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Hydrology During the 20th Century

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Introduction

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Hydrology is a geoscience, whose scientific basis lies mainly in physics, but also in chemistry and biology of the endless cycle of water. This so called hydrological cycle is a global geophysical process that circulates a relatively constant amount of water among the various components of the system. The main components are oceans, atmosphere, glaciers, groundwater and lakes. At present, man acts as an important agent by changing water flows and storages according to his needs.

Until the early 1900s, hydrology was largely an empirical branch of hydraulics and water engineering. The scope of hydrology was dominated by the practical needs of agriculture, water supply and hazard reduction. The first formal recognition of the scientific status of hydrology was the establishment of the International Association of Scientific Hydrology in 1922.

By the mid-1900s, research on the scientific aspects of hydrology was well under way in universities and research institutes. In addition to expanding observation networks and the establishment of experimental fields, the studies focused on understanding laboratory-scale physical processes of the hydrological cycle.

The International Hydrological Decade from 1965 to 1974 raised consciousness about regional and global problems and about man's impact upon the hydrological cycle. During the Decade, the development of computers started to revolutionarize data processing and hydrological analyses. The computers also initiated the era of conceptual hydrological models. At first they were relatively simple, often lumped, but development towards detailed, distributed models was rather rapid.

In late 1970s, concern began to rise about the quality of waters and about the preservation of the natural environment in the Western World. This gave new possibilities and challenges to hydrologists, and led also to the development of environmental hydrology. In lake research, the hydrologists also met their co-scientists in limnology and hydrobiology.

The 1990s was the decade of hectic discussion on climate change and the development of GCMs, the global climate models. Hydrological aspects were introduced into these models rather slowly, and they still are relatively weak e.g. in the simulation of runoff even in large river basins.

Hydrology still differs from other geosciences by being strongly oriented towards practical problems related to all aspects of human water use. Recently, more and more applications are in the field of environmental problems, and the borders of hydrology and neighbouring sciences have started to vanish in multidisciplinary research teams.

The development of Finnish hydrology in the 20th century closely followed the international trends. In the former part of the century, focus was in applications within agriculture and hydropower development. Later on, the scope of applications became wider, but the amount of basic research remained rather low. Towards the end of the century, the competition on scarce resources with neighbouring sciences further limited the possibilities of pure research. On the other hand, the need of hydrology in the study of all aquatic environmental problems has been widely recognized.

Finnish hydrologists have also worked abroad, particularly in developing countries in Africa and Far East. The most extensive work was the water supply project in two Tanzanian provinces, Mtwara and Lindi, in the 1970s and early 1980s. In Vietnam the hydrological component has been important in the water supply projects of Hanoi and Haiphong. In recent years, Finnish know-how in lake hydrology has gained importance in several countries.

As to teaching in hydrology, Finnish hydrologists have e.g. trained students from African countries in the Water Supply and Sanitation courses of the Helsinki and Tampere Universities of Technology. On the other hand, several Finnish hydrologists have studied shorter or longer periods abroad.

In the following those parts are emphasized in the history of hydrology which are related to geophysics. Important units in this field are the Finnish Environment Institute with its predecessors, Technical Universities and the University of Helsinki. History of international co-operation generally and its special questions in the Finnish Academy are also presented.

Hydrology at Research Institutes

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In the political history of Finland, the year 1899 was the beginning of a period of oppression: Czar Nicholas II broke his oath to Finland. Even Nature was harsh towards a small northern country. The Deluge of the Broken Oath is still the largest flood in the Finnish Lake District for which there is quantitative data.

In the hydrological history of Finland, the 1899 flood had beneficial consequences. The damages caused by the deluge were examined by a committee appointed by the Senate. One of the recommendations of this committee was that hydrological investigations should be intensified. Consequently, the Hydrographic Office was established in 1908.

The first director of the Office was Edvard Blomqvist. He started to work with a very basic issue: the extension of hydrometric observations towards nationwide networks. Water level observations had already been made in navigationally important watercourses, e.g. a gauge had been established for Lake Saimaa at Lauritsala in 1847, and there were altogether 118 gauges in the country. In 1911, the number of water gauges had increased to 370, including five recording gauges capable to operate even all winter.

Hundreds of discharge measurements were performed during the first few years, but rating curves could be constructed only many years later as a sufficient variation of water levels and other pertinent circumstances did not occur all years. For the calibration of current meters the Office had a calibration channel, with a 100 meter run, built in 1912. This outdoor channel was in use until 1966, when a modern indoor channel, 42 meters long, was constructed into the basement of the Vuorikatu office-house.

For many hydrological purposes it proved necessary to ascertain the head of water over long distances along the watercourses by precise levelling. Additionally, the determination of the position of the divides, necessary for the estimation of the catchment areas, required extensive field work.

The programme of the Office included the analysis of the quality of water from a large number of watercourses during the period 1911 to 1931. This fundamental work and the analyses necessary to check the pollution of the watercourses were performed by Ms. Linda Holmberg. This work had to be discontinued in the 1930's for various reasons, notwithstanding the protests of the Office. These observations could be restarted some thirty years later when the public consciousness had awakened to the importance of such studies.

Fig. 1. The calibration installation at Tikkurila in 1913.

Fig. 2. The field team of the Hydrographic Office on their way to a discharge measuring site in Kainuu in 1910.

Fig. 3. Staff members of the Hydrographic Office in 1920s.

Fig. 4. Many sites of today's hydropower stations were photographed in their natural states by the Hydrographic Office, including Jäniskoski in the River Paatsjoki. A powerplant was built there during the Second World War; it is now located in the Russian territory.

The observational data were published in yearbooks from 1912 onwards. Monographs were also printed in the first years of the Office on the Vuoksi and Kymi rivers: the latter was an extensive work on 470 large-size pages and some 80 plates. The results of the precise levelling necessary for the determination of elevations had been worked

out and been published by the Office. Other publications of the first years included a list of the important rapids in Finland, evaporation measurements on Lake Pyhäjärvi and the first purely scientific paper: “On the summer rains and their hydrological consequences”, written by Henrik Renqvist, who later succeeded Blomqvist as director of the Hydrographic Office.

In the 1930s, voices were raised for transforming the Office into an independent national central institute, considering the growing importance of hydrological investigations to the society. Such an institute would have made possible a more scientific orientation of the work. But the Office remained subordinate to the Board of Public Roads and Waterways. Most of the activity of the Office was set to meet the growing demand for basic data for technical projects, primarily the regulation of the watercourses.

