 Operational phase

The final organigram of the program will be defined in the program design phase. It will largely depend on the funding arrangements; e.g. the number of entities which commit funding to the program. The organogram presented in figure 7 is a realistic option.

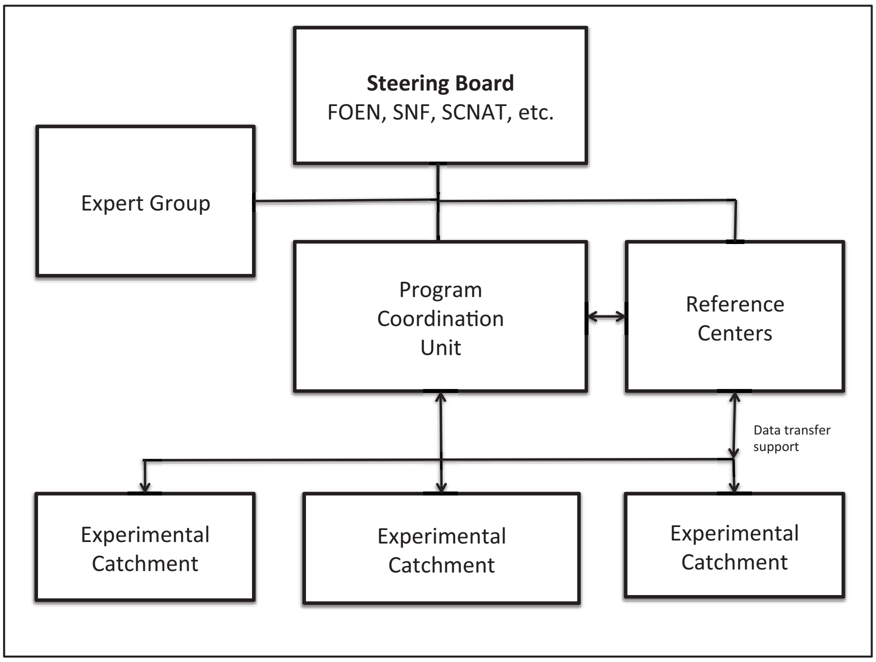

Figure 7: Option for an organogram in the operational phase

Steering Board: This will be the same as in the program design phase, with less frequent meetings. The entities which finance the program will meet 1-2 times per year to approve plans and reports. In case that there will be only one financing entity, there is no need to establish a board.

Expert group: The former Program Design Board (component 1) might be transformed into an expert pool which provides guidance and advice to the Steering Board at the strategic level. CHy would be qualified for this role.

Program coordination unit: This unit has a contract with the funding entities (Steering board). It supports research teams in the Experimental Catchments, prepares annual reports, compiles monitoring data, facilitates contacts to funding agencies, prepares the meetings of the Steering Board, etc.

Reference centers: They are the result of component 4 (see figure 4) and work at the national level. To be operational, they need a mandate and a contract. Preferably, they stay in a direct contract relationship with the financing organization or the Program Coordination Unit. Experimental catchments collaborate with them.

Experimental catchments: They will be represented by an area coordinator, preferably a research institute which can guarantee a long-term commitment. They will have a contract, preferably with a funding agency represented in the Steering Board, which specifies the details for the operation of the experimental catchment.

6.4 Financing

At present, there are no concrete proposals at the table. SNF could have interest in a program approach, also through its instruments (e.g. SYNERGIA). FOEN is likely to play a role in implementing the action plan for climate adaptation.

Program design phase: The most important step is to agree on vision, objectives, and principles. Afterwards, the program can be developed gradually, using also existing budgets - e.g. regular budgets FOEN, new SDC/SNF funding mechanism, SYNERGIA.

The Program Design Board will require a budget for workshops, meetings, studies. Eventually, a coordinator has to be appointed on a temporary basis.

Operational phase: Only FOEN and the Federal Research Institutes can guarantee the long-term financing which is needed for the launching and long-term operation of such a national process monitoring and research program in hydrology.

Regarding research funding in the catchments, the following options merit further discussion:

1. establishment of a national fund for process research in experimental catchments
2. define funding rules to be applied in the program (e.g. for process research in experimental catchments): e.g. that FOEN covers 50% of the costs, and the remaining 50% have to be organized by the research teams from other sources
3. collaboration of FOEN and SNF: FOEN covers all infrastructure costs, and SNF all research costs.

7

Brief Assessment of Benefits and Risks

The consultant held a number of interviews, partly with the objective to assess strengths and weaknesses of the proposed program framework (chapters 4, 5 and 6). In this chapter, he presents the results of his independent assessment.

7.1 General

The establishment of a national program for the long-term monitoring and research of hydrological processes is a logical consequence of NRP 61 and CCHYDRO. Hydrology needs to move from a project to a program approach.

The program is needed to prepare water resource management in Switzerland for new phenomena, also to reduce possible economic risks and damages. It is of high priority for Switzerland, also from an economic and political point of view. Efforts to establish a system for long-term monitoring are needed[54].

Water resource management is a cantonal task. Therefore, it will be important that the cantons are adequately represented in the design and steering of this program. The proposed program framework (chapter 5) works in this direction.

Interest, ownership and motivation of researchers is a prerequisite to make a research program successful. The proposal has a potential. However, more promotion is needed in the program design phase, under the leadership of the Program Design Board, to bring the research community on board.

The program approach can help to bundle resources (e.g. research funding of SNF) on the relevant issues of integrated water resource management. It may become a stimulus to form research consortia.

7.2 Ownership for the program in the research community

The workshop in Olten (November 2011) was an intensive one-day brainstorming. At the end there was relatively little time to cross-check whether there was sufficient ownership among the participating hydrologists for the proposal.

To achieve this ownership, it will be important to give the experts which favor a more dynamic approach – e.g. a “traveling science show”[55] – , and particularly the young generation of hydrologists a strong voice in the Program Design Board.

The envisaged program is likely to develop into a long-term partnership of various actors and entities. Therefore, it is also advisable to include the private sector in the Program Design Board. Examples are: spin-off firms of the ETH domain; hydropower sector; insurance companies.

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[54] NRP 61, CCHYDRO and other programs were a start on which it is important to build.

[55] Field research in different areas; integration of data with the support of meta-models.

7.3 Link to FOEN master plan for research 2013-2016

The proposal is in full accordance with the priorities defined in the FOEN master plan for research 2013-2016. It is an important contribution to the implementation of the plan, in particular in the following areas[56]:

1. **system knowledge:** e.g. process understanding of the climate system; link from global to local change; understanding meteorological extreme events; forecasting of extreme events; soil moisture; hydrological monitoring; monitoring of sediment; water quality; meteorology; operational modeling (improve the operational models); groundwater recharge modeling; hydro-ecology of rivers; new substances in the water cycle
2. **target knowledge:** e.g. water management options; climate change adaptation.

The FOEN master plan for research 2013-2016 is short and concise, and it sets priorities. The following topics which might play an important role in the new program, are eventually underrepresented: development of new methods (e.g. sensors) for monitoring; data integration platform.

7.4 Expected benefits

The list of expected benefits as expressed by the experts in the Olten workshop (see section 4.6) is confirmed. The consultant identifies the following additional benefits:

1. preparedness of Swiss stakeholders (federal, cantonal, private sector) for changes in the water cycle which are likely to increase in the next decades, will be substantially increased
2. pressure from neighboring countries on "the water castle Switzerland" is likely to increase in the forthcoming decades. Results from this program will help Switzerland to define and to mitigate its position[57]
3. results of this programs can be translated into tools and training programs to strengthen IWRM at the cantonal level
4. in the next decades, water infrastructure needs to be rehabilitated (e.g. waste water plants, drainage, irrigation, water power). The program will provide information for policy makers, public administrations, and project designers
5. the new program would enable Switzerland to play a lead role in monitoring hydrological processes at the international level. It is advisable to establish a link to relevant international monitoring initiatives (e.g. ECV).

7.5 Risks

It is important that the most important stakeholders – in particular: FOEN, SNF, ETH, EPFL, Federal Research institutes, universities - fully support the program. The program needs this support.

7.6 Open questions and issues

The program will be a long-term research and monitoring program. For the monitoring part, budgets for operation and maintenance of equipment need to be institutionalized to some extent by FOEN.

The relationship between the new program and the FOEN Hydrological Observation Areas (HUG) has to be clarified; first, to ensure that FOEN can assume the costs for operation and maintenance of infrastructure; secondly, to refresh the vision of the HUG program in the light of the new program.

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[56] Quotes from the research master plan, LIT [3].

[57] Similiarly, Austria will be under pressure.

Some ideas to be studied further:

1. the new Experimental Catchments become part of a HUG+ program to which new resources are assigned
2. the program would assign to each of the new experimental catchment an - undisturbed, but similar - catchment of the HUG program as reference area. Run-off of the two catchments could be compared.

It makes sense to gradually improve spatial data sets which are available for each HUG, preferably in a GIS format: digital terrain models; soil moisture data; soil data; land-use data. To achieve comparability, the same data could be made available also for the Experimental Catchments.

8
Recommendations for Next Steps

8.1 General

This report proposes a program framework. Elements can be implemented readily. What is needed most is a shared vision among all the stakeholders involved (e.g. FOEN, CHy, SNF, cantons, research community), in particular:

1. confirmation and strengthening of this vision
2. enthusiasm in the research community
3. commitment of funding organizations to the vision.

