Forsmark and Simpevarp-Oskarshamn coastal catchments and their wetland systems, Sweden

G. Destouni, J. Jarsjö, C. Prieto, E. Bosson, K. Persson, et al., 2012-05-06 update

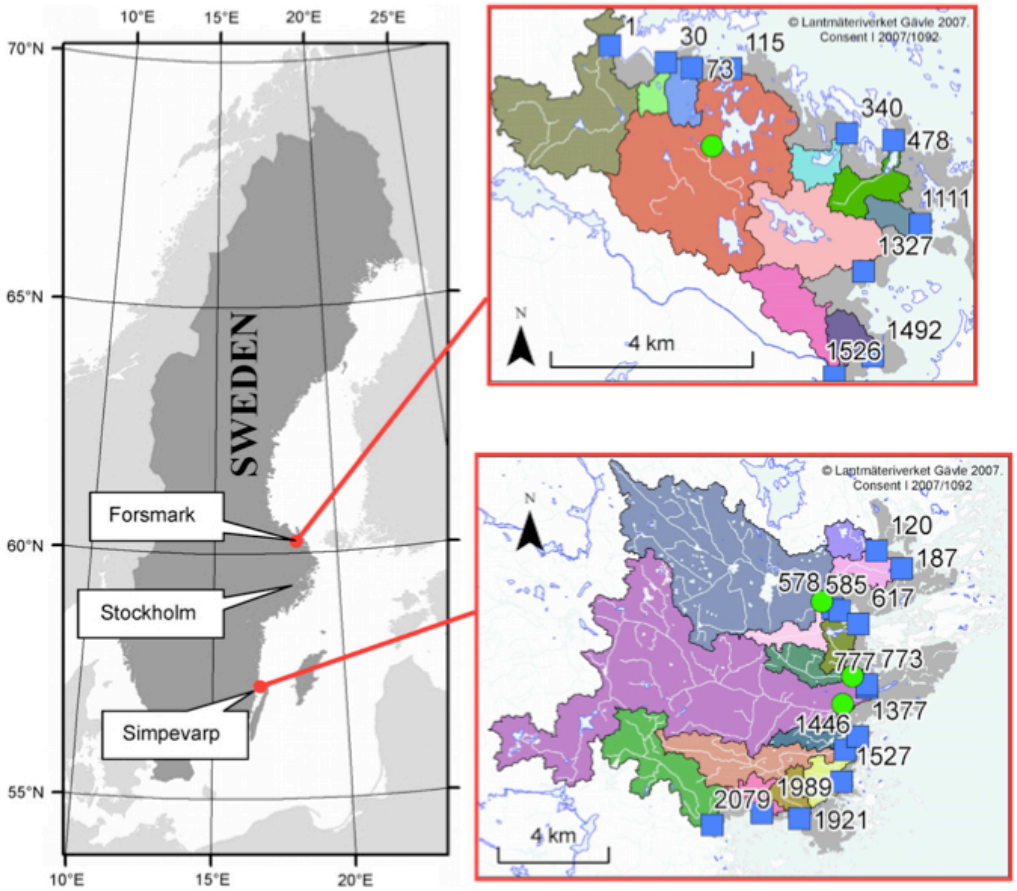

Figure. Main sub-catchments (coloured) and small near-coastal sub-catchments (grey), catchment outlets to the sea (numbered, filled blue squares), and measurement stations (filled green circles). (From Jarsjö et al. 2008).

Background information	The Simpevarp coastal catchment area -127.7 km^2 - in Oskarshamn extends about 8 km inland from the Baltic Sea, with a highest elevation of 63 m.a.s.l. It is part of the Swedish water management district Southern Baltic Proper (SBP) and is also associated with the underground (down to 460m below the surface) groundwater-rock research facility Äspö Hard Rock Laboratory (HRL) of the Swedish Nuclear Fuel and Waste Management Co (SKB). The Forsmark coastal catchment area - 29.5 km^2, extends about 4 km inland from the Baltic Sea, with a highest elevation of 27 m.a.s.l. It is part of the Swedish water management district Northern Baltic Proper (NBP), and is the site recently proposed by SKB as the Swedish high-level nuclear waste repository.
Main research and management problems	In the water management districts NBP and SBP, many inland and coastal waters have less than good water status, following the EU Water Framework Directive (WFD) classification requirements. This is due to excess anthropogenic nutrient and pollutant loading from the catchments to the Baltic Sea. Specific such loads, and not least the effects on them of wetlands in the landscape, remain to be investigated and quantified for the Simpevarp and Forsmark sites. Main application problems investigated there so far have been related to the risk and safety assessment of nuclear waste repositories, and the potential impacts of leakage from the latter on shallow groundwater, surface waters and ecosystems, including wetlands. An important general question, for different water-related environmental application and management problems, is: How are excess nutrients and pollutants from different surface and subsurface sources transported, retained and partitioned along and among different groundwater pathways to the surface and coastal waters. With regard to GWEN, a related main research question is: How do sediment-plant water-wetland systems, and individual wetlands, in drainage basins modulate the ecosystem services (and disservices) of filtering/attenuating (and exporting loads of) waterborne tracers and pollutants from drainage basins? The uniquely fine-resolved data sets and modeling work already available for Simpevarp and Forsmark provide good opportunities for further ecohydrological studies of these questions.

