EviWet: Evidence-based Decision Support for Hydrological Ecosystem Services from Wetlands

Goal and relevance

The capacity of wetlands to moderate extremes of flood and drought is an important rationale for including wetland restoration and construction in major climate adaptation investments being funded by Swedish authorities (e.g. LOVA Local Water Protection Projects, NV National Wetland Action). The success of such investments depends to a large extent on predicting the hydrological function of wetlands in different topographic settings under the climate of the coming century. The S-Hype modeling platform (Strömqvist et al., 2012) could be the basis for an interactive dedicated decision support tool for planning wetland management. The hydrological function of wetlands in Swedish landscapes, however, is not well characterized (Naturvårdsverket, 2017). Until this knowledge gap is rectified, it will undermine efforts to make effective use of the hydrological ecosystem services that wetlands can deliver.

Part of the knowledge gap is due to the shortage of relevant hydrological data from wetlands. This is explained by the fact that wetlands are often only a smaller fraction of the gauged catchments that have provided much of the data used to model runoff hydrology under Swedish conditions, including S-Hype. Fortunately, the interest in greenhouse gas evasion from peatlands has resulted in the hydrological instrumentation of peatlands which often includes eddy covariance systems that measure evapotranspiration. This allows for detailed water balance analyses of how peatlands store and release water, either laterally as runoff, or vertically back to the atmosphere and regional vapor flows. The longest data records (>10 years) are from relatively pristine wetlands and forests, but the newer data sets include drained and restored peatlands, with nearby control sites. The behavior of constructed wetlands would also benefit from measurement campaigns, with water level being a particularly valuable variable for modeling such sites (Lindström, 2016).

These observational data have opened up new, largely unexplored possibilities for quantifying the hydrological function of peatlands (pristine, drained or restored). This project will make use of our experience in analyzing high-resolution runoff data (e.g. Karlsen *et al*., 2019)to determine the storage and release characteristics of wetland catchments and define parsimonious modeling strategies to quantify this function in peatlands and wetlands. These models will be used to explore how different types of wetlands will function under future climate conditions in differnet topographic settings. The results of these detailed studies will then be used to improve the representation of wetlands in the landscape scale hydrological modeling system S-Hype. While the focus is on the hydrological ecosystem services of wetlands, this work will also improve S-Hype's modeling of nutrient retention by wetlands which is closely linked to hydrology (Pers et al., 2016).

With the enhanced, evidence-based predictive capacity of S-Hype developed in this project, we will create a decision support tool for planning hydrological ecosystem services from wetlands. This will improve the capacity of municipalities, government agencies and private actors to increase the delivery of ecosystem services in a landscape perspective and better utilize wetlands in climate change adaptation.

Questions and hypotheses

How do different types of wetlands alter the amount and timing of runoff? Specifically, to what extent will wetland management choices influence low flows and flood peaks at different spatial scales under Sweden's geographic and climatic conditions in the coming century?

How can the range of hydrological function for different wetland types (both pristine, drained or restored peatlands and constructed wetlands) be simulated in S-Hype under future climate scenarios in different topographical configurations?

How can the specific issues regarding wetland management be addressed in a bespoke wetland decision support tool for public and private actors with a stake in wetland management?

Hypothesis: New, wetland-specific data sources can fill the current gap in knowledge about wetland hydrological function. This evidence-base can be developed into an operational decision support tool for planning delivery of hydrological ecosystem services from wetlands.

Expected results

A set of high temporal resolution water balance data will be compiled from ten catchments with at least 30% peatland (but often over 50%) and two nearby forest catchments (<10 % peatland). These data sets, already being created by other projects, are new to Nordic research in that they supplement the rainfall, groundwater level and runoff data with measurement of evapotranspiration from Eddy Covariance (EC) used primarily for measuring greenhouse gas fluxes, all at hourly temporal resolution. Additional data sets, but without EC data, will be collected from constructed wetlands, since these are another key tool in Swedish climate adaptation. (Table 1)