8.2 Recommended next steps

Step	What	Who	When
1	Formulation and endorsement of a Management Response to this report, including a roadmap with next steps	CHy	February 2013
2	Financing organizations agree on the vision and establish a Steering Board	open	open
3	Establish Program Design Board (Component 1), which will operate at the basis of terms of reference	Steering Board	open
4	Eventually a questionnaire among interested research institutes to assess (a) priorities in research, and (b) commitment and financial needs related to existing and planned experimental catchments	Program Design Board	open
5	Drafting of an agenda (draft) for the program design phase	Program Design Board	open
6	Workshop with invited experts to discuss the draft and to get additional inputs	Program Design Board	open

Annexes

Annex 1 List of persons contacted
Annex 2 Selected list of literature reviewed
Annex 3 Good examples of networks of research sites (catchments)
Annex 4 Coordination platforms in the water sector in Switzerland
Annex 5 Future research challenges for Swiss hydrology
Annex 6 Swiss hydrology: selected list of specific know-how and resources
Annex 7 Research in Experimental Catchments in Switzerland
Annex 8 Consultant’s proposal of a long list for the new program
Annex 9 Criteria for the selection of Experimental Catchments

Annex 1

List of Persons Contacted

Workshop in Olten

Organizers

Bérod, Dominique, Dr., FOEN

Schädler, Bruno, Dr., Uni Bern

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Weiss, Heinz Willi, Dr., member of CHy

Wildi, Walter, Prof., Institut F.A. Forel, Uni GE, interdisciplinary research, sediment, water pollution, walter.wildi@unige.ch

Others

Barben, Martin, Dr., FOEN, coordinator HUG program

Flückiger-Schwarzenbach, Barbara, Dr., SNF, responsible for NFP 61

Hering, Janet, Prof. Dr., EAWAG, director

Leibundgut, Christian, Prof. Dr., Coordinator of NFP 61

Parlange, Marc, Prof. Dr., EPFL

Schnoor, Merry, Dr., coordinator WATERNET

Schudel, Bernhard, Dr., AWA, Canton of Berne

Seiz, Gabriela, Dr., MeteoSwiss, coordinator GCOS

Volken, David, Dr., FOEN, coordinator CCHydro

Wehrli, Bernhard, Prof. Dr., EAWAG

White, Tim, Dr., manager Critical Zone Observatory (CZO) program

Annex 2

Selected List of Literature Reviewed

Published

1. BAFU, 2009: Ergebnisse der Grundwasserbeobachtung Schweiz (NAQUA): Zustand und Entwicklung 2004-2006. Bern.
2. BAFU, 2011: Auswirkungen der Klimaänderung auf die Wasserkraftnutzung: Synthesebericht. Bern
3. BAFU, 2012: Forschungskonzept Umwelt für die Jahre 2013-2016: Schwerpunkte, Forschungsbereiche und prioritäre Forschungsthemen. Bern.
4. BAFU, 2012: Auswirkungen der Klimaänderung auf Wasserressourcen und Gewässer. Synthesebericht zum Projekt CCHydro. Bern.
5. BUWAL, 1996: Einzugsgebietskenngrössen der hydrologischen Untersuchungsgebiete der Schweiz. In: Hydrologische Mitteilungen: 23.
6. Centre for Development and Environment (CDE), University of Berne, 2009: Mountains and climate change – from understanding to action. Berne.
7. Chorover, J. et al, 2007: Soil biogeochemical processes within the Critical Zone. In: Elements, 3: 321-326.
8. Conference Universitaire de Suisse Occidentale (CUSO), 2011: Rapport d'activité 2010.
9. Davie, T., 2008: Fundamentals of hydrology. London: Toutledge
10. Fisher, M., 2012: Investigating the earth's critical zones. CSA News.
11. Fleckenstein, J.H. et al., 2010: groundwater-surface water interactions: new methods and models to improve understanding of processes and dynamics. In: Advances in Water Resources, 33(11): 1291-1295
12. Gerwin, W. et al, 2009: The artificial water catchment "chicken creek" as an observatory for critical zone processes and structures. In: Hydrology and Earth System Sciences Discussions, 6: 1769-1795.
13. Grasso, A. et al., 2010: Monitoring von Feststofffrachten in schweizerischen Wildbächen. In: Wasser Energie Luft, 102: p. 41-45.
14. Hering, J.G. et al., 2012: Moving targets, long-lived infrastructure, and increasing needs for integration and adaptation in water management: an illustration from Switzerland. In: Environmental science and technology. 46: 112-118
15. Ingelrest, F., et al., 2010: SensorScope: Application-specific sensor network for environmental monitoring. In: ACM Transactions on Sensor Netowrks, 6(2): Article 17.
16. IPCC, 2007: Synthesis report. New York.
17. Kasey, J. et al, 2010: Human-impacted water resources: domain stratification and mapping to determine hydrologically similar units. In: Environmental Science and Technology, 44: 7890-7896.

18. Macchi, M. et al-, 2011: Climate variability and change in the Himalayas: community perceptions and responses. ICIMOD. Kathmandu.
19. Meteo Swiss, 2007: National Climate Observing System – GCOS Switzerland. Zuerich.
20. Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg, 2011: Bewertung des Hochwasserrisikos und Bestimmung der Gebiete mit signifikantem Hochwasserrisiko in Baden-Württemberg. Stuttgart.
21. Netzwerk Wasser im Berggebiet, 2011: Informationsbroschüre. Davos.
22. Regierungsrat des Kantons Bern, 2010: Wasserstrategie. Bern
23. Rehbein, K. et al, 2011: Das Nationale Bodeninformationssystem NABODAT in der Schweiz. In: Mitteilungen der DGB: 2 p.
24. Roth, T.R. et al., 2010: Stream Temerature response to three riparian vegetation scenarious by use of a distributed temperature validated model. In: Environmental Science and Technology, 44(6): 2072-2078.
25. Schweizerischer Nationalfonds (SNF), 2011: Reglement über die Gewährung von Sinergia Beiträgen. Bern.
26. SDC, 2012: Annual report of Swiss international cooperation, 2011. Berne.
27. Seneviratne, S.I. et al, 2010: Investigating soil moisture-climate interactions in a changing climate: a review. In: Earth Science Review, 99(3): 125-161
28. Simoni, S. et al., 2011: Hydrologic response of an alpine watershed: application of a meteorological wireless sensor network to understand streamflow generation. In: Water Resources Research, 47(10): 1-16.
29. Tobin, C. et al., 2011: Improved interpolation of meteorological forcings for hydrologic applications in a Swiss Alpine region. In: Journal of Hydrology, 401: 77-89.
30. UNEP, 2011: Annual report 2010. Nairobi.
31. Zimmermann, W., 1988: Umweltbeobachtung und Umweltforschung in der Schweiz: Auswertung der Umfrage “Ist-Zustand der Umweltbeobactung in der Schweiz”. In: Schriftenreihe Umweltschutz: 81.

Internal Reports

32. FOEN, CHY, 2012: Results of the workshop in Olten. Bern.
33. Hering, J.G., 2011: Preliminary concept paper: Swiss EnviroNet. Duebendorf: 2 p.
34. National Ecological Observatory Network (NEON), 2010: Bylaws of the National Ecological Observatory Network. Sheldon.
35. Schädler, B. und Gossauer, M., 1992: Testgebiete; Vorstudie. Bericht NFP 31.
36. Schädler, B., 2011: Neue Erkenntnisse zu den Auswirkungen des Klimawandels auf die Wasserkraftnutzung. Solothurn: ppt Präsentation Jahrestagung des SWV.
37. SGHL, CHY, 2001: Hydrologie Schweiz – Standortbestimmung und Vorschläge zur Förderung: Bern.
38. VAW, 2011: Gletscher- und Abflussveränderungen im Zeitraum 1900-2100 in sieben Einzugsgebieten der Schweiz. Schlussbericht Teilprojekt CCHydro. Zurich.

Websites

39. Australian Supersite Network TERN: www.tern-supersites.net.au
40. CCES: www.cces.ethz.ch
41. CEWAS: www.cewas.org
42. Conférence universitaire de Suisse occidentale: www.cuso.ch

43. Consortium of Universities for the Advancement of Hydrologic Science: www.cuahsi.org
44. CREALP: www.crealp.ch
45. Critical Zone Obervatory (CSO) National Program: www.criticalzone.org
46. EAWAG: www.eawag.ch
47. EPFL Lausanne: http://echo.epfl.ch, http://eflum.epfl.ch
48. ETH Zurich: www.iac.ethz.ch
49. GCOS Switzerland: www.gcos.ch
50. International Association of Hydrological Sciences (IAHS): www.iahs.info
51. MeteoSwiss: www.meteoschweiz.admin.ch
52. National Ecological Observatory Network (NEON): www.neoninc.org
53. Netzwerk Wasser: www.netzwerkwasser.ch; Regierungskonferenz der Gebirgskantone (RKGK): www.gr.ch
54. Project Chicken Creek: www.tu-cottbus.de
55. PERMOS: www.permos.ch
56. SNF: www.snf.ch; www.nfp61.ch
57. SoilTrEC Project: www.soiltrec.eu
58. Swiss Experiment: www.swissexperiment.ch
59. SwissSMex: www.iac.ethz.ch/URL/research/SwissSMex
60. TERENO: http://teodoor.icg.kfa-juelich.de/overview-de
61. University of Berne, Department of Geography: www.hydrology.unibe.ch
62. University of Geneva, Forel Institute: www.unige.ch
63. University of Lausanne, Department of Geography, Alpine studies: www.unil.ch/igul/
64. US Long Term Ecological Research Network: www. www.lternet.edu
65. US Network of test sites: www.watersnet.org
66. Weather Stations: www.meteocentrale.ch
67. WSL: www.wsl.ch

Annex 3

Good Examples of Networks of Research Sites (Catchments)

Critical Zone Observatories (CZO)[58]

Critical zone Observatories are environmental laboratories established to study chemical, physical and biological processes that shape the Earth surface. The program started in 2007 as an initiative of the US National Science Foundation.