At the onset of the Winter War in November 1939, the Hydrological Office was evacuated to Vähäkyrö in Ostrobothnia. Another evacuation period came in 1944, when the Office spent seven months in Lauttakylä, half-way between Turku and Tampere. Finland’s major dry spell of last century also occurred during the Second World War, in 1940–42.

In the war, Finland lost several major hydropower plants to the Sovietunion. The Hydrological Office played a key role in supplying data and performing analyses for new hydropower projects in northern Finland, at first in Oulujoki Basin and later in Kemijoki Basin. Also elsewhere in Lapland hydrological observation networks developed.

The capacity to develop research was still limited in the 1940s and 1950s. Larger research efforts included the determination of the land uplift in the inner parts of Finland, based on gauge readings. This work was published as a PhD thesis by Allan Siren in 1951. The Office was led by Åke Fabritius in 1948–52, after which the directors position was open for seven years until Heikki Simojoki, originally a meteorologist, became the director in 1958.

Hydrological investigations were performed also in other organizations. The Soil and Hydrotechnical Research Bureau of the Board of Agriculture had studied the drainage from small basins since 1929. Later, these studies were supplemented by measurements of precipitation and snow cover. Three doctor’s theses were based on small basin network during the existence of the Hydrotechnical Research Bureau: Pentti Kaitera’s study on the influence of snowmelt on the regime of watercourses (1939), Kauko Niinivaara’s analysis of evaporation (1953) and Seppo Mustonen’s investigations on the influence of meteorological and basin factors on runoff (1965).

The Soil and Hydrotechnical Research Bureau also established an experimental field at Maasoja, Vihti, in 1938. It has during more than six decades been the site of numerous experiments related not only to agricultural water issues, but also to a number of other hydrological topics, comparison of precipitation gauges etc. The creator of this field, Matti Wäre, published his PhD thesis on the relationships between soil water balance and harvests in 1947.

Mustonen's work was based on the new network of small basins, where each basin had a measuring weir and there were practically no lakes, unlike the old network. This reorganization was made in the late 1950s: the new network consisted of around 50 basins, of which four had also belonged to the old network. Basins were established all over the country to gain information under different climate and soil conditions. Later on, Pertti Seuna directed the network and summarized the long-term hydrological results in the new basin network in his PhD thesis in 1983.

The 1960s was a decade of increased international contacts for Finnish hydrology. The first impulse was given by the International Geophysical Year in 1958, but much more important was the launching of International Hydrological Decade in 1966. The participation of Finnish hydrologists to international conferences increased, and Finland, too, started to host conferences more frequently. In 1967, the Nordic Hydrological Conference was held in Finland first time; this series of conferences had started in 1955 in Stockholm.

Several committees had dealt with the reorganization of water administration since the early 1950s. Most of them did not devote too much attention to hydrology, but the so called Kemppainen committee discussed the merging of the Finnish Meteorological Institute and the Hydrological Office in 1964–65. This idea could not be realized, although it is the most common model in Europe.

In June 1968, the Kilpeläinen committee presented a proposal to a thorough reorganization of water administration. This proposal was followed by the work of the Temmes committee, and in July 1970 the National Board of Waters was established. The Hydrological Office, into which the hydrological activities ot the Agricultural Research Bureau were also transferred, became part of the Water Research Institute in this new organization. The first chief of the Hydrological Office was Seppo Mustonen, followed soon by Risto Lemmelä, who lead the Office 22 years until 1995.

When the new Hydrological Office was established, the staff included some 45 persons. The number of academic people was less than ten, but several young hydrologists were recruited in the early 1970s. In the 1980s, the whole staff of the Office varied between 60 and 65 persons.

The computers of the first generation – clumsy, ancient monsters from today's perspective – had entered the leading hydrological research institutes in mid-1960s. They led to the development of the first conceptual rainfall-runoff models, pioneered by the Stanford Model. The computers also improved the possibilities to apply statistical methods more effectively, which e.g. led to the development of stochastic hydrology in the 1970s. Flood forecasting methods, too, developed considerably due to increased computing capacity. In these works, the Hydrological Office first relied on the services of the State Computer Centre. The National Board of Waters received its first own computer, PDP 11/35, in 1976, but several hydrologists also utilized the computers of the University of Helsinki.

Fig. 5. A discharge measurement in Saramojoki River in Northern Karelia in the 1970s (photo by Esko Kuusisto).

Groundwater had gained more importance in water supply, and a new observation network of 54 groundwater stations was established in the mid-1970s by Jouko Soveri. This network produced data concerning groundwater quantity and quality, their natural variations and the geohydrological factors affecting groundwater status. Results from the first decade of observations were analysed in Soveri's PhD thesis in 1985. – Risto Lemmelä also dealt with groundwater issues in his thesis in 1990.

Soil moisture is a problematic but important component of the hydrological cycle. In order to follow the time variations of this component, consecutive measurements should be made from the same sample. A neutron emitter, which could be inserted in a measuring tube in the soil, offered a possibility to this kind of monitoring. This method was used in the Hydrological Office since the late 1960s.

Lake research became one of the strongest areas of the Hydrological Office in the 1970s and 1980s. This was mainly due to increased concern of water quality and ecological aspects of lakes. It was realized that hydrological research was a prerequisite to successful water quality management. Engineering projects, where lake hydrological modelling was needed, included several road embankments narrowing the current fields and the location of the intake pipe of the Päijänne tunnel, the water supply artery of the Helsinki region.

Lake evaporation was also a major research topic of the Office in 1970s. This continued the long traditions of the Office in evaporation studies. Evaporation from Lake Pyhäjärvi at Tampere had been measured by floating pans as early as in 1912–13. A registering lysimeter was constructed by Henrik Renqvist in the 1940s, and detailed studies of bog evaporation had been carried out by Juhani Virta for his PhD thesis in the 1960s.

Bathymetric mapping of lakes became an important duty of the Hydrological Office in the 1970s. At first stage, it was mainly carried out in northern and eastern Finland, where unemployed people could be recruited to this work particularly in wintertime. Later on, the development of technology lead to summertime mapping with an echosounder. Localizing was first based on theodolite, but in the 1990s it became possible to use GPS. This increased greatly the efficiency of the work.