Table 1 - Catchments with detailed water balance information

Site	Program	Character	Period*	Area	% wetland	Lat./Long.	Contact
Degerö	ICOS	mire peatland	2005-2022	270	70	64°11'N, 19°33'E	M. Nilsson
Svartberget	ICOS	forest	2015-2022	47	18	64°11'N, 19°33'E	M. Peichl/H. Laudc
Nyänget	Kyrcklan	mire*	2002-2022	18	44	64°11'N, 19°33'E	H. Laudon
Mycklemossen - Norra	SITES	mire peatland	2012-2022	91	44	58°22'N, 12°10'E	L. Klemedtsson
Mycklemossen - Sodra	SITES	mire peatland	2016-2022	77	38	58°22'N, 12°10'E	L. Klemedtsson
Kulbäcksliden- Stormyran	SLU	mire peatland	2019-2022	30	38	64°11'N, 19°33'E	M. Nilsson
Kulbäcksliden-Hålmyran	SLU	mire peatland	2019-2022	40	66	64°11'N, 19°33'E	M. Nilsson
Kulbäcksliden-Stormyran	SLU	mire peatland	2019-2022	106	53	64°11'N, 19°33'E	M. Nilsson
Forest with ditches	EU Life IP	forest - mineral soil	2019-2022	10	0	64°09'N 19°32'E	M. Peichl/H. Laudc
Peatland forest	EU Life IP	forest - drained mire peatland	2019-2022	12	30	64°09'N 19°32'E	M. Peichl/H. Laudc
Peatland restoration - treatment	EU Life IP	mire - restored watershed East	2020-2022	18	90	64°10'N 19°50'E	J. Järveoja/H. Laud
Peatland restoration - treatment	EU Life IP	mire - restored watershed West	2020-2022	6	100	64°10'N 19°50'E	J. Järveoja/H. Laud
Constructed wetlands (10)	SMHI	constructed wetlands*	2020-2022	2-20	50-80	from Vattenveb	N Hjerdt

* Evapotranspiration from Eddy Correlation not available

These data series, combined with laser-scanned micro-topography and other map attributes, will help to quantify and conceptualize the ability of wetlands to initially retain inputs of rainfall/snowmelt, and then release some of this as runoff, during both flood and drought situations. This will be a development of our previous work analyzing flow initiation and then recession to define the nature of hydrological storage function using high resolution data in the forest landscape (Karlsen et al. 2016, 2019). These analyses will be used to explore the response of different types of wetlands in different geographic settings under the range of climatic conditions across Sweden during the coming century. The S-Hype system will then be adapted to explicitly capture the salient aspects of wetland function in order to support operational planning by local and regional authorities and enterprises. Parallel work with end-users will develop a stand-alone decision support tool (DST) built upon the improved S-Hype. This DST will facilitate planning different types of wetland management in a landscape perspective to optimize hydrological ecosystem services and climate adaptation regarding flow extremes.

Usefulness for NV and HaV

Results from this study will help Swedish authorities to achieve specific environmental quality objectives in cooperation with county boards, municipalities, and land owners (both small scale and corporate). The project is particularly significant to the objectives of *Reduced climate impact*, *Flourishing lakes and streams*, and *Thriving wetlands,* but also has implications for other objectives, including *Zero Eutrophication* and the EU Water Framework Directive. The expected outcome of the project will improve our ability to quantify the effects of wetland management on the hydrological regime. The project's DST will address questions that include:

- Can wetlands provide reduce the impact of climate change on water resources? (Objective: *Reduced climate impact*)
- Can wetlands reduce the negative impacts of flow extremes in downstream lakes and rivers? (Objective: *Flourishing lakes and streams*)
- Can wetlands in themselves have an impact on the local climate by regulating air moisture and temperature in the surrounding landscape? (Objective: *Thriving wetlands*)

This will aid in realizing plans for climate adaptation and Agenda 2030. At the larger scale, results from the project will we useful to identify potential measures in River Basin Management Plans (RBMP) to meet the requirements of the EU Water Framework Directive. The national library of potential measures within VISS can also be updated with quantitative results from this project to help identify cost-efficient wetland restoration/construction sites.

Over the last decade, open data from the hydrological model S-HYPE has also emerged as a useful source of information for many water-related decisions in society. By improving the conceptualization and parameterization of wetlands in S-HYPE, this project will also increase the quality of hydrologic data already distributed via SMHI Vattenwebb, as well as S-Hype's prediction of nutrient retention by different types of wetlands (Pers et al., 2016).

Target Groups

Target groups will be identified at an early stage in the project to include wetland administrators, specialists and managers at different scales. At a national scale, specialists at NV, HaV, SGU and Jordbruksverket are interested in wetland function and the possibility of utilizing the hydrological properties of wetlands more effectively. At the regional scale, wetland experts/administrators at the County Administrative Boards (länsstyrelse) and Regional Water Authorities (Vattenmyndigheterna) are central to the project as they often initiate and administer specific projects. They also carry out the work dictated by the EU Water Framework Directive, regional climate adaptation plans, and regional water resources plans. At the river basin scale, improved evaluation of the impact of wetland restoration/construction will be very useful. At the local scale, municipalities, NGOs and stakeholders will also benefit from the DST's guidance on how individual wetlands can be managed for ecosystem services.