Research focuses on geological layers, soil horizons, vegetation cover, groundwater as well as surface water and also the air in the near surface part of the atmosphere and in the soil.[59] Little is known about how the processes are coupled and at what temporal and spatial scales.

Each Observatory receives around USD 1 million per year. Presently, 215 persons are involved[60].

The national CZO program is a community resource of the US, serving the international scientific community through research, infrastructure, data, and models. Research is interdisciplinary: hydrology, geology, soil science, biology, ecology, geochemistry.

In order to better understand the processes of the critical zone, research is done in watersheds.

SoilTrEC[61]

The CZO has a partner program in Europe, SoilTrEC. The focus of this program is mainly on understanding the life cycle and the development of soils.

The Damma glacier is part of this program. The site is managed by soil scientists of the ETHZ.

Network of Artificial Catchments[62]

Natural watersheds are often black boxes, particularly regarding underground or catchment boundaries. Artificially created watersheds might be appropriate alternatives as boundaries and inner structures can be planned and defined in advance.

An example of an artificial catchment is the Chicken Creek close to Cottbus, Germany. It measures 6 ha and was constructed in an open cast mine. Other sites are located in China (hydrohill), Canada (South Bison Hills), and in Spain (El moral artificial slopes).

The idea is to analyze structures and processes of initial ecosystem development. Three main phases in ecosystem development are identified: (a) more or less abiotic geo-system; (b) followed by a hydro-geo-system; and (c) the bio-hydro-geo-system.

Results are compared with reference sites. One of them is the glacier forfield of the Damma glacier (municipality of Goeschenen, Switzerland), which is also part of the CZO network.

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[58] See LIT [7], [45].

[59] See LIT [7].

[60] Information from Tim White, director.

[61] See LIT [57]; information from Tim White, director of the CZO program in the US.

[62] See LIT [12], [54].

Long Term Ecological Research Network (LTER)[63]

The LTER network in the US comprises 26 research sites, covering a wide range of ecosystem types, and spanning broad ranges of environmental conditions.

Each site develops an individual research programs in one or more of five core areas: e.g. pattern and control of primary production; patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface waters.

The network is governed by an elected chair and an executive board, comprised of nine rotating site representatives and one member selected to provide expertise on information management. It has eight standing committees, a network office, and a science council with a representative from each site. The science council establishes the scientific direction and vision of the LTER Network. It reserves ultimate authority for decisions affecting the Network.

The network research agenda is supported by a coordinated program of information management that involves data managers from each site, common metadata standards and a centralized information architecture that provides access to site data.

The LTER office has duties such as: e.g. to facilitate communication among the LTER sites and between the LTER program and other scientific communities; to support the planning and conduct of collaborative research efforts, including the provision of technical support services; to facilitate inter-site scientific activities. It organizes national and international meetings and is the focal point for the external representation of the LTER Network.

National Ecological Observatory Network (NEON)[64]

This network focuses mainly on collecting ecological data on the impacts of climate change, land use change and invasive species on natural resources and biodiversity. The plan is to equip 62 sites across the US. Implementation will start in 2012.

The main focus is on plant ecology. Hydrology will play a role as support science. Data exchange is an important component. More than 100 professionals will work in the network.

Consortium of Universities for the Advancement of Hydrologic Science (CUHASI)[65]

CUHASI is a non-profit consortium of US universities. It was established in 2001, to focus on common needs of scientific hydrology and address common infrastructure needs and the overall research and education agenda.

The network collaborates at the basis of statutes. It has a bottom-up structure and an annual budget of USD 1.146 million (2011). A considerable part is funded through membership fees.

WATERSNET[66]

The network started as a project under the US National Science Foundation (NSF). The objective was to develop a national water observatory system for monitoring, modeling and forecasting of water quality and quantity.

The original proposal comprised USD 300 million. It was never founded.

Today the program is more modest. WATERSNET comprises 11 sites. For each of them, there will be a responsible university.

WATERSNET is related (a) to the NEON ecological observatories program of NSF, and (b) to the CUHASI HIS test sites, mainly for the testing of the HIS data model.

Australian Supersite Network (TERN)[67]

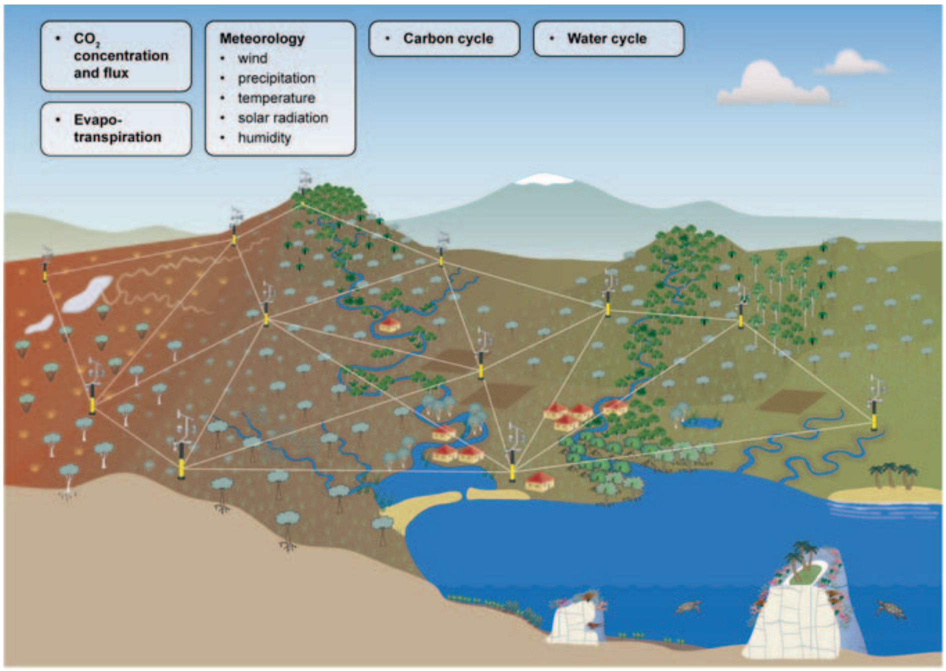
[63] See LIT [64].

[64] See LIT [52].

[65] See LIT [43].

[66] See LIT [65].

A Supersite uses existing and recently deployed environmental monitoring installations to collect comprehensive sets of long-term ecosystem data of high temporal and spatial resolution.



Core research conducted at a Supersite includes measurements from micrometeorological flux stations (OzFlux), plant physiological measurements, as well as long-term vegetation and fauna monitoring.

Data Collected at Supersites:

1. **Meteorology and fluxes (hourly averages):** meteorology (air temperature, humidity, wind speed, wind direction); radiation (incoming and outgoing short wave and long wave); soil (temperature, moisture, depth to watertable), precipitation, land-atmosphere fluxes of radiation, heat, water vapour carbon dioxide)
2. **Vegetation (daily to annual)**
3. **Faunal monitoring (daily to annual)**
4. **Soils and hydrology (hourly to decadal):** soil structure and characterisation,

Terrestrial Environmental Observatories (TERENO Network)[68]

TERENO has four observation sites, representing different ecosystems in Germany. It is supported by 6 partners.

Observatories have a considerable size (> 500 km^2), covering a catchment.

At the national level, services are available: e.g. Newsletter, online data, website, meetings and workshops.

[67] See LIT [39].

[68] See LIT [60].

Annex 4

Coordination Platforms in the Water Sector in Switzerland

Water

Interdepartemental Sustainable Development Committee (IDANE): This is the main platform for the coordination of international policy issues regarding sustainable development. The water group is chaired by the Swiss Agency for Development and Cooperation (SDC). FOEN is represented by its Division for International Affairs.

FOEN Group of Operational Hydrology (GOH): This network is coordinated by FOEN water resources. It comprises representatives of cantonal offices for water, and the main purpose is to discuss operational issues. Recently, it has become quite active. The link to hydrological science and research is quite loose and informal.

Water agenda 21[69]: This is a network of actors in the Swiss water economy. It promotes the dialogue among actors in Swiss about issues of water management. It has working groups on water catchment management, sustainable use of water power, management of infrastructure.

Network Water of Swiss Mountain Cantons (NWB): This is a collaborative network, promoted by the conference of governments of mountain cantons (RKGK), with support of the Swiss State Secretariat of Economic Affairs (SECO). The main purpose is networking. Private sponsoring plays a significant role. It focuses on topics like the annual water award, water and tourism, impacts of climate change on the water economy. In 2012, it ceased its operations.

Hydrology

Swiss Geoscience: This is a platform of The Swiss Academy of Science (SCNAT). It supports research teams in tasks which can be carried out only inter-university level, bundling expert knowhow from research and applied sciences. It identifies geo-scientific developments which are relevant from society. Furthermore, it plays an important role in information dissemination, communication, and it represents the geo-scientific themes in international platforms. The website, an online data base, and working groups are its tools.