The advances in lake hydrodynamics were closely tied to the development of current meters. ADCP devices replaced the rotating current meter as the key field instrument of the Hydrological Office in 1994. These instruments (Acoustic Doppler Current Profilers) measure the velocity distribution by using the reflection of acoustical waves from particles in the stream. As compared to the old method, the time needed for a measurement was greatly reduced.

The present ADCP equipments are capable of measuring water velocity in layers with a thickness of only five centimetres. A revolution has also taken place in bathymetric mapping of lakes: the boat with depth sounding devices can be located with an accuracy of a few metres by cross-referencing from satellites.

Two PhD theses were essentially based on the results of hydrodynamic measurements in lakes. Juha Sarkkula presented his work at the University of Tartu in 1992, Timo Huttula at the University of Helsinki in 1994.

New technologies could also be applied in the study of runoff formation. By analyzing the oxygen isotope concentrations in a water sample, the fractions of event water and pre-event water could be separated. This research was first carried out at Vihti experimental field, and later on in some other small basins. The method was also combined with chemical water research, and Ahti Lepistö presented his PhD thesis on hydrological processes contributing to nitrogen leaching in forested catchments in 1996.

In 1986, the National Board of Waters became a part of the environmental administration. The old administrative units were given new names: the whole organization was renamed to the National Board of Waters and the Environment, and the research unit to the Water and Environment Research Institute. The name of the Hydrological Office was, however, not changed.

The number of water level gauges had remained practically unchanged, a little less than 500, for several decades. In the beginning of the 1990s, a project was started to rationalize the hydrometric network. This led to the reduction of the gauge network to about 350 in 1998. The doctor's thesis of Markku Puupponen in 1998 was concentrated on this topic. This work also led to a new division of monitoring duties between central and regional authorities.

The massive archives of hydrological data had required an extensive work of two groups of people: the observers and field technicians. Several thousand people all over the country have made hydrological observations, many of them more due to their own interest than due to the very modest economic return. There are a number of regional and even national celebrities among them, including Lenni Kujanpää, long-term water

level observer of Kyrö River, and Urho Kekkonen. The latter is better known as a long-term President of Finland; his career as the water level observer at Oulu Lake lasted only a short time in summer 1943.

Among the field technicians, Einar Lönnqvist became a legend during his forty year's career. He was by far the best known figure of the Hydrological Office among the Finnish public. He knew every corner of the country and performed thousands of discharge measurements in difficult conditions at remote sites. The length of his career was, however, beaten by Raoul Sjöblom, a drawer, who served the Office for 48 years.

A detailed classification of catchments covering the whole country, a multi-year work of the Office, was finalized in 1993. Finland was now divided into about 6000 catchments, whose divides, areas and lake percentages were exactly known. The first effort to classify Finnish river basins had been made already in 1863 by C.W. Gyldén; later the classifications of T.V. Olin (1936), Allan Siren (1955) and Pertti Seuna (1971) had been published.

A major reorganization of the administration was made in 1995, when the Finnish Environment Institute was established. The old administrative units, such as offices and departments, were dissolved and replaced by result units. A unit called Environmental Monitoring and Assessment was now responsible for hydrological monitoring, while also other units took care of hydrological research projects.

In 1998, the organization of the Finnish Environment Institute was revised so that operational hydrology was merged to the Division of Hydrology and Water Management. Research projects of a hydrological nature are, however, carried out in several other units of the FEI, such as Environmental Impacts Division. The future will show the success of the decentralized model.

Towards the end of the 1990s, most of the river basins in Finland had received their own hydrologic models. Immediate observations and values of hydrological variables calculated by models can be used as complements to each other. These models have also been used to estimate the damages that would be caused by a flood equally large as the 1899 flood.

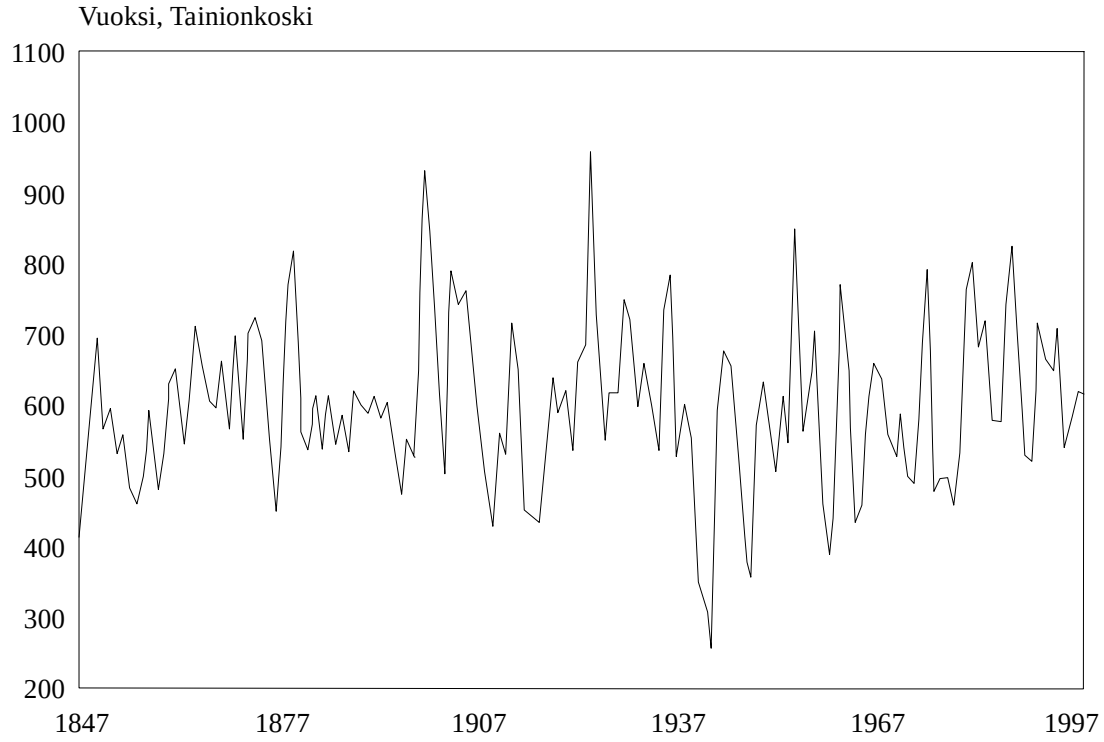

Fig. 6. Mean annual flows (m^3/s) of the Vuoksi River in 1847–1999 (Graph by Hannu Sirviö).