Reference Group

SMHI has established contacts with many water managers from all target groups mentioned above. During the first month of the project, the project will use this network to recruit half a dozen wetland specialists and administrators to a reference group for the development of the wetland decision support tool (DST). The first task of the reference group is to identify the capabilities needed in the DST. Later in the project, the reference group will test and give feedback on the interactive design of the DST. These tasks are relatively independent of other tasks in the project, so work with the reference group on the DST can start early and progress throughout the project.

Research Task – Theory and method

The central issue for this project is defining the way in which peatlands/wetlands first store and then release precipitation inputs into streamflow and evapotranspiration. Knowing how these storages work is essential for planning the availability of water in streams and aquifers. In Sweden great strides have been made in this type of modeling for landscapes, based on extensive observational data. This has contributed to the established S-Hype model system that provides real time and future flows (Strömqvist et al., 2012). S-Hype is already a key part of Swedish infrastructure planning from local to national scales. There are, however, great local differences in how catchments store and release water that our research using high resolution runoff data from nested catchments has identified (Karlsen et al. 2016a,b). In these analyses, wetlands stood out by functioning differently than forests, both in total annual runoff, but also in the timing of that runoff (Karlsen et al., 2019). Our climate scenario studies also found that wetlands are decisive for future hydrological regimes (Teutschbein et al., 2015 & 2018).

The hydrological differences bewtween wetlands and forests result in large part from the ecohydrological properties of peatlands that are entirely distinct from those of other soils types. One key to this is the ability of peatlands to expand vertically, increasing storage by as much as 100 mm and changing the water holding properties of the peat (Nijp *et al.*, 2017). While this behavior is recognized, there has been a paucity of relevant data at the catchment scale to quantify this behavior at temporal and spatial scales suitable for planning the placement of wetlands in landscapes to achieve the specific ecosystem services of flood and drought mitigation (Waddington et al., 2015).

The high spatial resolution of our data from the Krycklan basin enabled us to identify that wetlands influenced overall catchment hydrological response at a seasonal scale, but even in this exceptionally rich data set there were few subcatchments with more than 20% wetland, and none over 50%. When a wetland is just 5-20% of a catchment, it is difficult to quantify the specifics of wetland function. Furthermore, ET had to be estimated by difference from the water balance (as is the case in almost all hydrological literature), giving little insight into the short term storage of water in wetlands vs forests. The shortage of relevant data is exacerbated by the fact that natural wetlands behave differently that drained or restored wetlands (McCarter and Price, 2013) .

This project will provide the missing quantification of wetland function. This project is based on exploiting new data sources for peatland dominated catchments at an hourly scale. The existence of contemporaneous ET on multiple peatland sites, water level on the constructed wetlands, and surface microtopography provide an unprecedented opportunity to resolve wetland function.

These data, together with our expertise in analyzing high resolution runoff data to define the storage properties of catchments, will enable us to quantify and model the function of wetlands under future climate scenarios. This will provide the evidence base needed to upgrade the capacity of the S-Hype Model for simulating wetlands and create a dedicated DST to help landscape-scale planning deliver hydrological ecosystem services from wetlands.

Work Package 1: Quantification of storage and release using high-resolution observations
Objective: Assemble hourly water balance data and other catchment info for further analysis
Research Questions:

- *Quality controlled and commensurate data sets*
- *Establish supplementary measurements on constructed wetlands, including water levels*
- *Exploratory analyses of the data including storage calculations and temporal variations*

All of the data are provided by research studies that adhere to best practices for data management. Still, our experience with such catchment data is that rigorous quality control and initial characterization of the properties of the data set are essential prior to further analysis and modelling. Eddy covariance data on moisture exchange needs particular care to identify periods when turbulence conditions allow for accurate measurement, and then the treatment of gaps in the record.
For constructed wetlands, 10 sites will be identified for high resolution measurements from SMHI's register of such wetlands. Where needed, new measurements will be started, since even two years of data can be useful for estimating the properties of such sites (Lindström, 2016).