Hydrological Commission (CHy): It is the main platform of the SCNAT with regard to hydrology. The link to Swiss Geoscience is established. Most research institutions and also the cantons are represented. Investments into a secretariat had a positive effect. Today, CHy can give impulses, but it has little capacity to steer processes effectively.

Swiss Society for Hydrology and Limnology (SGHL)[70]: The SGHL is engaged in mobilizing and integrating knowledge from different disciplines for the protection and the sustainable management of water resources in Switzerland. is an interest and lobby group. It comprises members from all relevant sectors (research, cantons, federal, private sector) and has an annual budget of around CHF 15,000. Main activities are: publications, conferences, support to young researcher.

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[69] www.wa21.ch.

[70] www.sghl.ch.

National research programs: The NRP 61 has become an important platform for the coordination of research. The research teams meet regularly, and many feel that this is important. Regarding the international water agenda, there is the National Centre of Competence for Research (NCCR) North-South.

Others

Conference of Universities in the French speaking part of Switzerland (CUSO): Main objectives of CUSO are: to foster collaboration between universities at the phd level; the harmonization of curricula; capacity building at the universities. Members are the Universities of Fribourg, of Geneva, of Lausanne (UNIL), and of Neuchatel. Partners are the university of Berne (UNIBE) and of Basle (UNIBA), and the EPFL.

Recently, members of CUSO have started an initiative to develop a phd program in water management. This could become an important crystallization point for the coordination of initiatives.

Center for Environment and Sustainability of the ETH Domain (CCES): The goal is to foster major advancements in research, to establish partners of CCES as international national focal points for environment and sustainability. CCES should have a long-term structuring effect. It should establish a strong wide-ranging education and outreach program, to achieve social impacts.

Center for Climate System Modeling (C2SM) at ETHZ[71]: Strong Focus on water cycle research in the context of climate change.

[71] See www.c2sm.ethz.ch.

Annex 5

Future Research Challenges for Swiss Hydrology

Here is the list of challenges which were identified by hydrologists in a brainstorming session in the workshop in Olten (November 2011). The list is complemented with the results of brainstormings in a meeting of the CHy (February 2012) and in discussions with hydrologists.

Scenario: Programs such as NRP 61 and CC HYDRO brought some consensus that there will be an increase in temperature in all seasons; a clear decrease of precipitation in summers till the year 2100; in other seasons a slight increase; the duration of snow cover till 2100 will be up to 8 weeks shorter than today; regions up to 3500 m a.s.l. in summer will be without snow; many glaciers (around 75%) till 2100 disappeared; a shift of seasonal run-off maximum towards spring in high altitudes; the water volume may increase, also with less annual run-off; for power production, there will be till 2050 small changes in high altitudes; in low altitudes increase possible.

This leads to issues like:

- how much water will be available in the future; and where (and when) will it be needed?
- a better understanding of the dynamics in run-off; of floods; of droughts
- middle-range prognosis of N; would be important for management of hydropower lakes, for prevention of floods
- urban hydrology: how to bring water out of the settlements in case of extreme and frequent flooding
- cloud phenomena are not yet in precipitation (N) models. This information would allow to better predict and model effects of thunder storms in summer. Till now, models assume that there is a plain
- main relevance in areas which are dominated by geology, water (alpine). In other areas, eco-hydraulics is eventually more relevant
- physical hydrology: drop movements
- snow can moderate the run-off; this is a new phenomena.

Processes are not the same in (a) alpine areas which are dominated by rocks, glaciers, water, and in (b) areas with vegetation cover. In the latter, eco-hydraulics could be a more feasible approach for research.

There are prediction models from climate change. We have now to monitor, what really happens."

General

Glacier retreat is a mayor challenge. Impacts on the water cycle are particularly strong close to the glaciers.

Impacts of climate change can be studied everywhere in Switzerland. But the big changes are expected to happen in the Alps. ICCP scenarios are not sufficiently precise.

Particularly in the Alps, spatial variability is a mayor issue; from exposition to exposition. Remote sensing data would be important, but they are not always precise enough in rough terrain.

An important questions not yet answered: e.g. how much snow is there in the Alps?

After 2050, the main cause of water scarcity will not be lack of rainfall in summer but rather new patterns and acceleration of sequences of events, e.g. if a dry spring is followed by a dry summer. It is important to understand these chains.

Process chain knowledge is the most important challenge for hydrological science in the coming decades. The sequence of events and the interactions between the hydrological systems have to be understood.

Methodology, sensors

Swiss hydrology stays at the forefront in the development of new sensor systems: e.g. visual techniques; optical fibers.

How to use mobile technology (telematics) in water management is a big challenge. Each coffee machine has a web address. How could this technology be used in hydrology[72]?

Sensors are a big opportunity for hydrology. Examples are: optical fibers; wireless sensor networks. They allow an intensive monitoring of small catchment areas (high spatial resolution).

Cantonal offices are still waiting for a good methodology to measure run-off in rivers which have a backwater problem (e.g. around river power stations; at the outlet of lakes):

- further development of methods for monitoring of bed load, run-off in case of floods, and water quality
- potential of new sensor systems (optical fibres, visual techniques, sound)
- how to use mobile technology in water management
- wireless sensor networks for the monitoring of small catchment areas.

Hydrological cycle

Forecasting of run-off is working well in large catchments where the reaction time is longer, and where there are sufficient measurement points. But it is working relatively poorly in smaller catchments (500km^2). Big need to improve this situation, with research:

- area precipitation, after all in high altitudes: there are big spatial variations from exposition to exposition. This has an impact on run-off
- quantification how much water is stored in glaciers, soils, moraines, rock beds
- interaction groundwater and superficial water; e.g. along revitalized rivers
- improved understanding of systems, in particular with regard to the generation of run-off (border processes, climate change)
- improved knowledge about process chains (mass transport)
- physical hydrology (movement of drops)
- better understanding of land-climate interactions (soil moisture, ground water)
- better understanding of the interfaces between the hydrological systems (e.g. ground water, surface water, atmosphere, snow)
- better understanding and forecasting of meteorological extreme events
- cumulative processes
- impacts of glacier melting, particularly alpine areas
- spatial variability of processes.

[72] Example: when rain starts, networks for mobile communication have to increase power. This data could be used to predict precipitation.

Monitoring, modeling

Unfortunately, monitoring is not considered as a very innovative science. Today, there is a lack of data, particularly in altitudes.

Modeling must be better linked to monitoring (calibration). There should be no modeling without monitoring and vice versa.

Hydrologists also have to focus better on policy related themes, where monitoring and modeling are relevant for decision making:

- improved understanding of systems, in particular with regard to the generation of run-off (border processes, climate change)
- improved knowledge about process chains (mass transport)
- physical hydrology (movement of drops)
- better understanding of land-climate interactions (soil moisture, ground water)
- better understanding of the interfaces between the hydrological systems (e.g. ground water, surface water, atmosphere, snow)
- better understanding and forecasting of meteorological extreme events
- cumulative processes
- impacts of glacier melting, particularly alpine areas
- spatial variability of processes.

Run-off forecasting

Forecasting has sufficient precision in big catchment areas. Decision makers need more precise models; e.g. to forecast in smaller catchment areas like Simme, Kandertal (500km^2).

Other countries[73] have developed systems to alert for critical incidences (disposition warning). Cantonal offices could profit from such a system. Switzerland has to make similar steps. Integrated models can help.

A better understanding of spatial variability and its impacts on run-off (stream-flow discharges) is needed[74]. Spatial variability needs to be quantified.

A new focus on distributed fields like evaporation or soil moisture puts distributed measurement at the center.

Land-Climate interactions

The interaction of soil moisture, ground water (critical zones) can be decisive for plant growth; and also for water which runs off at the surface.

Land-weather and micro-climate interactions are still the subject of significant uncertainties. A major problem is the lack of direct observations of the relevant climate variables (soil moisture, evapotranspiration). This is an obstacle to the associated processes and their necessary validation in climate models.

Soil moisture is a key variable of the climate system. It constraints plant transpiration and photosynthesis. It is also a storage component for precipitation and radiation anomalies, at the global, regional as well as at the local scale.

Research on the processes controlling soil moisture and land processes in general (droughts, vegetation, snow cover, ecosystem exchanges, land water and energy cycles) needs to be intensified.

Forecasting of rainfall (N) has to be substantially improved.

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[73] E.g. Baden Wurtemberg, see LIT [20].

[74] See Simoni, see LIT [28].

Interfaces between hydrological systems

Interactions between groundwater, superficial water; particularly when regimes are changed.

How do groundwater storages function? In dry and wet phases? Different geological and morphological conditions?

The dynamics of run-off is not clear. Long-term studies are needed. It is surprising how fast rivers can turn to low water table regime.

It is not clear how raindrops reach the river and related processes (resilience), similiarly, how and under which conditions the water is released from soils.

In the past decades, Switzerland has practically never experienced an extreme drought, over a number of years. How will the system recover after several years of massive droughts? What will be the role of the different hydrological systems (e.g. atmosphere, soil moisture, surface water, groundwater, snow).

Snow melting will be earlier; and some glaciers will give less water. What does this mean; also in quantitative terms?

There is an increased interest in groundwater-surface water interactions[75].

Water quality

Today, the state of groundwater is generally good in both quantitative and qualitative terms. However, traces of synthetic and persistent substances such as plant protection products, hydrocarbons or pharmaceuticals are often found, especially in intensively farmed or densely populated areas. Nitrate concentration is also increasing.