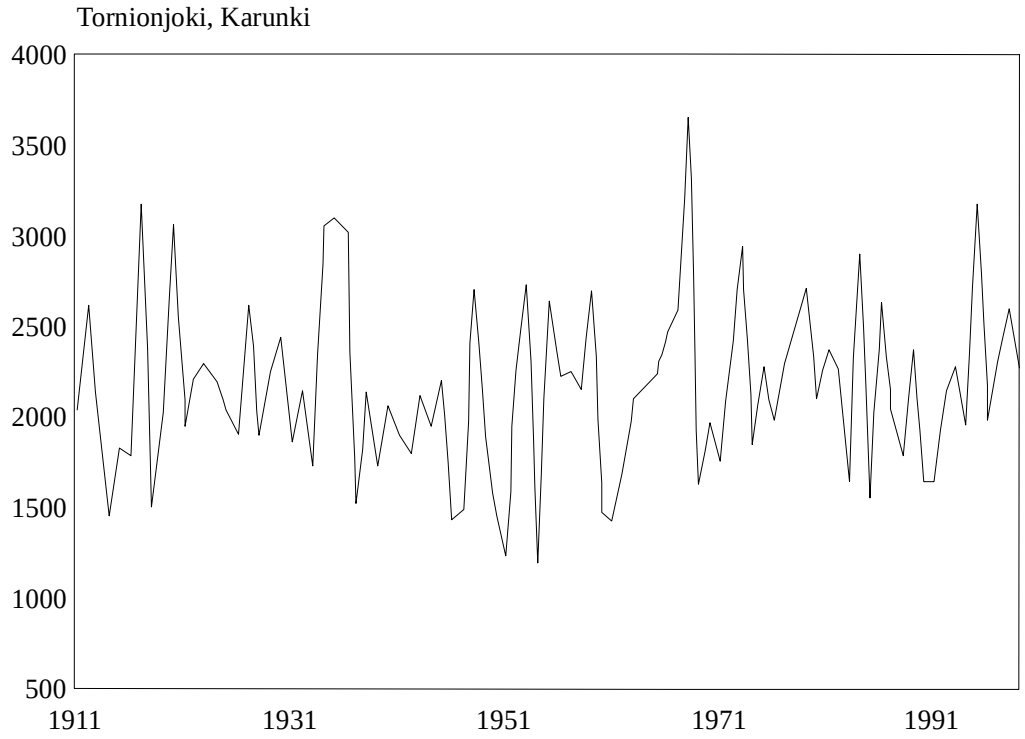

Fig. 7. Annual flood peaks (m^3/s) of the Tornio River in 1911–1999. (Graph by Hannu Sirviö).

Hydrology at the University of Helsinki

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At the beginning of the last century hydrology as well as other geophysical sciences were taught in connection with physics. The most well-known teacher at the University of Helsinki was Theodor Homén (1858–1923) the professor of physics. Homén´s field of interest covered meteorology, especially micrometeorology. He reached a very good international level in his research of the energy budget above different kinds of underlies. He also studied lakes.

Meteorology was the first of geophysical sciences, to separate from physics in 1921 to form an independent science, when a professorship in meteorology was founded. Geophysics became an independent subject in 1947. However, no permanent professorship was established in geophysics, but teaching was still carried out by special teachers or docents as had been done earlier. The responsible person in hydrology was Henrik Renqvist (1883–1953), who was nominated as a docent already in 1926. The topic of Renqvist´s doctoral dissertation (1916) was "Om sommarregnarnas hydrologiska konsekvenser" (On summer rains and their hydrological consequences) and Professor Theodor Homén acted as the opponent.

Renqvist was also active in other branches of geophysics, i.e. in seismology and oceanography. In hydrology his name is still associated with some instruments such as Renqvist´s evaporimeter and Renqvist´s limnograph. Mauno Porkka, who was later Professor of Geophysics at Oulu University, did his Master of Science thesis with Renqvist´s evaporimeter in the nineteen fifties. Renqvist´s limnograph was used in Lake Saimaa at Lauritsala until the 1970s.

In 1951, the first Ph. D. in geophysics specialising in hydrology was granted when Allan Sirén presented his thesis "On computing the land uplift from the lake water level records in Finland". The data used in this study covered several water level records made in greatest lakes of Finland. In this study special attention was paid to correct measured water level for winds and through flow. The method which Sirén used gave us the possibility to study continuously land uplift over an area of land.

The second Ph. D. in hydrology in this era was that of Maunu Seppänen. In 1961 he submitted his thesis entitled "On the accumulation and the decreasing of snow in a pine dominated forest in Finland". His study involved organising systematic snow measurements in small forest areas. From these measurements he was able to draw for

example, conclusions concerning the effect of a single tree in the forest on snowmelt. This study gave valuable background information for the development of snow monitoring by Hydrological Office.

The last Ph. D. of this era was that of Juhani Virta. In 1966 he submitted his thesis entitled “Measurement of evapotranspiration and computation of the water budget in treeless peatlands in the natural state”. The study was based on evapotranspiration measured with lysimeters and on the water budget computed with the aid of water level observations. The methodology was in principle the same, as that used in modern conceptual runoff models, except that in Virta´s study the functioning of the storage was based on physical information.

In 1957, geophysics was moved into a closer union connection with meteorology, when Lauri Vuorela (1913–1999) was nominated Professor of Meteorology. He represented geophysics at Faculty meetings and acted as an examiner in geophysics. Professor Vuorela was very active in developing geophysics and the fact that Professorship in Geophysics could be established in 1966 and the Department of Geophysics in 1967 was mainly due to him.

There was a long discussion about future development of geophysics in the Faculty of Sciences as well as among teachers. It was discussed, if teaching should be focused more on advanced courses and less emphasis should be given to teaching basic courses. The alternative with basic courses was selected, because it was thought that a science at the university cannot survive without basic courses. Also there were discussions about the definition of the teaching area of the professor.