Work Package 2: Storage properties of different wetlands
Objective: Quantify the ability of different types of wetlands to store and release water
Research Questions:

- *Threshold and recession analyses to characterise reservoir storage-discharge relationships*
- *Evaluate differences between different wetland types*
- *Modelling of the observed behaviour of the catchments*

Exploring the storage and release of water from different types of wetlands using recession and threshold analysis techniques will be the starting point for conceptualizing the hydrological function of pristine, drained, restored and constructed wetlands. Models are excellent tools for learning about processes from observations and conceptualizations by formalizing hypotheses in a model structure that predicts the hydrological behaviour of different land management choices under future climatic scenarios. The HH-model (Cresto-Aleina *et al.*, 2015), complemented with the ecohydrological mechanisms formulated by Nijp *et al.* (2017) seems to be a particularly interesting combination for our study at this point as it includes explicit consideration of ecophysiological feedbacks and micro-topography on wetland hydrological function. Such an exploratory model will be more complex than an operational planning tool. This work package will develop an exploratory, process-based modelling perspective needed to define the key functionality needed for operational modelling.

Work Package 3: Significance of climate and catchment topology for ecosystem services
Objective: Explore the role of climate and wetland siting for hydrological function
Research Questions:

- *Define the hydrological ecosystem services achieved (mitigation of drought and flooding) with different configurations of wetlands in landscapes under future climatic scenarios*
- *Define the key functionalities that need to be captured in an operational decision support tool*

The planning of wetland location and type to improve the delivery of hydrological ecosystem services from the landscape is the central goal of this project. This WP will use scenarios to explore how different distributions of wetlands in Swedish landscapes will influence the timing and amount of surface water flows using the models from WP2 and SMHI's regionally downscaled climate scenarios for the coming century. This will provide a basis for defining the essential level of functionality needed in the wetland model components of the operational S-Hype model.

Work Package 4: Operational modeling of wetland hydrological function
Objective: Improving the representation of wetlands in S-Hype
Research Questions:

- *Evaluate S-Hype with respect to observations (WP2) and simulation scenarios (WP3)*
- *S-Hype Model development for wetland functionality*

The existing peatland and wetland routines in S-HYPE will be evaluated using the observed wetland function and modelled scenarios from WP's 2&3. This will be used to develop the ability of S-Hype to account for ecophysiological dynamics of peatland water storage properties, as well as lateral flow from surrounding land areas into peatlands/wetlands. Drainage and restoration of peat soils will also be explicitly included in the S-HYPE model. Implications of the enhanced wetland hydrology for water quality related predictions by S-Hype (e.g. nutrient retention) will also be considered.

Work Package 5: Creation of an Interactive Decision Support Tool (DST)
Objective: Develop an interactive wetland planning tool based on end-user needs
Research Questions:

- *Identify the most important functionality needed for managers*
- *Develop an interactive design for the DST*
- *Utilize the enhanced S-HYPE from WP-4 to provide an evidence-based DST for capitalizing on the unique hydrological ecosystem functions of peatlands/wetlands*

The ultimate delivery from this project is an openly available, user-friendly, interactive DST for wetland/peatland planning . We will start by discussing the functionalities of wetland planning tools available in other countries with our project reference group to identify the most important features for Swedish requirements. The DST will meld the scientific findings of this project with specific user requirements. The DST will be based on existing S-Hype code at the beginning of the project, to allow interactive testing by the reference group, and evolve as more sophisticated representations of wetland function from other work packages become available. Since S-HYPE provides hydrological data for all of Sweden at a high resolution (ca 40 000 sub-basins with an average area of 7 km^2), wetland planners in all parts of Sweden will be able to use the new planning tool for decision support. The DST will be hosted online by SMHI with other tools in SMHI Vattenwebb.

State of the Art

The function of wetlands

Swedish wetlands are generally peatlands, built up largely from mosses. These retain and release water differently than mineral soils due to the ecophysiology of peat which rapidly changes its structure, volume, and water holding capacity in response to precipitation inputs (Acreman *et al.*, 2007). The short-term changes of the peat in response to wetness conditions are fast (days to months), and reversible, but generally nonlinear (Waddington et al., 2015). Due to these and other characteristics, wetlands are capable of offering multiple ecosystem services (e.g. Naturvårdverket, 2009, 2019). Biodiversity, water quality, carbon storage, groundwater recharge and mitigation of flow extremes are some examples of these services. Constructed wetlands do not necessarily have peat substrate, but can also achieve key ecosystem services (Land et al., 2016). Landscape scale restoration of wetlands will give quick initial responses, (Richardson *et al.*, 2011; Bufkova, *et al.*, 2011). The recovery of hydrological function towards that of an undisturbed peatland takes much longer though (McCarter and Price, 2013). In the case of cutover peat, it can take 40 years after restoration for the hydrological dynamics to approach natural levels (Taylor and Price, 2015). Peatlands also undergo irreversible changes in response to human interventions such as drainage or restoration (Bullock and Acreman, 2003)