This vulnerability is likely to increase with the expected increase in water temperature.

Better integration of water quantity monitoring with quality monitoring will make it possible to understand how changes in quality are related to climatic changes.

Equally important will be to determine also changes in land uses and intensity of uses in the experimental areas. They are equally important as water quantity.

How is the quality of the alpine and pre-alpine rivers changing, due to new sediment transport patterns, rock falls, and changing in glaciers?

Threshold processes, regarding: (a) flooding; (b) sediment transport.

New substances in the water cycle.

Impacts of increase of water temperature on water quality (ground water, surface) and ecosystems.

New phenomena in Alpine areas

Alpine environments are very much dominated by elements, snow, ice, glacier, rocks.

There are new phenomena like lakes, caused by melting of glaciers. The melt-off of glaciers will increase drastically in the next decades (warming scenario). This will lead to new lakes, also on the surface of the glaciers. Later, it will decrease again (cooling scenario).

Glacier melting continues to be important. The Rhone glacier e.g. is melting 30 cm every week.

The new lakes can be used as storage for electricity. This will be important for the European energy sector, already in the near future.

Rock falling into these lakes can be a problem. These lakes are not natural phenomena. A number of problems are related to this. Infrastructure needs to be protected. In the second part of the century, enormous rock falls (e.g. permafrost rock falls) can cause damage, also on telecom infrastructure.

Increase in sediment transfer from alpine areas to locations further downstream, increasing the risk of sediment-related flood hazards.

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[75] Fleckenstein et al., see LIT [11].

Water stress and scarcity

Peaks in glacier run-offs into the rivers become a factor.

After 2050, the main cause of water scarcity will not be lack of rainfall in summer but rather new patterns and acceleration of sequences of events, e.g. if a dry spring is followed by a dry summer.

Effects affect in particular the dry areas, e.g. in alpine valleys.

Water scarcity also an issue in karst areas. An estimated 50% of groundwater in Switzerland is in karst areas (Jura, pre-alpine, alpine), amounting to almost the double of glaciers. Karst is very vulnerable to water scarcity since rainwater infiltrates rapidly.

Dry seasons will further increase the demand for irrigation water. It is estimated that water need for agriculture will increase by a factor 2 to 4 after 2050, because of more and more dry seasons in summer[76].

Water for ecosystems

What will be the effects of longer periods of water scarcity on the ecosystems (e.g. borders of lakes, river ecosystems)? How often is it possible to support a low water period?

Eco-hydraulics is a new research field. Define water requirements for nature. How to better define operation manuals for dam operators?

Water quality: goes more and more into direction of ecosystem research.

Will forests in mountains have sufficient time to recover after severe droughts?

Fish killing: water temperature seems to be an important factor.

Water management

Flood protection and energy production have to be analyzed together.

It is increasingly important to think about the whole system. Integrated Water Resource Management (IWRM) is still relatively weak in Switzerland.

There will be more demands for water uses. Ownership over water will become a major issue in the near future. Switzerland has to deal with demands from neighboring countries.

Water management problems will probably be relevant in densely populated areas (also tourism areas). The pressure of different water uses will increase.

Water quality in densely populated areas. Micro pollutants. Stressors will increase: temperature is increasing; dry periods; additional uses; intensive agriculture.

How much water will be available in the future? What have the different water users to expect?

Management of dam lakes becomes more dynamic. For example: we have eventually to water the Aare in the future, because there will be water scarcity.

Thresholds for ecological systems: e.g. trouts suffer when temperature raises > 20 degrees. New sensor systems to measure temperature.

Water management options have to be developped.

Management to deal with dynamics of run-off (e.g. rapid changes from high to low water table regimes).

Water management in Karst areas in periods of water scarcity.

Understand effects of new water regimes on ecosystems (e.g. minimal requirements; how often is it possible to support a low water period).

Means to integrate flood protection and energy production.

New options for water management in high and inner alpine regions (dry).

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[76] Figures from Agroscope.

Water economy

Till 2035 relatively few changes are expected. Afterwards problems will increase, particularly in high regions in dry alpine regions (e.g. south and east Valais).

Scenario building

Methodologically, we have problems with building scenarios. We still have problems with classical scenario, e.g. because there is very little data on high mountain precipitation. If our task is to model glaciers, precipitation data is important.

Important because more and more cumulative processes. Characteristics will be: changing conditions; stochastic, cumulative effects; seasonality of runoff; integration of simple and complex models is needed.

Urban hydrology

How to bring water out of the settlements in case of floods and massive precipitation?

Annex 6

Swiss Hydrology: Selected List of Specific Know-How and Resources

General

The establishment of research cells was closely related to specific tasks such as e.g. river corrections Rhine, Limmat, Jura (19/20 century), dam constructions for water power (after 1950), need to improve water quality in rivers and lakes (after 1960), the prevention of natural hazards and floods. Federal research institutes closely collaborate with research cells at universities.

Fragmentation further continued in the past decade[77]. Today, there is a high expertise in a number of areas on which it will be possible to develop the new program.

To move to a more programmatic approach is welcomed also by the SNF. Till now, there has been a tendency that each newly appointed hydrologist selected a "personal" catchment area for research. This lead to high costs.

The objective of this annex is to briefly describe the state of the art and the competencies in the hydrological research community on which the future program can be build.

Good experiences with trans-disciplinary collaboration

Experiences with collaboration in the NRP 61 are reported to have been very positive. The program forced the research cells to submit joint proposals. Synthesis workshops contribute to foster collaboration. Results are expected in autumn 2013. Sustainability of the monitoring infrastructure is not guaranteed.

Collaboration with other sciences and among the research institutes is important. Many universities have established research units in hydrology. If funding proposals are submitted without coordination, credibility of hydrology can be suffering.

National monitoring and long time series

In Switzerland, FOEN or the National Research Institutes such as EAWAG, WSL, VAW, or MeteoSwiss are in a good position to guarantee continuity for long time series in measuring parameters of the water cycle. This section gives a brief overview.

One of the key factors for success and long-term operation of a network is a clear mandate. FOEN has such a mandate under the Federal Act on the Protection of Waters (GschG, SR 814.20).

To meet these obligations, FOEN would like to integrate better all components of water cycle: N, run-off, snow, evaporation, soil moisture, glacier monitoring. This is not yet possible with the present monitoring network.

MeteoSwiss is the focal point for monitoring of Essential Climate Variables (ECV)[78]. The focus of GCOS is on parameters and stations which are relevant for progress reporting on climate

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[77] See analysis in 2001; LIT [37].

[78] See LIT [19].

change. Examples are water availability for vegetation, permafrost, glaciers (e.g. mass balance, snow cover, snow equivalent, isotopes, water use, ground water, lakes, river discharge, precipitation, radiation, clouds, or water vapor. Coordination with FOEN is important.

At the federal as well as at the cantonal level, funding of long-term monitoring comes under pressure when times call for austerity budgets. Regarding long-term monitoring, the focus is more and more on monitoring systems which are needed to meet international or legal obligations (e.g. ECV, run-off data). Harmonization is also high on the agenda.

Status (examples) of national monitoring

Run-off data: FOEN has the main responsibility (basic network). Cantons like BE, ZH, VS, LU also run cantonal networks.

There are some deficiencies, partly related to methodology. Examples: how to determine the run-off in situations where there is variable “Rückstau”, e.g. from lakes, or river power stations. Water management in cantons needs precise data for management, also in situation in which the speed is variable. They are willing to provide funding for construction and electricity, since they can justify these expenses with their role in river flow management (regulation).

Meteo-Data: Data from MeteoSwiss (e.g. precipitation) are crucial for any hydrological model. At present, data resolution is sufficient at the country level. For the modeling of hydrological catchment areas, there are still important gaps. “The Alps are a big white spot”. Precipitation data are lacking precision for process research.

Similarly, there are gaps in temperature measurement series, particularly (again) in high mountain areas where it is difficult to operate measurement stations in winter.

MeteoSwiss is the focal point for the WMO. Recently, it started to make significant steps towards standardizing its monitoring network.

Evapotranspiration: Together with ETH Zurich/IAC-ETH, FOEN is working in this direction. FOEN would like to invest into lysimeters, a reference measurement for evapotranspiration. Switzerland would need around 10-15 lysimeters at representative sites. Some existing sites (e.g. Rietholzbach) could serve as reference for the newer measurements. In addition, some measurements with the eddy-covariance measurement technique are also performed by ETH Zurich (Institute for Agricultural Sciences, SwissFluxnet network).

Soil moisture: There is not yet a concept for soil moisture data available. ETH Zurich / IAC-ETH is managing an experimental network (SwissSMEX) in collaboration with MeteoSwiss, Agroscope and WSL (18 sites). The sites are mostly located in the Mittelland, with continuous measurements, at 10 minute interval. MeteoSwiss is considering the inclusion of soil moisture measurements within the operational SwissMetNet network, in collaboration with IAC-ETH /ETH Zurich.

Snow cover: Data lacks precision for process research in catchment areas. Ideally, data would be collected in each 10km grid, and this information could be combined with detailed data from process research.

Groundwater: Measurement stations are mainly in the “Mittelland”. There is virtually no data available about groundwater outside the flat valleys. Information on the hydrological storage capacity of rock slopes etc. would be extremely valid for hydrological monitoring.

Terrestrial Climate Observation System, with focus on ECV: This is a future challenge. Young researchers should play a role. Not clear, how related to GCOS.