Possible end-users	The water district authorities of SBP and NBP, and associated municipalities and county administrations are primary stakeholders. They would benefit from Simpevarp and Forsmark investigation results related to GWEN research objectives and questions, for instance regarding how pollutant loads could and should be best monitored and decreased in a changing climate. SKB is also an important stakeholder for wetland research related to risk and safety assessment of nuclear waste repositories.
Site conditions	In both Forsmark and Simpevarp, land is mainly covered by forest, with lakes and wetlands covering up to 20% of the area. The wetlands can be partially forested. Quaternary deposits, which cover a major part of the surface, are dominated by till (mainly sandy). The groundwater-surface water systems and their hydrological interactions include coastal aquifers with gaining streams, wetlands and lakes. Watercourses are generally small and groundwater levels are shallow (e.g., with a mean annual level of 1 meter below the surface in monitoring wells of Forsmark). In Simpevarp, quaternary deposits cover most of the area, but the presence of exposed bedrock is considerable at higher elevations, with estimates of the proportional distribution of quaternary deposits and exposed bedrock being 65% and 35%, respectively, at a regional scale. The mean ground slope is about 2.8º and more than 80% of the area has a slope of less than 5º. The landscape is undulating with narrow valleys and almost all slopes steeper than 10º are located in such valleys or at lakeshores. The tectonic uplift in Simpevarp is presently around 1 mm/year (less pronounced than in the Forsmark catchment, see below). The annual mean temperature varies between 6 and 7ºC, and the annual mean precipitation varies between 500 and 600 mm/year. In Forsmark, quaternary deposits cover approximately 75% of the area and small but frequent bedrock outcrops cover about 5% of the area. The area is generally flat with a mean slope of around 1.5º and more than 95% of the area being characterized by slopes of less than 5º. Almost all slopes steeper than 10º are man-made (the area includes a nuclear power plant and its inlet channel). The site is located in a region with considerable tectonic uplift (presently around 6 mm/year) and associated shoreline displacement, with the major part of the area still water-covered around 1000 years ago, implying that, e.g., peat formation and many chemical weathering processes started relatively recently. The annual mean temperature varies between 5.0 and 5.5º C within the area and the annual mean precipitation varies between 600 and 650 mm/year.