In Sweden, 5-20% wetland cover effects catchment scale hydrological responses with respect to the amount and timing of flows (Karlsen et al., 2016). But with such a small percentage of wetland area, it is difficult to separate the specific functioning of wetlands from that of other soils. So there remains a great need for detailed studies of peatland/wetland hydrology that can go beyond the finding that wetlands change the hydrological regime to support evidence-based planning of peatlands/wetlands in a landscape perspective to improve the ecosystem services. This is similar to the conclusion that the Swedish Environmental Protection Agency's own review of the knowledge base for wetland ecosystem services arrived at (Naturvårdsverket, 2017). The fact that the hydrological functionality of different peatland types varies widely further emphasizes the need for dedicated studies of wetland hydrology (Bullock and Acreman, 2003). High resolution hydrological data from wetland/peatland dominated catchments, including continuous water table measurements and or land-atmosphere exchange of water from eddy correlation will thus be a useful starting point for this project. Laser scanning now also provides micro- and macro-topography as well as slope at scales useful for defining surface storages and landscape connectivity.

Techniques for distinguishing hydrological function, and models for defining wetlands

The new data sources in Table 1 do not themselves define peatland hydrological function, especially given the potential for non-linear behavior. Analysis of recession curves and response thresholds are promising approaches to initially characterize catchment water storage and release (Roques et al., 2017; Staudinger et al., 2017, Karst et al., 2019). During conditions with high rainfall or snowmelt, the discharge and peak flow will depend on the varying capacity of the wetland to store water. During low flow on the other hand, we are interested in the ability of the wetland to slowly release water, so that the flow is sustained even under dry climate conditions.

Multiple models have been developed to reproduce peatland hydrological functionality at various scales and complexity levels. Many of these models represent peatlands as a 1-dimensional column and simulate the water fluxes and storage either as Darcian flow (e.g. CLASS3W-MWM, Wu *et al.*, 2012)) or in a simplified way with equilibrium soil moisture states (PEAT-CSLM, Bechtold *et al.*, 2019). One special aspect of wetland hydrology is the non-rigidity of the peat matrix, called 'mire breathing' by Kellner and Halldin (2002). While peatlands often can be seen as units which can be simulated by 1-D representations, this does not allow the explicit representation of drainage ditches. For this, at least a 2-D representation is required, such as FEMMA (Haahti *et al*. 2017). Others have used fully distributed models to simulate peatlands and their interactions with the surroundings. Jaros et al. (2019), for instance, used the HydroGeoSphere (HGS) model to simulate the hydrology of a wetland landscape in Northern Finland. Other models have focused on peat structure (Rezanezhad *et al.*, 2016) and water retention capacity (Golubev and Whittington, 2018). Specifically for the case of Sweden, Nijp et al. (2017) showed that adding ecophysiological mechanisms for self-regulation of water storage and release greatly improved water table and water content simulations. Another feature of peatlands is the importance of micro-topography, which is considered explicitly in the Hummock-Hollow (HH) model (Cresto- Aleina *et al.*, 2015).

Generally, self-regulating processes and feedback mechanisms are often deemed necessary since peatlands structures are highly dynamic (Ise *et al.*, 2008). Specific functions identified as important for wetland hydrological function include hysteretic behaviour in hydraulic conductivity during wetting and drying (Rezanezhad *et al.*, 2016) (Golubev and Whittington, 2018); vegetation water content (McCarter and Price, 2014); peat surface elevation fluctuations with water table position (Nijp *et al.*, 2017); and the degree of vegetation degradation, (Piniewski *et al.*, 2012); together with overland flow regulation by vegetation (Holden *et al.*, 2008).

For operational modeling, such detailed models are not feasible. However, a more complex model of wetland hydrology can be used to generate data which then is used to train simpler models (Weiler and McDonnell, 2004). We will pursue this strategy by applying a wetland model appropriate to reproducing the observations in WP2 (probably a combination of what Cresto-Aleina et al. (2015) and Nijp et al. (2017) have already developed). Then in WP3 these models will be run using regionally downscaled climate scenarios for the next century (e.g., Teutschbein et al., 2015) and changes in wetland characteristics (e.g., size, topographic setting). These simulations will provide virtual experiments which deliver data that can be used to constrain the simpler, S-Hype operational model formulations in WP4.