Snow: The snow monitoring system of SLF has been developed specifically the prediction of avalanches. There are over 200 monitoring stations for snow, but only 43 measure snow water equivalence.

DB-Solid: “Geschiebemessnetz”; long-term. Dependency from many factors, such as slope; form, size and geology of catchment area; permafrost.

Monitoring of bedload transport: continuous measurement of bedload transport intensity with the Swiss plate geophone system in several catchments.

Competence in sensors for environmental monitoring

Switzerland is a high-tech country. Research institutes of the ETH domain have become competence centers for technological innovations (e.g. optical fibers; visual techniques; audio techniques; LIDAR technology).

Small wireless sensor networks allow to make quantitative research on spatial variability[79]. EPFL has made field measurement campaigns in small catchments (20 km2) with wireless networks of 12 weather stations and river discharge monitoring. It succeeded to investigate spatial variability of meteorological parameters and their impact on run-off.

Environmental monitoring is the new paradigm. Some examples of recent developments in sensor technology:

Mobile sensors: Sensorscope is a project for Mobile Information and Communication Systems (MICS) of the EPFL. The stations are specifically designed to be easily deployable[80]. No configuration or programming is needed.

The stations may arbitrarily be placed, moved or removed according to requirements of the projects. They auto-organize into a wireless network to transfer data in a multi-shop fashion to their master station. The latter is in charge of sending data to the servers.

Sensorscope develops techniques how to deal with variable quality in difficult measurement conditions. Examples are signal processing techniques for better calibration, detection of outliers, de-noising, or interpolation.

New sensors: EPFL uses DTS instruments with 1.5 m spatial resolution to measure temperatures along optical fibre cables (1260 m) in streams.

ETH VAW has competence in continuous and real-time monitoring of suspended sediment concentrations - using laser diffractometers, turbiditymeters, accoustic techniques – and of bedload transport (geophone systems). Research sites are the Fiesch glacier and the Solis reservoir.

Long-term observations in hydrological catchments

The wish to establish networks of catchment areas has a long and thorny history, also in Germany and the US[81]. The main reason of failure was that lack of commitment and financing for long-term operation of the networks.

In Switzerland, FOEN or the National Research Institutes such as EAWAG, WSL, VAW, or MeteoSwiss are in a good position to guarantee continuity for long time series.

Examples are:

1. network of Hydrological Observation Areas (HUG) of FOEN
2. experimental catchments for process research.

HUG program (FOEN): The program dates back to the 1960ties. The main objective is long-term monitoring of run-off. The HUG are largely and preferably untouched areas where human impacts on the water sector play only a small role. Each HUG is described with some general parameters, only in qualitative terms.

Many of the areas are located in Flysch rocks, to minimize impacts of groundwater on run-off. Criteria for the selection of HUG were: climatic zones, landscape zones; small and middle-sized catchments; different altitudes; objective is to cover hydrological regimes in Switzerland in a representative way.

The HUG program is managed by a specialist in FOEN. There is a certain need to further develop the program, and FOEN is aware of this. Ideas are: Mapping of the conditions in GIS; modeling of hydrological processes which are relevant for the run-off. Modeling could help to correct the influence of human impacts on long time-series.

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[79] Parlange, Simoni, LIT [28].

[80] 20 minutes, by two persons, in each type of terrain.

[81] See e.g. WATERSNET; LIT [64].

More and more HUG have to be abandoned because of damages on infrastructure or human impacts on the water cycle (e.g. construction of small hydropower stations). Measurement points are damaged by rock falls. More resources are needed to maintain the HUG program in FOEN.

HUG management is at the division level. It would welcome that a new effort is made to revive the system. The young generation of hydrologists does even not know about HUG though it regularly uses HUG data. The program needs more resources.

Experimental catchments: There are a number of experimental catchments in which there are long-term observation and research of hydrological processes. Most of the areas are closely related to a federal research institute. Examples are: Rietholzbach (IACETH), Alptal (WSL), Dischma (SLF).

Super site research

In the international terminology of GCOS, supersites are an intensive ecosystem observatory to examine the status and processes of an ecosystem.

Each supersite comprises a main field site that takes vegetative, faunal and biophysical measurements and works over at least one gradient. They use existing and recently deployed environmental monitoring installations to collect comprehensive sets of longterm ecosystem data of high temporal and spatial resolution.

In Switzerland, the initiative for the establishment of supersites is taken by GCOS. Forest ecosystems made the start. In case of strong interest, the approach could develop into a model for long-term monitoring of ecological parameters: land-cover transformation; and its impacts on water, etc. Vegetation cover and plant diversity, soil characteristics, erosion potential, and their combined effects on the water balance and soil integrity.

The principle is the aggregation of biological, edaphic, meteorological, hydrological and economic data; scaling from plot- and plant community level to catchment wide implications. Key parameters will be specific water balances for each land cover type, the areal extent and degree of soil disturbance, and their combined hydrological consequences (water yield, discharge characteristics, sediment load). The approach is bio-geo-hydroscience. Data are collected at different scales – spatial (from plot to micro catchment) and temporal scales (from season to decade).

Super sites have to be special from a global perspective. At present, there is one on the Furka and one in Davos (Prof. Koerner, together with GIUB).

Hydrological process research and modeling

Switzerland has a rich tradition in research on hydrological process modeling. In ground water research, for example, main driving forces are: (a) new mathematical models, allowing to simulate e.g. interactions between groundwater and river flow water; important to understand the low water table problems; (b) sensor development.

Institutes which have particularly high level of modeling expertise are IACETH, ETHZ and EPFL. There is a certain risk that each research cell develops its own model. At the end there is a loss of credibility, nationally and internationally. Research community does not speak with one voice.

Today, there is no national steering or control over this research and experimental catchments. At best, FOEN receives information.

In Karst, modeling is more difficult. Often, there is no alternative than to conclude from behavior of the source on the geology. This is rather limited. Drilling is difficult, modeling very difficult. Therefore, Karst hydrology is more an applied science.

Proposals SwissEx and Swiss EnviroNet

Both initiatives are quite ambitious and could have an important impact on fostering collaboration in hydrological research[82]. However, till now, they are not yet fully discussed and taken up by the hydrology research community (e.g. CHy).

Pilots are supported by the Competence Center Environment and Sustainability (CCES) of the ETH domain. Once operational, research could become more flexible, allowing to extrapolate data from one catchment to another one. Subsequently, it will not be necessary to work all the time in the same catchment area.

SwissEx: The objective of the Swiss Experiment (SwissEx) is to make hydrological data (e.g. meteo, snow, water) which is collected by research teams transparent and accessible to all interested groups (e.g. type of measurement, sensor). The focus is on knowledge management (Data warehouse).

Research could become more flexible. Data have to be consistent, but not conform to a standard. Each data owner measures what makes sense to him, and the result is mapped on a general standard. Afterwards, the users can ask the questions which make sense to them. The system links the two sides together.

SwissEx is an ambitious program, aiming at sustainability. The list of interested partners from hydrology is quite large[83]. At present, the WSL (SLF) and the EPFL are in the lead. They have the needed design skills. Once designed, operation is likely to need 2-3 positions. Similar to GCOS, SwissEx has to become a research unit, with a clear mandate.

Swiss EnviroNet: The CCES is interested to fund a data/knowledge platform which has the potential to become a mechanism to build a user community among Swiss environmental researchers. Swiss EnviroNet would build on the experience of SwissEx and incorporate analysis tools from other CCES projects[84].

Data management is increasingly a topic of discussion across the scientific community[85]. In Swiss EnviroNet, this issue is addressed from the perspective of environmental data, for the following reasons:

1. Switzerland has a long history of observation and/or monitoring of the environment. These observational and/or monitoring data are currently managed by a diverse set of organizations
2. pilots of the technology platform SwissEx were successful. The experience could be used for a broader effort, in the whole environment research community
3. the two Research Institutes in the ETH Domain that deal most intensively with environmental data, Eawag and WSL, have a strong interest in data conservation and access and would be interested in leveraging their current initiatives in this area.

The CCES and the participating institutes consider Swiss EnviroNet as an investment. The CCES would provide funding during the proposal preparation process. The ETH Domain institutions would make explicit commitments for matching funds, including but not limited to in-kind contributions).

The Swiss voice internationally

There are experiences and initiatives which could be further developed to strengthen the voice of Swiss hydrology in international programs[86]:

1. the GCOS Cooperation Mechanism (GCM). The mechanism is developed by GCOS and the Swiss Agency for Development and Cooperation (SDC): It can finance projects which develop monitoring capacity in developing countries. A number of

[82] A good example ist he data base oft he US Geological Survey.

[83] Mainly ETH domain and federal research institutes; see www.swissex.ch.

[84] E.g. statistic methods from the project EXTREMES.

[85] In February 2011, the journal Science dedicated a whole journal to this issue.

[86] See also section 2.5.

projects are already running. GCOS considers them as show-cases, to demonstrate that it is not only a western-biased program

2. the Global Terrestrial Network (GTN) of the UN Food and Agriculture Organization (FAO). Monitoring is high on the agenda: GTN-H (hydrology), GTN-G (glaciers), GTN-GW (ground water), GTN-SM (soil moisture)
3. swiss involvement in the Critical Zone Observatories (CZO) program. The ETHZ is represented with one site, the Damma glacier forefield
4. the new initiative between SDC (Global Program Division) and the SNF: see section 2.5.