Monitoring and data	In particular SKB has carried out multiple hydro-biogeochemical and ecological studies of both Simpevarp and Forsmark. These include surface and subsurface water sampling, vegetation analyses of land, lakes and wetlands, airborne surface geophysical and elevation investigations, mapping of quaternary deposits, soils, watercourses, catchment boundaries and morphometry of lakes, and lithological mapping of rock surfaces. Extensive model analyses have also been carried out for Simpevarp and Forsmark, including the water flow, solute transport, travel times and attenuation processes that occur along different flow paths toward the sea.
Site-related publications by GWEN participants	**Surface-subsurface water system links and interactions with coastal waters** **Journal articles** • Bosson E., Sabel U., Gustafsson L.G., Destouni G., ***Influences of shifts in climate, landscape, and permafrost on terrestrial hydrology***, *Journal of Geophysical Research-Atmospheres*, 2012 (accepted subject to minor revisions). • Persson K., Jarsjö J., Destouni G., ***Diffuse hydrological mass transport through catchments: scenario analysis of coupled physical and biogeochemical uncertainty effects****, Hydrol. Earth Syst. Sci*., 15, 3195–3206, 2011 • Darracq A., Destouni G., Persson K., Prieto C., Jarsjö J., ***Scale and model resolution effects on the distributions of advective solute travel times in catchments***, *Hydrological Processes*, 24(12), 1697-1710, 2010. • Destouni G., Persson K., Prieto C., Jarsjö J., ***General quantification of catchment-scale nutrient and pollutant transport through the subsurface to surface and coastal waters***, *Environ. Sci. Technol*., 44, 2048–2055, 2010. • Darracq A., Destouni G., Persson K., Prieto C., Jarsjö J., ***Quantification of advective solute travel times and mass transport through hydrological catchments***, *Environmental Fluid Mechanics*, 10, 103–120, 2010. • Persson K., Destouni G., ***Propagation of water pollution uncertainty and risk from the subsurface to the surface water system of a catchment***, *Journal of Hydrology*, 377, 434-444, 2009. • Jarsjö J., Shibuo Y., Destouni G., ***Spatial distribution of unmonitored inland water discharges to the sea***, *Journal of Hydrology*, 348, 59– 72, 2008. • Destouni G., Shibuo Y., Jarsjö J., ***Freshwater flows to the sea: Spatial variability, statistics and scale dependence along coastlines***, *Geophys. Res. Lett*., 35, L18401, 2008 • Destouni G., Hannerz F., Prieto C., Jarsjö J., Shibuo Y., ***Small unmonitored near-coastal catchment areas yielding large mass loading to the sea***, *Global Biogeochem. Cycles*, 22, GB4003, 2008. **Reports:** • Jarsjö J., Destouni G., Persson K., Prieto C., ***Solute transport in coupled inland-coastal water systems, General conceptualisation and application to Forsmark***, SKB Report R-07-65, Swedish Nuclear Fuel and Waste Management Co (SKB), Stockholm, 2007. • Jarsjö, J., Shibuo, Y., Prieto, C., Destouni, G., ***GIS-based modelling of coupled groundwater–surface water hydrology in the Forsmark and Simpevarp areas***. Swedish Nuclear Fuel and Waste Management Co Report R-05-

	67, 2006. • Jarsjö, J., Shibuo, Y., Destouni, G., **Using the PCRaster-POLFLOW approach to GIS-based modelling of coupled groundwater–surface water hydrology in the Forsmark Area**. Swedish Nuclear Fuel and Waste Management Co Report R-04-54, 2004. **Multi-phase flow in the deeper groundwater system of the catchments** **Journal articles** • Jarsjö J., Destouni G. and Gale J., ***Groundwater degassing and two-phase flow in fractured rock: Summary of results and conclusions achieved during the period 1994-2000***, SKB Technical Report, TR-01-13, Swedish Nuclear Fuel and Waste Management Co, Stockholm, 2001. **Reports:** • Jarsjö J., Destouni G., ***Degassing of deep groundwater in fractured rock around boreholes and drifts***, *Water Resources Research*, 36, 2477-2492, 2000. • Jarsjö J., Destouni G., ***Groundwater Degassing in Fractured Rock: Modelling and data comparison***, SKB technical report TR-98-17, Swedish Nuclear Fuel and Waste Management Co, Stockholm, 1998. • Jarsjö J., Destouni G., ***Conditions for fracture transmissivity reduction due to degassing of groundwater: Analytical expressions, numerical simulations and analysis of laboratory and field data***, SKB progress report HRL-97-03, Swedish Nuclear Fuel and Waste Management CO, Stockholm, 1997. • Jarsjö J., Destouni G., ***Groundwater degassing: Pilot injection-withdrawal field tests with gas saturated water***, SKB progress report HRL-97-02, Swedish Nuclear Fuel and Waste Management CO, Stockholm, 1997. **PhD theses (supervised by GWEN participant G. Destouni):** • Persson K., ***Quantifying pollutant spreading and the risk of water pollution in hydrological catchments: a solute travel time-based scenario approach***, *PhD thesis*, Department of Physical Geography and Quaternary Geology, Stockholm University, 2011. • Darracq A***., Long-term development, modeling and management of nutrient loading to inland and coastal waters***, *PhD thesis*, Department of Physical Geography and Quaternary Geology, Stockholm University, 2007. • Shibuo, Y., ***Modeling water and solute flows at land-sea and land-atmosphere interfaces under data limitations***, Ph.D. thesis, Department of Physical Geography and Quaternary Geology, Stockholm University, 2007.