Planning tools at the landscape scale for wetlands

For a successful use of wetland hydrological function in landuse planning, the complex hydrological processes taking place within a wetland need to be formulated in tools appropriate for planners (Mitsch and Gosselink, 1993). In some parts of the world, particularly in the USA, specific planning tools for wetland restoration/construction are available, e.g., California (https://scwrp.databasin.org/) and Wisconsin (https://www.wetlandsbydesign.org/). These tools vary in complexity but usually combine geographical and hydrological data. Most tools offer support to identify the most appropriate sites at which to implement restoration. The criteria for siting are based on a wetland's ability to provide an ecosystem service, as indicated by factors such as occurrence in a floodplain, or in an area with drought risk, or in an area with recreational value. For planning tools to be useful in the Swedish situation, input from an end-users will be needed, a feature of our proposal (WP5).

The starting point for work with the decision support tool, besides end-user inputs, will be the HYPE model (Hydrological Predictions for the Environment) developed by the Swedish Meteorological and Hydrological Institute (SMHI) to support the implementation of the Water Framework Directive in Sweden (Lindström et al., 2010). It models the flow of water and elements in large-scale applications, and includes both natural conditions and man-made alterations. S-HYPE is a high-resolution version covering all of Sweden (Strömqvist et al. 2012). Both S-HYPE and HYPE are being continuously improved (e.g. Pers, et al., 2016). Model results are available at www.vattenwebb.se. S-HYPE is also the corner stone of the Swedish flood warning service.

Due to the unusually dry summers of 2016-2019, construction of wetlands has been suggested as a measure for re-distributing water flow in time, i.e increasing low flows and decreasing flow peaks. In response to this, a new routine for constructed wetlands with respect to water and nutrient flows was implemented in HYPE during 2019. Although some testing has been done (e.g. Arheimer and Pers 2017) there is a need for data to test and improve the routines for both constructed weltands, and the existing treatments of peatlands. That is the starting point of our proposed project.

Organization and management

Kevin Bishop is Professor of Environmental Assessment and SLU's Pro Vice Chancellor with responsibility for environmental monitoring and assessment (70%). The subsurface hydrology and biogeochemistry of the Swedish landscape has been a focus throughout his career. He will coordinate the contributions of the senior scientists to achieve the overall goals of the project. Faculty funds will cover his involvement.

Jan Seibert is Professor of Geography at the University of Zurich, Switzerland, as well as a guest professor at SLU. Seibert's internationally recognized work on modeling the hydrological implications of climate change, and the value of data in hydrology will guide the work to model wetland function. He will have primary responsibility for mentoring the post-doc, and WPs 1-2. Funds for his guest professorship at SLU will cover his involvement.

Claudia Teutschbein is an associate senior lecturer at Uppsala University. Her expertise is in predicting the effects of climate change, from regional downscaling of scenarios to ensemble modeling. This will be her focus in the project, leading WP3.

Niclas Hjerdt is a senior hydrologist at the Department of Core Services within SMHI. Since 2010 he coordinates the development of SMHI Vattenwebb, an open web portal offering hydrological data and tools for water managers in Sweden, with an annual budget of 15 Mkr. He will lead WP5 and the development of the DST, with assistance from web developers at SMHI.

Göran Lindström is a senior hydrologist at the department for research and development at SMHI. He has long experience with developing the HYPE model. He was the project leader during the initial development of the HYPE model, and is responsible for the continuous improvement and development of S-HYPE. He will lead WP4.

Charlotta Pers is a researcher at the hydrology research and development at SMHI. She has many years of experience in programming and systems analysis, including developing a lake model for eutrophication studies. She is responsible for the code of the open source hydrological model, HYPE and will contribute to WPs 4&5.

Johan Strömqvist is a hydrology and water quality expert at the department for research and development at SMHI. He was responsible for implementing routines for simulating nitrogen and phosphorus during the initial development of the HYPE model and, at a later stage, the development of suspended sediments, water temperature and pathogens modules in HYPE. Johan has also been heavily involved in the set-up of various large-scale HYPE applications (e.g. national set-ups for Sweden and England, the La Plata basin and the pan-European E-HYPE model). He will contribute to WPs 4&5

A Post-Doc will be recruited to work 100% in the project, with primary involvement in WPs 1,2&3.