Know-how transfer research to application

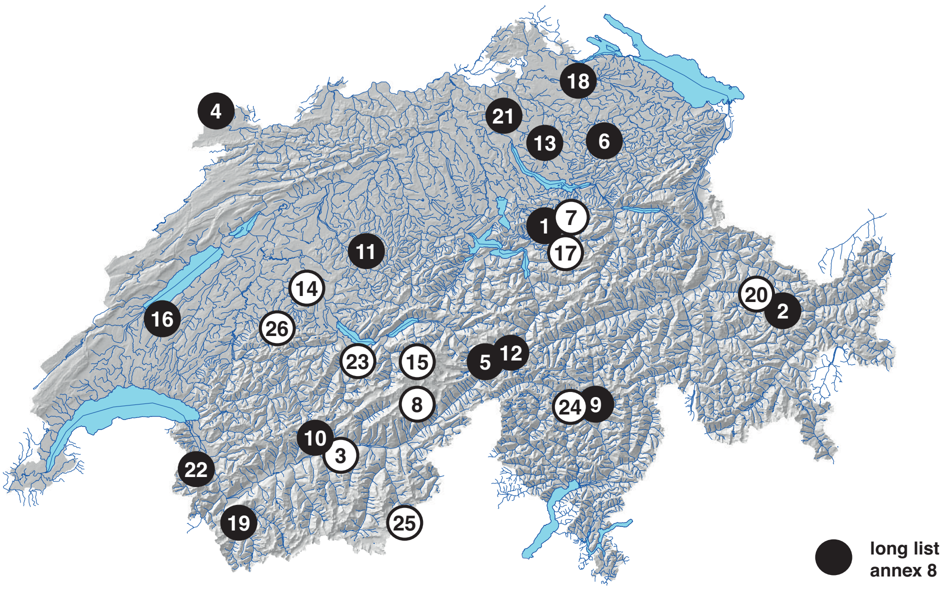
In Switzerland, and to a large extent, the cantons are responsible for water management. They depend on FOEN taking the lead. Particular areas are: know-how transfer, data management, computer programs.

Know-how transfer from hydrological research to the cantons is presently still quite weak and not implemented in a systematic way. The Group of operational hydrology, coordinated by FOEN, has a potential to become an important platform. The link to research is not yet established in a systematic way.

Cantonal offices for water management have relatively little direct collaboration with research units. They have little means to react to general recommendations from National Research Programs. Daily politics is dominating.

Annex 7

Research In Experimental Catchments In Switzerland



Old study areas

1	Alptal	WSL

Pre-alpine 1200-1400 m.

After a longer time of little activity, reactivated. Long measurement chain. History of the area is known.

Typical sub-alpine hydrological features with an interesting mix of vegetation and a most significant trend in snow cover. Bed load transport monitoring.

GIUZ and the University of Cambridge are also involved.

2	Dischma valley	WSL, SLF

Isotope research; modeling; remote sensing and snow cover monitoring.

3	Illgraben	WSL

Test site to study mass transports, earth movements; Leuk, Susten.

4	Milandre	SISKA

Karst hydrology; close to Porrentruy; detailed information on the whole catchment area, including the caves; site of SWISSKARST, of STALCLIM (financed by SYNERGIA), NAQUA QUANT; measurement of many parameters; long term observations available; underground laboratory.

Team is interested to collaborate with other research institutes (e.g. EAWAG, WSL, CHYN).

5	Rhone Glacier	ETHZ

NRP 61; CC Hydro; catchment has two run-off stations; 40 km^2; many old studies; a new lake is developing (has doubled its size in 2011); run-off station in Gletsch.

Study Andreas Bauder with 15 measurement points on the 8km long icefield; measurement of ice movements. Ice balance measurement (ice volume).

Expected 90% of the glacier will melt away till 2100; similar like other big glaciers such as Aletsch or Gorner glacier.

6	Rietholzbach	ETHZ (IAC-ETHZ)

Pre-alpine; long time series. Allows to address research questions related to agriculture and the Swiss Mittelland. FOEN HUG.

Large number of new measurements of surface fluxes (e.g. evaporation, sensible heat flux) and of soil moisture since 2008. Involved in SwissSmex and in the SwissFluxmet network. Also includes measurements of other institutes (EAWAG, UNIZH).

7	Wäggital	ETHZ, GIUZ MeteoDat

Measurements of snow equivalent for 120 years.

New study areas

8	Aletsch Glacier	CC HYDRO

Massa Blatten is the biggest run-off station, managed by FOEN; 100 m^3 per second, in peaks; in next 40 years still increase in run-off; later decrease.

Station is in the BLN and UNESCO biosphere reserve.

9	Brenno	WSL, EAWAG

SEDRIVER, NRP 61; Mr Rickenmann; sediment transport; habitats of trouts; monitoring of changes in the river profiles.

No long-term studies planned; few field research.

10	Crans-Montana	GIUB

Model catchment; GIUB; MontAqua; water stress in the Alps; development of options for water resource management.

100 km^2, covering three watersheds; measurement of water balance.

Typical for dry alpine region (950mm per year); Bovèrèche valley. 1900 m.; Plaine morte glacier is melting, relatively small glacier.

Pressure on water resources increasing: artificial snowing; swimming, golf court. 15,000 inhabitants; plus 35’000 tourists; water for consumption is free of charge; many have no water meter; Electricity production (Lac de Tseuzier).

Critical issues: changes in run-off; future of the glacier.

11	Emme, Kleine Emme	CHYN, GIUZ, ev. EAWAG

Interactions groundwater and surface water (rivers).

12	Furka / Urseren	UNIBA, GIUB

Recognized as super site; Prof Koerner (geobotany, UNIBA); interdisciplinary collaboration with hydrologists from GIUB.

13	Greifensee	EAWAG, IWAQUA

NRP 61; coordinated research; in particular pressure from agriculture on the bioscoenose; only few equipment in the field; water quality; together with EAWAG; integrated water governance; water demand of agriculture; little interest to develop area into experimental catchment.

14	Guerbe	EAWAG

Focus on water quality; context of a flood protection program and the rehabilitation of the river system (environment).

15	Lower Grindelwald glacier	GIUZ

Mainly study of mass transport, rock falls, risks and other phenomena, related to the melting of glaciers.

16	Mentue	EPFL, EAWAG

Small tributary; discharge into Broye; study area of EPFL; little of EAWAG to develop the area into an experimental catchment.

17	Muotathal, Schlichenden Brünnen	SISKA

KARST hydrology; relatively few historic data; NAQUA; average height of the catchment: 1,650 m; no glaciers; 31 km^2; FOEN run-off station.

18	Thur: Niederneunforn, Attikon	EAWAG

NRP 61; RIBACLIM; CCES RECORD project (Restored Corridor Dynamics); team has interest to develop site into a reference area for interactions of groundwater and surface water, in the context of river rehabilitation.

Dynamics of river bed development; interaction with ground water; forecasting of effects of river rehabilitation projects; long-term monitoring of water uses; development of guidelines for water management.

19	Val Ferret	EPFL

25 weather stations; 3 mayor measurement towers - radiation, evaporation, precipitation sensors; LIDARS for wind, air humidity; 10 cameras; investments of around CHF 1 million CHF.

20	Wannengrat, Davos (Weissfluhjoch)	WSL, EPFL

Study of the interfaces between the hydrological systems (atmosphere; snow; etc.). Data management part.

Planned study areas

21	Furttal	EAWAG

Suited to test findings and methods of NRP 61 such as SWIP, IWAQUA; AGWAM, DROUGHT, HydroServ, IWAGO (contact: M. Maurer).

22	Vallée de Nants	UNIL, WSL

Natural, uninhabited catchment at the transition from the frozen/glaciated to the unfrozen zone. Unique setting for studying process chains and effects of changes related to the rise of the forest, the snow, and of the permafrost line.

Analysis of processes. Each research group (WSL, UNIL) has specific interests; in the planning phase; Proposal till autumn 2012.

WSL interested to study mass transports, into rivers.

Possible to study process chain from glacier to forest. Rock fall processes and their impact on the mass transport. How is quality of the alpine and pre-alpine rivers changing?

History of the area is not well known.

Equipment needed: run-off station, meteorological stations (both supplied by UNIL).

Abandoned study areas

23	Leissigen	GIUB

GIUB wanted to transfer the catchment to FOEN; but measurement stations did not meat the criteria of FOEN.

24	Leventina	WSL

Western slopes of the Leventina, direction Bellinzona; Mr Zappa.

25	Mattmark	ETHZ

Glacier, Early pioneer.

26	Plaffeien	WSL, EPFL

Study of the impact of forest on the water cycle; Rothbach (HUG), and Schwendibach (afforested, new area).; both measuring 1.5 km^2; abandoned in 1990ties since run-off station of Schwendibach was not impermeable.

Still existing SwissSmex site (soil moisture measurements), as a collaboration between ETHZ (IAC-ETHZ) and MeteoSwiss.