Finally it was decided that the teaching area of the professor should be the “physics of the hydrosphere”, which at the same time defined the main line of the research of the Department of Geophysics to be hydrology and physical oceanography. One reason for this selection was the fact that rising area of environmental research in early nineteen-sixties needed support from research into the physics of hydrosphere. However, it was decided that the curriculum should also cover other parts of the geophysics. Heikki Simojoki (1906–1990) was nominated as the first Professor of Geophysics in 1967.

The structure of the geophysics curriculum remained in principle the same till the end of the 20th century. Hydrology was included together with oceanography into the physics of the hydrosphere (H-line). The first level (approbatur) was formed by four basic courses and second level (cum laude approbatur) by the most relevant methodological and substance topics in hydrology. The third level (laudatur) consisted of more advanced courses as well as Master of Science dissertation. Also field exercises were included in the studies. The most important minor subjects were physics, mathematics and meteorology.

Erkki Palosuo (1912–) was Professor of Geophysics between 1974–1978. His important topic of research was sea ice, but he also studied the structure of lake ice. A more accurate description of Palosuo’s activities can be seen in the “snow and ice” section.

Juhani Virta (1935–) acted as a professor between 1980–1998. During his time, the principal research in the field of hydrology in the department was the physics of lakes. This was based on the fact that due to the high lake percentage in Finland, lakes are of a exceptionally high significance in various ways. The other reason was that in Finland we do not have any special research unit which specialises on the physics of lakes. This research uses the processes, instrumentation and numerical computations as oceanography, which means there are a profitable synergies between two disciplines. It has been possible to develop techniques for current measurements using new acoustic current meters and other modern instruments.

A new topic is the optics of lakes and important winter conditions in lakes. The Department took part in the SILMU programme with a project on the effects of possible changes in climate on the temperature conditions of lakes. A representative of the Department has acted as an expert of the physics of lakes for the international EU-project REFLECT. The project started in 1998; the other researchers are from Sweden, United Kingdom, Ireland, Austria, Germany and Switzerland.

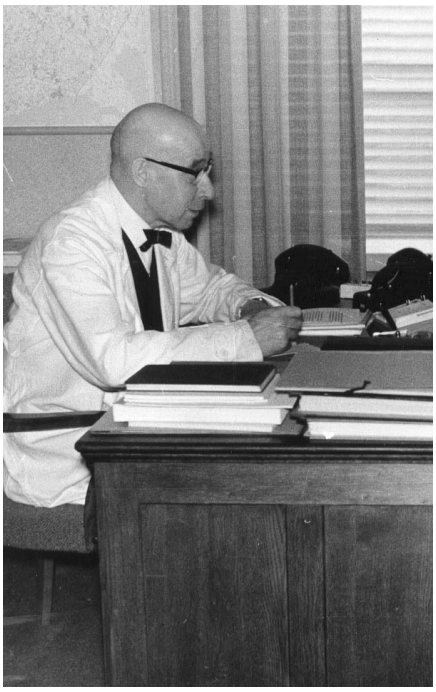
In addition to lake research, other hydrological research has been done at the Department. These include the modelling of ground water flow as well as the modelling of summer runoff. There has also been some research into the application of remote sensing in hydrology.

There was some co-operation with other Nordic countries within IHD and IHP. Important co-operation has been with the optics group of the Estonian Marine Research Institute in joint monitoring of optical parameters in several Finnish and Estonian lakes. This activity included measuring campaigns and four joint seminars on the optics of natural waters. The department also took part in the international project NOPEX by carrying out optical and temperature measurements in two lakes situated in Sweden.

During the period 1967–1999, three academic dissertations have been presented in hydrology:

- Esko Kuusisto: Snow accumulation and snowmelt in Finland (1984)
- Bertel Vehviläinen: Snow cover models in operational watershed forecasting (1992)
- Timo Huttula: Modelling the transport of suspended sediment in shallow lakes (1994)

The work for these theses was made at the Hydrological Office, and they were supervised and examined at the Department of Geophysics.



Professori Heikki Simojoki

Heikki Simojoki (until 1928, “Simelius”) was born on 22 January 1906 in Tornio. He passed his matriculation examination in Kuopio 1926. He got his Master of Sciences degree in year 1931 and his Ph. D. in meteorology was published in 1940, both at the University of Helsinki. The topic of his thesis was “Über die Eisverhältnissen Der Binnenseen Finnlands”.

Simojoki’s scientific career began at the Finnish Meteorological Office in 1931. From here he moved back to Kuopio, where he served as a teacher of mathematical subjects from 1932. Later in 1945 he came back to scientific circles, when he started his work at the Institute of Marine Research. At this Institute his most important posts were as Head of the Ice Department and the Hydrographical Department. In 1956, he moved to the Finnish Meteorological Office to become the Head of the Climatological Division and two years later he was appointed Head of the Hydrological Office. In 1967, he was appointed the first Professor in Geophysics at the University of Helsinki. Actually, his first post in the University was already in 1948, when he was appointed a docent of geophysics. He retired from the University in 1972.

Simojoki's extensive study work covers several branches of geophysics. His earlier publications give new results for the ice conditions and winter water temperature in Finnish lakes. Special attention was given to effects of area and width, location and ice cover on heat balance. He studied short term and long term variations, lasting over decades, of water level variations in open and ice covered lakes. His research results have had a significant influence on later studies.

In addition to the lakes studies, Simojoki also did research on the physical properties of the Baltic Sea. His findings on Baltic Sea evaporation have given material for comparisons to be made with later results calculated by different methods. Increasing winter navigation, for example, has made use of his studies in developing more effective forecasting of the dates of freezing. He did calculations for river inflow to the Baltic Sea and his studies of the water balance were included in IHD. All the countries around the Baltic Sea are now engaged in a joint water balance study.

Simojoki also presented valuable results on snow, its melting and the effects of meltwater in watercourses. These studies also included his observations on river ice jams during floods. In his climatological investigations he focused on long rhythmic variations. He pointed out that the rhythmic water level variations in the Lake Saimaa over 30 years are connected with the rhythm of precipitation.

The second to last paper by Simojoki was published in 1978, and deals with the history of geophysical research in Finland from 1828 to 1918. This work covers the whole range of the geophysical sciences and as it is very comprehensive, it called for great skill and zeal on the part of its writer. The list of references comprises original papers, manuscripts and letters.

