

## **The Hydrological Suså-Study**

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The paper gives a short description of a 4½-years hydrological research project constituting a Danish contribution to UNESCO's International Hydrological Programme. The Suså-project was a joint effort among many different institutions working within all parts of the hydrological cycle. The main objective of the project was to investigate the potential of applying distributed hydrological catchment models in integrated water resources management, taking into account in particular consequences of increased groundwater abstraction.

### **Objective and Background**

A hydrological research project was conducted in the Suså-catchment during the period 1977-81 as a Danish contribution to UNESCO's International Hydrological Programme.

The main objectives of the project were to study

- The hydrologic processes in a catchment with a regional confined aquifer covered by boulder clay, a typical situation in Denmark.
- The consequences of increased groundwater development on groundwater hydraulic heads and streamflow.
- The possibilities of establishing an integrated water resources development, taking into account joint effects of water abstraction and sewage disposal on the water quantity and quality of the streams in the catchment.

The background for the study was an increased interest in the water resources of

the area for the purpose of water supply to the city of Copenhagen. Such an export of water out of the area results in competition with local demands for water to public supply and irrigation as well as in a decrease in the minimum stream-flows, giving rise to a decreased capacity for sewage disposal and a reduction in the recreational value of the streams. The final choice between these conflicting interests is of a political nature. The study aims at establishing a rational basis for the decisions to be taken. Furthermore, the situation described for the Suså-basin is fairly similar for other areas in Denmark.

### **The Suså-Catchment**

The Suså-catchment is about 750 km<sup>2</sup> and is located in the central part of the island Zealand, Denmark. The maximum altitude difference within the area is about 110 m with the highest level being approx. 120 m.a.s.l. The surface geology of the area is characterized by glacial deposits mainly consisting of clayey moraine that locally may contain varying amounts of sand layers. The Quarternary till deposits overlay the main regional confined aquifer which is of Paleocene age and consists of limestone deposits alternating with layers with higher content of clay and marl.

The watercourse Suså flows in a valley cut into the Quarternary till deposits without anywhere getting in direct contact with the underlying Paleocene deposits forming the regional aquifer.

A schematical description of the Suså-basin is shown in Fig. 1.

Lakes are covering 2.3% of the catchment, while agriculture and forestry take up 69% and 16%, respectively. Artificial drainage of the agricultural areas is very common, as the drainage percentage is 78.

The mean annual precipitation is about 720 mm. The mean annual potential evapotranspiration is 630 mm, whereas the corresponding figure for the actual evapotranspiration is 490 mm/year. The remaining 230 mm/year is what totally is available for streamflow or for export of water out of the area. The water balance of the Suså-basin is shown schematically in Fig. 2 for the situation with a ground-water development of 20 mm/year.

### **The Study**

The main themes of the study are:

- Field studies of hydrologic processes
- Mathematical modelling of hydrologic processes and systems
- Management of water resources

The whole project consisted of a series of sub-projects described very briefly below:

# The Hydrological Suså-Study

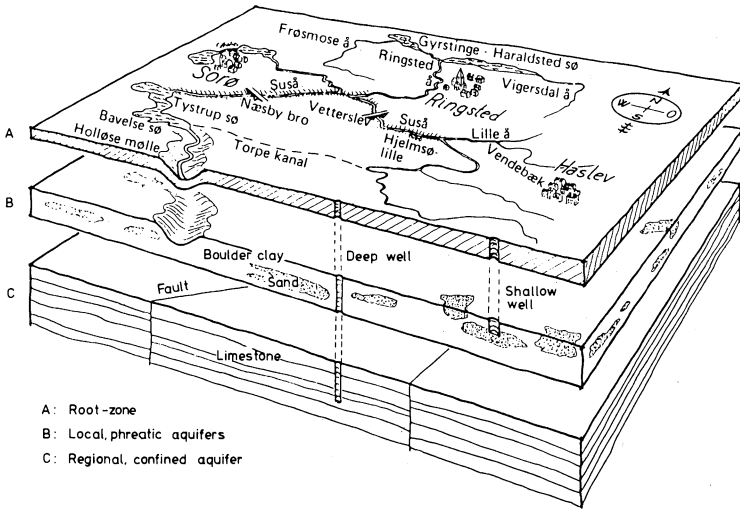


Fig. 1. Schematical description of the Suså-basin.

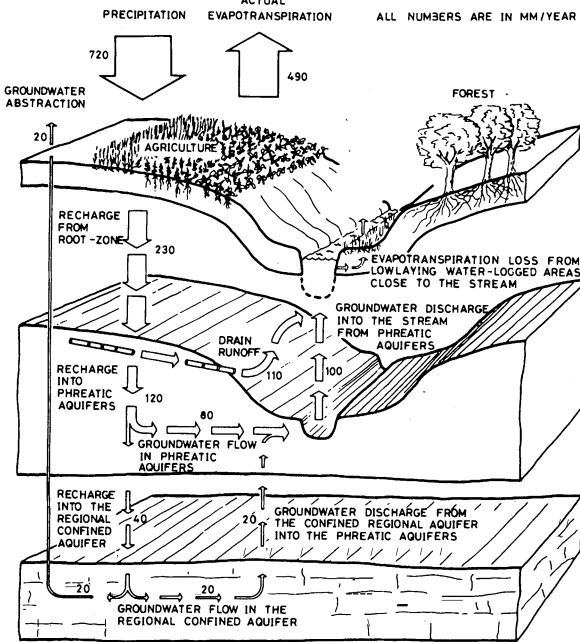
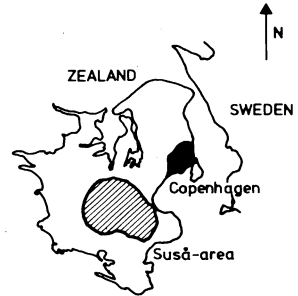


Fig. 2. The water balance in the Suså-basin (schematic) with 20 mm/year groundwater development.