Annex 8

Consultant's Proposal of a Longlist for the new Program

Here a first proposal of the consultant, to be discussed and complemented by the Program Design board:

Nr.	Name	Cantons	Processes
1	Alptal	SZ	Pre-alpine; forest, land-use
2	Dischma	GR	Alpine; snow, water balance; changes in land use
4	Milandre	JU	Jura; Karst phenomena; water quality; ground water
5	Rhone Glacier	VS	High alpine; glacier melting and its impacts; new glacier lakes; capacity of talus to store water
6	Rietholzbach	SG	Mittelland
9	Brenno	TI	South-alpine
10	Crans-Montana	VS	Inner-alpine; pressure on water resources from tourism; melting glacier; models for water management
11	Emme / Kleine Emme	BE	Pre-alpine; water-ground water interactions; water management; rehabilitation of river beds
12	Furka Urseren	VS, UR	Vegetation cover and water cycle; supersite for GCOS
13	Greifensee	ZH	Middle land; pressure on water resources from agriculture; lake; water management
16	Mentue	VD	Middle land; pressure on water resources from agriculture; water management
18	Thur: Niederneunforn - Altikon	ZH, TG	Middle land; water management options; groundwater surface water interactions
19	Val Ferret	VS	Alpine; development of monitoring parameters
21	Furttal	ZH	Pressure on water resources; water quality
22	Vallée de Nants	VS	Small glacier; mass transport; water quality

Comment

Many of these sites are relatively small (size of sub-catchments) and have eventually to be extended to meet criteria of the new program (provision of a regional component).

Annex 9

Criteria for the Selection of Experimental Catchments

General

- motivation of a significant group of hydrologists to select this particular catchment because it offers interesting research opportunities
- area is likely to be affected by major changes, either due to climate change or to increased pressure on water management (challenges for water resource management)
- option to use HUG area as (largely untouched) reference area
- certain density with long time series of measurement of hydrological parameters
- representative for a hydrological type and regime
- at least three institutes have expressed interest
- regional size (50-250 km2), with sub-catchments.

Operational criteria

- existing investments, particularly in expensive fixed measurement points with long-term data: e.g. ground-water
- long-term operation and maintenance of the infrastructure and equipment is guaranteed: accessibility, funds, regular visits to the sites by FOEN or Federal Research Institutes
- opportunity to initiate development of the HUG program, resulting in a more consolidated network of HUG and experimental areas, in which HUG can also be used for references
- infrastructure, access.

Research criteria

- relation to future problems, and an area where new processes are likely to occur
- potential to study new processes
- link to ongoing long-term monitoring sites: biodiversity, water quality, water quantity, etc.
- typical, for a constellation of interfaces of hydrological systems
- potential interest of an international monitoring program (e.g. GCOS) in the site.

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Nr. 1 Hug, J.; Beilick, A.,1934: Die Grundwasserverhältnisse des Kantons Zürich, mit Karte der Grundwasserströme des Kantons Zürich. Herausgegeben gemeinsam mit der Baudirektion des Kantons Zürich. XX+ 328 Seiten, 146 Figuren und Karte 1:100 000.

Nr. 2 Eugster, E., 1938: Schneestudien im Oberwallis und ihre Anwendung auf den Lawinenverbau. VIII+ 84 Seiten, 42 Textfiguren und 7 Tafeln.

Nr. 3 Bader, H.; Haefeli, R.; Sucher, E.; Neher, J.; Eckel, 0.; Thams, Ch. (Einführung von P. NIGGLI) 1939: Der Schnee und seine Metamorphose. Erste Ergebnisse und Anwendungen einer systematischen Untersuchung der alpinen Winterschneedecke, durchgeführt von der Station Weissfluhjoch-Davos der Schweiz. Lawinenforschungskommission. 1934-1938. XXIII+ 340 Seiten, 18 Tafeln,
154 Figuren, 18 Tabellen. vergriffen

Nr. 4 Lütschg-Loetscher, 0.: Zum Wasserhaushalt des Schweizer Hochgebirges.
1945: I. Band, 1. Teil, Erste Abteilung, Kapitel 1-3 (Mitarbeiter Rudolf Bohner): Heutiger Stand der Niederschlagsforschung. Heutiger Stand der Abflussforschung. Zusammenhänge zwischen Niederschlag und Abfluss. Mit Tabellenwerk: Ergebnisse der Niederschlagsforschungen. VI+ 60 Seiten. 9 Karten, 10 Textfiguren, 17 Tabellen.
1944: I. Band, 1. Teil, Zweite Abteilung, Kapitel 4, 5: Vorratsänderungen im Wasserhaushalt der Gletscher. Verhalten des vorstossenden Obern Grindelwaldgletschers. VII+ 34 Seiten, 10 Tafeln, 21 Figuren und 6 Tabellen.
1949: I. Band, 1. Teil, Dritte Abteilung, Kapitel 6-8 (Mitarbeiter Rudolf Bohner),

mit einem Beitrag von Hans Burger. Boden und Vegetation im Wasserhaushalt des Hochgebirges. Die Bedeutung des Schneetransportes durch den Wind. Die Bedeutung der Nebel-, Tau- und Reifbildungen. VIII+ 68 Seiten, 4 Textfiguren, 4 Fototafeln.
1950: I. Band, 2. Teil, Kapitel9 (Mitarbeiter Rudolf Bohner), mit Beiträgen von H. Huber, P. Huber, F. de Quervain. Zur Hydrologie, Chemie und Geologie der winterlichen Gletscherabflüsse der Schweizer Alpen. VI + 121 Seiten, 26 Textfiguren, 6 Falztafeln.
1954: I. Band, 3. Teil, Kapitel10 (Mitarbeiter: Theophil Hauck, Rudolf Bohner). Die Eis- und Schneeverhältnisse der Oberengadiner Seen, insbesondere des St. Moritzer Sees. Beitrag zur Gewässer- und Klimakunde des Oberengadins. VI+ 173 Seiten, 54 Textfiguren, 8 Tafeln, 48 Tabellen.
1944: II. Band, 3. Teil (mit Beiträgen von Rudolf Bohner und Walter Dietz). Zur Hydrologie der Landschaft Davos. XLIV+ 490 Seiten, 2 Karten, 9 Tafeln, 146 Textfiguren, 173 Tabellen.
1948: 111. Band, Forschungsgebiet Nr. 16, F. GYGAX. Niederschlag und Abfluss im Einzugsgebiet der Magliasina. 100 Seiten, zahlreiche Textfiguren und Tafeln.

Nr. 5 Eugster, H.P., 1952: Beitrag zu einer Gefügeanalyse des Schnees. 64 Seiten, 42 Textfiguren, 1 Falztafel, 1 Fototafel.

Nr. 6 Sucher, E., 1948: Beitrag zu den theoretischen Grundlagen des Lawinenverbaus. Herausgegeben gemeinsam mit der Schweizerischen Schnee- und Lawinenforschungskommission. 113 Seiten, 67 Textfiguren.

Nr. 7 Hofer, F., 1952: Über die Energieverhältnisse des Brienzersees. 95 Seiten, 4 Textfiguren, 8 Tafeln, 3 Kunstdrucktafeln.

Nr. 8 Hoeck, E., 1952: Der Einfluss der Strahlung und der Temperatur auf den Schmelzprozess der Schneedecke. 36 Seiten, 22 Tafeln, 22 Tabellen.

Nr. 9 Nydegger, P., 1957: Vergleichende limnologische Untersuchungen an sieben Schweizerseen. 80 Seiten, 57 Figuren, 24 Tabellen.

Nr. 10 Steinemann, S., 1958: Experimentelle Untersuchungen zur Plastizität von Eis. 72 Seiten, 91 Textfiguren.

Nr. 11 Reist, M., 1960: Beiträge zur Morphologie und Hydrologie des Bavonatales. 65 Seiten, 44 Figuren.
Hirsbrunner, G. Beiträge zur Morphologie und Hydrologie der Rovanatäler. 79 Seiten, 18 Figuren, 26 Fotografien.

Nr. 12 Binggeli, V., 1961: Zur Morphologie und Hydrologie der Valledel Lucomagno. 124 Seiten, 30 Tabellen, 64 Figuren, 9 Fototafeln.

Nr. 13 Zeller, G., 1964: Morphologische Untersuchungen in den östlichen Seitentälern des Val Blenio. 111 Seiten, 64 Textfiguren, 2 Tafeln.

Nr. 14 Niklaus, M., 1967: Geomorphologische und limnologische Untersuchungen am Öschinensee. 116 Seiten, 26 Textfiguren, 1 Tafel.

Nr. 15 Grütter, E., 1967: Beiträge zur Morphologie und Hydrologie des Val Verzasca. 92 Seiten, 9 Karten, 36 Figuren, 27 Abbildungen, 33 Tabellen.

Nr. 16 Nydegger, P., 1967: Untersuchungen über Feinststofftransport in Flüssen und Seen, über Entstehung von Trübungshorizonten und zuflussbedingten Strömungen im Brienzersee und einigen Vergleichsseen. 92 Seiten, 58 Abbildungen, 6 Tafeln, 29 Tabellen.

Nr. 17 Schweizer, H.U., 1970: Beiträge zur Hydrologie der Ajoie (Berner Jura). 221 Seiten.

Nr. 18 Jaggi, Ch., 1970: Hydrologische Untersuchungen in verschiedenen Tessinertälern. 167 Seiten.

Nr. 19 Kasser, P.; Schram, Karin; Thams, J.C., 1970: Die Strahlungsverhältnisse im Gebiet der Baye de Montreux. 46 Seiten.

Nr. 20 Föhn, P., 1971: Methoden der Massenbilanzmessung bei grossen Schneehöhen, untersucht im Firngebiet des Grossen Aletschgletschers. 111 Seiten.

Nr. 21 Tripet, J.P., 1973: Etude hydrogéologique du bassin de la source de l'Areuse (Jura neuchâtelois). 183 pages.

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