The last paper by Simojoki was published after his death in 1990. He dictated the text on a magnetic tape, from which the paper was later edited. The paper explains the events which led to the formation of geophysics as the independent subject at the University of Helsinki in 1947 and the foundation of the Department of Geophysics in 1967.

All in all, Simojoki's published works cover a wide range of subjects related to oceanography, hydrology and meteorology. His approach to these subjects was often empirical, although it was based on a thorough knowledge of the theories behind the processes. His research was characterised by a critical attitude toward methods and data, so the results obtained are reliable. His early interest in meteorology and in the hydrosphere was evident even when he was schoolboy; he ordered a rain gauge from the Finnish Meteorological Office and used it to make observations.

When Simojoki acted as the head of the Ice Department of the Institute of Marine Research , he undertook several important studies, *e.g.* on the strength of sea ice and the interaction between weather and ice fields, and these have played an important role in the advance of winter navigation. His influence on the development of the Hydrological Office was great. Under his influence the basic data network, especially field working facilities and research activities were greatly improved. He was particularly occupied with studies of water balance and evaporation. Hydrological forecasts for different practical purposes were also started at this period.

Simojoki greatly promoted co-operation between different scientific fields; he served as a vice-president of the Surface-Water Committee of the Hydrological Association of the IUGG, has took part in preparation of the programme for the IHD on the international level, and acted as the first chairman of the Finnish National IHD-Committee.

Simojoki's role as a docent in geophysics started as early as in 1948, when he took responsibility for the planning of studies at the University of Helsinki. His students will well remember his approach to teaching in particular, it concentrated on the most essential questions of the hydrosphere and on critical physical surveys of different processes. His teaching, however, was never a mere collection of facts; it was a product of his broad outlook on life and a fine sense of humour.

(This presentation has slightly modified and shortened from the paper "Mälkki, P. and Virta J. 1981: Professor Heikki Juhani Simojoki – 75 years old on 22 January 1981. *Geophysica*, 17:1–2, pp 1–4.)

Hydrology at Technical Universities

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Finnish engineering hydrological research has its roots in agrohydrology. The purpose of the research has been to give answers to forthcoming problems and therefore it has usually focused to applied hydrological research.

Helsinki University of Technology was founded in 1849 as Polytechnic Institute and got the university status in 1908. Civil Engineering Department had two study programmes, of which one was agricultural water management. The person responsible for research and teaching was I.A. Hallakorpi. He was appointed a professor by the President of the Republic in 1925. Professor Hallakorpi had already published a Finnish textbook "Drainage" in 1917, in which he had presented knowledge of that moment needed for designing drainage systems. Although assessment of drainage benefits was the speciality of professor Hallakorpi, he also carried out extensive water management research. His most significant achievement in hydrology was the formula for estimation of mean high flow, published in 1934.

Professor Hallakorpi was a passionate advocator of agriculture. An example of this is a dispute between him and Dr. Henrik Renqvist. Dr Renqvist had claimed at the 5th Baltic hydrological conference in 1935 that drainage increases discharges in lower stretches of watercourses. Applying statistics used by Renqvist, Hallakorpi proved that such increases had not happened. He wrote irritated: "It is natural that water does not flow more rapidly than it is raining or snow is melting. Digging ditches or dredging streams does not change that."

During the Hallakorpi era two engineers achieved doctor's degree. The first was Lauri Keso, a fiery promoter of sub-surface drainage in Finland and the first Managing Director of the Finnish Drainage Association. His thesis dealt with effects of soil types on drain spacing. In 1925 some experimental drained fields were established due to his actions. In these areas meteorological and hydrological measurements were carried out among others. The research on acid soils published in 1940 can be considered the most significant scientific achievement of Dr Keso.

The other doctor was Pentti Kaitera, who succeeded Hallakorpi in 1942. Dr. Kaitera was the head of the Soil and Hydrotechnical Research Bureau of the Board of Agriculture since the beginning of 1930s. His research dealt with the melting of snow and its influence on the disharge in streams and rivers. He soon became a highly respected ex-

pert in hydrology. In 1936 he was appointed a member of so called Flood Committee, in which the most prominent national expertise in the field of hydrology was united. The chairman of the Committee was Dr. Renqvist and other members were counsellor of forest Axel Cauton and chief engineer Richard Gylling. Dr. Kaitera acted as a secretary of the Committee. After a thorough analysis the Committee concluded that floods in Finland were not generally risen.

Dr. Kaitera started his work as a professor of agricultural water management after the Continuation War in autumn 1944. The first dissertation made under his guidance was the one written by Taneli Juusela in 1945. It dealt with the effect of drainage on soil moisture, ground frost and soil temperature. Two years later Matti Wäre made his dissertation by representing observations from Maasoja experimental field. The next candidate was Kauko Niinivaara who defended his thesis on areal evapotranspiration in 1953. During this period professor Kaitera worked out also two remarkable research papers, one on the method for evaluation of mean-high-flow and the other on hydrological effects of bog drainage. The most important effort in the 1950s was the construction of a laboratory in Otaniemi.

In 1960s the professorship of agricultural water management was renamed as hydrology and water resources management. At that time more emphasis was put on water quality aspects in teaching and research. Also detailed research on hydrological processes was regarded important and a lysimeter field was established in Otaniemi for studies on evapotranspiration and soil water physics. But statistical methods were used as well. Eero Kajosaari published in 1968 his dissertation on droughts and Jussi Hooli analysed in 1971 the effect of meteorological factors on crop yield. In this study he discussed problems of both evapotranspiration and soil water. Ibrahim Gürer, who made his reseach on hydrometeorological and water balanced studies in Finland in 1975, was the last one under the guidance of professor Kaitera.

In 1970s hydrological studies were carried out in all three professorships of water engineering at Helsinki University of Technology. After professor Kaitera's retirement his chair was occupied by Dr. Jussi Hooli in 1975. At that time studies were directed more and more to water quality problems. Siuntiojoki watershed was chosen a reseach area of the laboratory and many studies were based on the measurements collected there. In the laboratory of hydraulics Laila Hosia investigated head losses in small streams. Professor Harri Sistonen was the head of the laboratory. Matti Melanen was involved in urban hydrological studies in the laboratory of water supply and sewerage, that was headed by professor Eero Kajosaari. Ms. Hosia defended her thesis in 1983 and Mr. Melanen the year before.