Time and Communication plan

This research aims to improve the planning of wetlands in Sweden. Therefore the audience, besides the scientific community, are government authorities and municipalities as well as private enterprises and NGOs with an interest in making better use of multifunctional wetlands in the achievement of environmental goals and climate adaptation. We will make extensive use of SMHIs well-established role in infrastructure planning. This has developed channels for multidirectional information transfer between scientists, landuse professionals, policy makers and land owners, both large and small (www.smhi.se/ professionella-tjanster). This communication will help steer this project towards providing decision support of relevance to society as it comes to terms with the challenges of climate adaption and the achievement of environmental goals.

SLU's experience with environmental monitoring and assessment (www.slu.se/miljoanalys/) will also be taken as a role model. Our 12 environmental assessment programs promote increased availability of the data and analysis tools managed by SLU to the public and private sectors. We see this approach as a means for both sharing the information and tools developed in this project as well as a source of inspiration for the project.

We expect that members of the project group will regularly attend workshops and conferences relating to wetland planning in Sweden. At the end of the project we will organize a national workshop to launch the decision support tool developed by the project. The workshop will also summarize progress in better understanding the hydrological function of wetlands, and how this knowledge can contribute to achieving society's multiple goals for these key parts of the landscape. It is expected that the Post-doc involved in this project will develop into a resource in her/his own right for transfer of knowledge between the scientific community, policy makers and the public.

	Year 2020				Year 2021				Year 2022			
Time and communication plan	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36
Personnel activities												
PI Kevin Bishop	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Co-workers state *name*												
Jan Seibert	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Claudia Teutschbein					10%	10%	10%	10%	5%	5%	5%	5%
Göran Lindström	x	x	x	x	x	x	x	x	x	x	x	x
Charlotta Pers	x	x	x	x	x	x	x	x	x	x	x	x
Johan Strömqvist	x	x	x	x	x	x	x	x	x	x	x	x
Niclas Hjerdt	x	x	x	x	x	x	x	x	x	x	x	x
Web developer			x	x			x	x			x	x
Hiring staff/co-workers *Post-Doc n.n.*	67%	100%	100%	100%	100%	100%	100%	100%	33%			
Project activities												
WP 1 Quantification of storage and release												
Quality controlled and commensurate data sets	x	x	x									
Establish supplementary measurements		x	x									
Exploratory analyses of the data		x	x	x								
WP 2 Storage properties of different wetlands												
Threshold and recession analyses				x	x	x						
Evaluate differences between different wetland types					x	x	x					
Modelling of the observed behaviour of the catchments						x	x	x				
WP 3 Significance of climate and catchment topology												
Ecosystems services achieved in climate/landuse scenarios					x	x	x	x	x	x		
Define key functionalities needed in Dec. Supp. Tool							x	x	x	x		
WP 4 Operational modeling of wetland hydrology												
S-Hype evaluation on observations and simulation scenarios				x	x	x	x	x	x			
S-Hype Model development for improved wetland functionality	x	x	x	x	x	x	x	x	x	x	x	x
WP 5 Creation of an Interactive Decision Support Tool												
Identify the functionality needed for managers	x	x	x	x								
Develop an interactive design for the DST			x	x	x	x	x	x				
S-Hype developments (WP4) incorporated into the DST									x	x	x	x
Deliverables												
Quality Controlled Observational Data Set			x									
Storage Property Report						x						
Wetland Hydrological servcies under climate and land use scenarios - Report										x		
Wetland Enhanced S-Hype											x	
Decison Sopport Tool Prototype, and then Operational Version				x								x
Project meetings												
Kickoff, followed by annual meetings	x			x			x				x	
Conferences												
Scientific Conference (e.g. European Geophysical Union)						x				x		
Workshops												
Workshops on exploration of project data		x		x								
Workshop on modeling of wetland hydrological function						x			x			
Communication activities												
Conferences												
Scientific Conference (e.g. European Geophysical Union)						x				x		X
Final Conference												X
Dissemination												
WP4				x				x				x
WP5				x				x				x
Meetings												
Reference group meetings	x				x				x			
Reporting												
Progress reports to reference group				x				x			x	
Workshops/seminars/cources												
Workshop for Decisison Support Tool feedback from users				x								

Budget

The post-doctoral researcher will be essential to the work of WPs 1-3. This person will be recruited with the standard starting salary at SLU. The involvement the co-PIs from SMHI and Uppsala University will be at their current salaries, corresponding to their involvement as specified in the time plan. The involvement of K. Bishop and J. Seibert will be paid for by SLU faculty funds for their professor positions. An SMHI web developer will be engaged during three different periods in the project to create the DST. Supplementary instrumentation will complement the extensive data sources freely available to the project, significantly increasing the value of those data sources. Costs for workshops, travel to conferences and data publication and dissemination to relevant stake-holders are in accordance with the activities specified in the communication plan.
The respective overhead models are applied to the salaries paid by each organization. While all three only charge overhead on salaries, that rate of overhead differs, being 53%, 20% and 39% for SLU, SMHI and Uppsala University, respectively. The rate of 34% specified in the budget table below is the weighted average for all the overhead in the project.