### **Field Studies of Hydrologic Processes**

*Precipitation* – In addition to 12 existing precipitation stations 6 self-recording stations were established to determine the time and space variations of precipitation. Solid precipitation was measured by snow taxation. A special raingauge setup was established to study orographic effects as a basis for determination of areal precipitation.

*Evapotranspiration* – A climate station was established in the centre of the area, and the water balance was determined on field plots with vegetation characteristic of the area. A special investigation of forest evaporation was included in this subproject.

*Subsurface runoff* – The catchment has a large percentage of tile drained areas. Measurements of quantity and chemistry of drainage outflow was made in a characteristic area.

*Groundwater recharge* – The recharge process was analyzed based on well-logs of tritium concentrations and on the regional variation in groundwater chemistry.

*Hydrogeology* – A hydrogeological mapping of the area included a geological description of the aquifers and estimation of transmissivities and hydrological boundaries.

*Interaction between groundwater and surface water* – In situations with minimum discharge, the regional distribution of groundwater outflow to the streams was determined and compared with the groundwater hydraulic head relative to the water level in the stream.

*Runoff and lake storage* – A network of about 30 discharge and stage stations was used in the project.

*Chemistry of ground- and surface water* – The chemical characteristics of the water in the Suså-catchments were determined using data collected from 13 surface water stations and numerous groundwater wells.

### **Mathematical Modelling of Hydrological Processes and Systems**

*Evapotranspiration model* – Based on information on precipitation, radiation, vegetation and soil characteristics, evapotranspiration and soil moisture conditions are simulated.

*Groundwater model* – A numerical model for the regional confined aquifer has been established for simulation of natural and man-induced variations in the groundwater hydraulic head.

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*Rainfall-runoff model* – Runoff is simulated by a four-layer root zone model, using linear reservoirs for routing of groundwater flow. The model is distributed to account for variability in vegetation.

*Integrated hydrologic model* – The groundwater model and the rainfall-runoff model are integrated into one simulation model to permit physically based modeling of all runoff components. The model accounts for evapotranspiration, flow in tile drains, flow in shallow aquifers, seepage to and flow through deep aquifers. With input of rainfall, temperature and potential evapotranspiration, the spatial variations of evapotranspiration, groundwater hydraulic heads and streamflow can be simulated with time intervals of one day.

### **Management of Water Resources**

*Consequences of human activities* – The depletion of the minimum discharge as a result of pumping from groundwater aquifers is studied by use of the hydrological model.

A special study analyzes the possibilities of using lakes in the Suså-catchment as reservoirs for surface water. The lakes have a high recreational value so changes from the natural conditions should be as small as possible.

A study of the potentials of increasing the groundwater resources by injecting surface water into the groundwater aquifers was planned, but not completed due to problems with groundwater contamination.

*Integrated planning of water resources development* – Based on models developed during the study and on existing models on water quality, a computerized simulation model for water resources planning was developed.

The model simulates the integrated effects on water quantity and quality from:

- public water supply from groundwater
- public water supply from surface water
- irrigation water supply from groundwater
- pollution discharges to surface water

The environmental and economic consequences of various alternatives of water resources development in the Suså-catchment are investigated to determine the optimal structure of water works and sewage treatments plants.

### **Financing, Coordination and Reporting**

The study was financed by the Danish Agency of Environmental Protection, the Danish Agricultural and Veterinary Research Council, the Danish Natural Scientific Research Council, the Danish Council for Scientific and Industrial Research, and the Danish Council of Technology. Seven research institutions were par-

ticipating in a total of twelve sub-projects.

The Danish Committee of Hydrology was responsible for project management and coordination.

The results of the project were presented in 24 reports on specific subjects, as listed below. Some of the reports are in English and all of them have an English summary.

## **Report**

- No. 1: Precipitation. (D)
  - 2/3: Evapotranspiration from forests. (D)
  - 4: Soil moisture removal and evapotranspiration by agricultural vegetation. (D)
  - 5: Models for determination of actual evapotranspiration. (D)
  - 6: Groundwater recharge. (D)
  - 7: The hydrogeology of the Suså-basin. (D)
  - 8: Interrelations between groundwater chemistry and geology. (D)
  - 9: A regional groundwater model for the Suså-area. (E)
  - 10: Runoff characteristics of Suså-basin. (D)
  - 11: Daily fluctuations in stage and discharge of the Suså. (D)
  - 12: The surface water component of an integrated hydrological model. (E)
  - 13: An integrated groundwater/surface water hydrological model. (E)
  - 14/15: Concentration and transport of suspended material in the Suså-basin. (D)
  - 16: Surface water chemistry and transport of dissolved matter in the Suså. (D)
  - 17: Exchange of water between aquifers and streams. (D)
  - 18: The use of lakes as storage reservoirs. (D)
  - 19: Quantity and quality of tile-drain discharges in the Suså-basin. (D)
  - 20: Chemical and microbiological quality changes by injection of surface water in aquifers. (D)
  - 21: Data collection for integrated water resources planning in the Suså-basin. (D)
  - 22: Simulation model for integrated water resources planning in the Suså-basin. (D)
  - 23: Integrated water resources planning in the Suså-basin. Application of the simulation model. (D)
  - 24: Data base system for data from the Suså-investigation. (D)
- Summary report No. A1: Hydrological studies of the Suså-basin. (D)
- A2: Effects of water resources development on the hydrological cycle. (D)

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