Dr. Pertti Vakkilainen was appointed professor of hydrology and water resources management in 1983. He had got his doctor's degree at University of Oulu in previous year. His thesis was based on observation material collected at the lysimeter field in Otaniemi. Since 1980s the hydrological research activities in the laboratory have dealt with statistical, conceptual and physically based hydrological models. Special attention

has been paid on soil and ground water, their retention, movements and quality. In this respect the capability was remarkably strengthened when Helsinki University of Technology appointed Dr. Tuomo Karvonen associate professor of the laboratory in 1994. Two years earlier, laboratories of hydrology and water resources management and hydraulic engineering were united as one.

In 1990s the focus in the hydrological research of the laboratory has been on analysis and forecasting of man's influence on hydrological cycle. For that purpose the laboratory established agrohydrological experimental fields in Siuntio, Lapua and Tyrnävä. Hydrological measurements were also carried out in small forested catchment area located in Siuntio.

The following dissertations made under the supervision on Professor Vakkilainen belong to hydrology:

- Tuomo Karvonen: A model for predicting the effect of drainage on soil moisture, soil temperature and crop yield (1988)
- Matti Ettala: Short rotation tree plantations and hydrological aspects in landfill management (1988)
- Riyadh Al-Soufi: A mathematical model for the watershed hydrologic system (1989)
- Juhani Kettunen: Model oriented data analysis with applications to lake and soil water simulations (1993)
- Auli Niemi: Modeling flow in fractured medium (1994)
- Markku Puupponen: Structural development of the Finnish national hydrometric monitoring network (1998)

Hydrological research has been made also under other professorships of Helsinki University of Technology. Kim Pingoud defended his thesis on infiltration in 1985 under guidance of the professor of system theory. Risto Kuittinen's doctor's thesis on determination of areal snow water equivalent using remote sensing methods under the supervision of professor of photogrammetry was accepted in 1988.

In addition to Helsinki University of Technology, engineering hydrological re-seach has been carried out at University of Oulu and also in smaller scale at Tampere University of Technology.

The first professor of hydraulic engineering at University of Oulu in the years 1961–65 was Dr. Matti Wäre. He supervised Seppo E. Mustonen's dissertation on effects of meteorological and basin characteristics on runoff. Professor Wäre's succeeders were Kauko Niinivaara in years 1967–72 and Jussi Airaksinen in years 1973–78. The dissertation of professor Airaksinen was accepted in 1971 and dealt with flood routing.

Professor Jussi Hooli moved from Helsinki University of Technology to University of Oulu in 1982. Of the dissertions made under his guidance the one of Veikko

Lammassaari on hydrological effects of timber floating belongs to hydrology. Lammassaari published his thesis im 1990. A special attention in Oulu has been paid to developing suitable methods for water protection in peat production areas. Mauno Rönkkömäki developed hydrological models for this specific purpose and Raimo Ihme analysed the efficiency of the overland flow method for removal of pollutants from peat mining water in 1994.

The dissertation of Pertti Seuna on the hydrology of small research basins was accepted in 1983. The study of Jouko Saarela dealt with infiltration characteristics of different surface structures on landfills in 1997. Both thesis were accepted at Tampere University of Technology.

Professor Pentti Kaitera

Pentti Kaitera (1905–1985) received the degree of Master of Science in Civil Engineering with excellent grades in 1929. After the graduation he completed the national military service in a memorable way: he is still the only student of the Reserve Officers School who received highest grades in all subjects.

In 1932 The National Board of Agriculture assigned Kaitera to head research activities in agricultural water management. Doctor Pekka Kokkonen had initiated these activities in 1929. Kaitera's tasks were to investigate methods for dimensioning water channels and assess the impacts of drainage works on catchment hydrology. To accomplish the goals he established a network of research basins, which was the first network of representative basins in the world. In these basins terrain properties were mapped and precipitation, water equivalent of snow, depth of frozen ground, and runoff were monitored until 1958. In some of the basins groundwater levels were also recorded. In one of the basins hydrological effects of draining bog areas were studied.

Kaitera's first research publication addresses magnitudes of channel roughness length and application of normal distribution in describing the variability of hydrological variables. His most significant hydrological investigations dealt, however, with snowmelt and runoff produced from melting snow. These were the topics of his doctoral dissertation, which came out in 1939. The opponents, professor Hallakorpi and doctor Renqvist, awarded the dissertation with best possible evaluation. Despite of engineering background Kaitera´s research approach was typical to the way of reasoning in natural

sciences. He was also actively involved in the experimental part of the research. Error analysis of the experimental data was carried out thoroughly. An important part of the dissertation is discussion of evaporation from a snow surface.

During the Winter War Kaitera took part in the fortification works, where his main interest was organization of anti-tank defense. In summer 1940 he suggested to general Hanell how compressed air could be used to melt the ice cover of lakes. The concept was simple: a network of pipes is laid at the bottom of the lake to inject air into the water. The air stream forces 4 °C water to move towards the surface where it causes the ice cover to melt. Field marshal Mannerheim was excited by the idea, but it was used only little during the war. However, after the war this concept found use in keeping ferry routes and log pools of sawmills free of ice.

In 1942 Kaitera was nominated the professor of agricultural water management at the Helsinki University of Technology. Along with research in hydrology Kaitera had also earned credit in investigations of drainage methods and agricultural engineering in a wider aspect. Due to the Second World War he took the professorship only in autumn 1944. During the Continuation War he acted as the managing director of Suurtalkoot ry and thus participated in arranging food and fuel supply for the nation. At the end of 1942 he became the head of the Evacuation Office, where he was responsible for evacuation of 63 000 Ingrians from the Leningrad area to Finland.

Kaitera's first investigations at the Helsinki University of Technology addressed drainage of cultivated areas. In 1949 he extended the peak flow analysis of his dissertation thesis by incorporating flow data from the main river basins of Finland. This work resulted in a so-called Kaitera's nomogramme, which is a tool for determining the mean-high-flow as a function of catchment area, lake percentage, and water equivalent of snow. This nomogramme is one of the most prominent achievements of hydrological research in Finland.

Starting in the late 1940's Kaitera became more and more aware of the need to promote development in the remote areas, especially in northern Finland. These ideas stemmed from the early years of his academic studies. Research activities received less attention and he started actively to push for the establishment of a university in Oulu. Finally in 1958, the University of Oulu was founded and Kaitera became the first rector. His influence can be seen in the composition of the faculties. On the contrary to the usual European practice, technical sciences were not separated into their own university. Instead, the University of Oulu followed the American model where a faculty for technical sciences resides within the same university along with humanities and natural sciences.