	SEK year 1	SEK year 2	SEK year 3	Total
Project costs				
1. Salaries				
Salaries incl. social fees/LKP				- kr
Göran Lindström	69,692.00 kr	157,200.00 kr	209,076.00 kr	435,968.00 kr
Charlotta Pers	64,904.00 kr	146,400.00 kr	194,712.00 kr	406,016.00 kr
Johan Strömqvist	56,392.00 kr	127,200.00 kr	169,176.00 kr	352,768.00 kr
Niclas Hjerdt	65,569.00 kr	147,900.00 kr	196,707.00 kr	410,176.00 kr
Webbutvecklare	65,835.00 kr	148,500.00 kr	197,505.00 kr	411,840.00 kr
Claudia Teutschbein	41,938.00 kr	41,938.00 kr	41,938.00 kr	125,814.00 kr
Post Doc	571,509.00 kr	635,061.00 kr	55,817.00 kr	1,262,387.00 kr
2. Travels				
Travel to field sites and conferences	20,000.00 kr	20,000.00 kr	20,000.00 kr	60,000.00 kr
3. Other costs				
Project costs				75,000.00 kr
Supplementary instrumentation (precipitation, water level)	75,000.00 kr			
4. Cummunication				
4.1. Open access publications		30,000.00 kr	30,000.00 kr	
4.2. Conference and workshops for dissimination of results	20,000.00 kr	20,000.00 kr	50,000.00 kr	
4.3. Other communication costs (Use new row for each cost)				180,000.00 kr
4.4. Reference group meetings	10,000.00 kr	10,000.00 kr	10,000.00 kr	
Total 1-4	1,060,839.00 kr	1,484,199.00 kr	1,174,931.00 kr	3,719,969.00 kr
5. Overhead costs				
Overhead costs **(%)**				34%
Total sum	**1,421,524.26 kr**	**1,988,826.66 kr**	**1,574,407.54 kr**	**4,984,758.46 kr**

Data publication plan

A key focus of the project are potential users of the DST. Progress towards that goal, and the data that progress is built upon, will be made available through the project website, following both Swedish Environmental Protection Agency and SLU guidelines for open environmental data. We will disseminate data, results and conclusions to the scientific community through highly ranked peer-reviewed journals and international conferences/conference sessions devoted to wetland management.

To facilitate exchange of data from the project, metadata will be provided in accordance with the guidelines of www.Geodata.se that follows the metadata standard of the EU-Inspire directive. The costs of the data publication are covered with a special budget line, including Open Access for journal articles. We believe it is important that the basic observational data used in this project (even that provided by other open sources such as ICOS, SITES and SLU) are made public in a well-documented form. A data handling plan will be created at the start of the project to guide this effort.

Ongoing projects

The FORMAS project ‘Using wetland restoration as a tool to mitigate runoff extremes’ (Hjalmar Laudon, Jan Seibert) also addresses hydrological wetland functioning. However, the projects differ in several respects. One is observational data, with the existing FORMAS project using only data from catchments in the Krycklan Catchment study, most of which have less than 20% wetland area. None of these wetlands have evapotranspiration data from eddy correlation that can quantify short term changes in water storage. The FORMAS project also does not include development of either S-Hype or a decision support tool. We do however expect that findings from the FORMAS project on modeling small catchments in the forest landscape will be useful for the model development we are proposing which will improve the representation of wetland hydrology in S-Hype and creation of a new decision support tool for utilizing the hydrological ecosystem services of wetlands.

The FORMAS-funded project 'Hydrological droughts now and in the future: Swedish hotspots of hazard, vulnerability, and risk' (Claudia Teutschbein, reg.-no. 2015-01123) focuses on the characterization and early recognition of critical drought conditions in Sweden. It facilitates an analysis of past, present and future drought events in a large number of catchments with the goal to identify primary landscape traits such as topography, soil types, and landuse (e.g. wetlands, forests) that promote the emergence of hydrological droughts in different parts of Sweden. This project can help identify vulnerable regions in a future climate where the potential of wetland hydrological ecosystem services for climate mitigation will be of special interest.

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