After resigning from the University of Oulu, Kaitera took interest in two issues: tectonical investigations of continental plates, and promotion of emerging development co-operation. He developed a theory of crustal movements based on the hypothesis that chancing pressure in the oceans induces mass flow towards the continents under the crust of the earth. After visiting Africa on several occasions he first had an idea to use development co-operation resources to establish and fund an university in an African

country. Soon he realized this to be unattainable, and instead he organized a MSc-course in water resources for African students at the Helsinki University of Technology in Otaniemi.

In 1968 Kaitera found again more time for hydrological research, and had a lysimeter field built in Otaniemi to study hydrological processes at small scale. The observations for Kaitera's last research project in hydrology were carried out in the lysimeter field. The project dealt again with evaporation from the snow surface and the results, which were published in 1972, confirmed the conclusions presented 33 years earlier in his doctoral dissertation.

After his retirement Kaitera discussed in several publications problems arising from the relations between scientific knowledge and religious faith. It is intriguing to observe that in these studies, too, he applied statistical methods.

Finnish Participation in Unesco Hydrological Programmes

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As early as the 1950s, Unesco launched a research programme on arid lands. Based on experiences of this programme, Unesco planned and carried out the International Hydrological Decade in 1965–1974. The main aim of the International Hydrological Decade was to increase knowledge of water resources. The limited amount of world water resources was generally known, as the need for water was tremendously increased due to both the rapid growth of world population and industrialisation.

Participation by the Nordic countries in the International Hydrological Decade varied both administratively and economically. In Finland, the Finnish Unesco Committee appointed an International Hydrological Decade subcommittee which held its first meeting on 16 October 1963, Dr. Simojoki was elected unanimously Chairman of the subcommittee and Pentti Mälkki was invited to act as its secretary. The first Nordic Decade meeting was held in Stockholm in March 1966. In February 1967, the subcommittee nominated Dr. Simojoki to act as Finnish representative in the Nordic co-ordination organ.

Fig. 8. An outdoor banquet of Nordic Hydrological Conference in Iceland in 1996 (photo by Esko Kuusisto).

To Finnish hydrology the Unesco International Hydrological Decade marked a period of increasing internationalization. The Decade particularly advanced and further developed Nordic co-operation in hydrology. An enormous amount of basic hydrological data was compiled in the Nordic countries using similar methods. In the implementation of the programme, the National Board of Waters had a central role.

The International Hydrological Decade was followed by the International Hydrological Programme launched in 1975. In its first meeting (April 1975) the IHP Intergovernmental Council recalled the basic philosophy of the IHP. It reaffirmed that this programme was not a mere continuation of the efforts undertaken during the International Hydrological Decade, but an expansion of past activities in order to cover the various applications of hydrology to water management and its environmental implications. Nowadays IHP programme has expanded from a pure hydrological programme into an extensive multidisciplinary environmental programme.

With the introduction of the IHP activities in Finland, it was expected that the resources channeled in Finland to the programme would be increased to the same level as in Sweden or at least to that of Norway. However, it was realized soon that the resources allocated to the programme would remain insufficient. The period when the Finnish IHP activities were taken care of by a person (Dr Heikki Niini) working full-time with IHP was only an ample two years.

From the outset of 1984, the secretarial duties of the UNESCO programmes have been taken care by civil servants working in the Research Councils of the Academy of Finland. With the reorganization of the Academy in 1995, IHP was transferred into a working group to act under the Research Council for Environment and Natural Resources. The IHP group held its last meeting on 10 March 1997 by stating that the term of the group ends with the introduction of the Finnish Global Change Research Support Group (FIGSU) on 11 March 1997.

At present, there are no special funds earmarked to IHP research projects but these applications go through the same scientific assessment procedure as all other applications addressed to the Academy. The administrative costs of the programme are covered by the expenditure of the Research Unit for Environment and Natural Resources.

Generally, the forms of Nordic co-operation established during the International Hydrological Decade have also been applied during the IHP Programme. Only some minor changes have taken place, for example: the name of the Nordic co-ordination organ was changed to KOHYNO (Koordineeringskommitten för hydrologi i Norden) and the IHD projects series is followed by the NHP report series.

Following changes in the focus of the IHP activities have taken place during the programme:

- The focus has shifted from Nordic co-operation towards co-operation between the Baltic Sea countries.
- Co-operation between the UNESCO scientific programmes has been intensified.

- Participation in the activities of the UNESCO IHP Secretariat and IHP working groups has grown.
- Finland has arranged several international conferences and meetings related to the IHP Programme, among the biggest two conferences on Climate and Water in 1989 and 1998. In can be noted here that the Finnish IHP activities have been best seen internationally in the arranging of these very successful conferences.
- Supporting developing countries in many ways.
- Promoting equality. For example, the IHP Council decided in its meeting in 1995, on the Finnish suggestion, to amend the regulations and to revise the terminology of the IHP Programme in favor to promote gender equality; this further contributed to the revision of the UNESCO terminology in terms of gender equality. On the suggestion by France and Finland in the same council meeting, UNESCO also launched a project with special emphasis on women's role, entitled Women and Water Resources.

Finland has adjusted its national IHP activities to the resources available by focussing its work. A limited number of tasks have been selected from the IHP Programme for implementation. The IHP projects have been carried out in co-operation with the Academy of Finland, universities (mainly University of Helsinki, Helsinki University of Technology), research institutes (Finnish Environment Institute) and individual persons. The same names reappear in the composition of the Finnish IHD/IHP organizations. This is also seen at the IHP Council level: the IHP Council meeting in June 2000 was attended by many of those participating the first Council meeting in 1975.

Through the IHD and IHP programmes Finnish researchers had the opportunity to meet their Nordic colleagues and were thus better prepared to deeper international co-operation, too. Later, this gave them better tools apply for EU funding. UNESCO/IHP has been a channel to co-operation with other international organizations, e.g. WMO. Today the main interest of Finnish researchers and research/funding organizations is focussed on EU projects, not so much on global programmes. It should be remembered, however, that problems related to water and sufficient water resources are particular topical in the developing countries today.

International Activities and Co-operation in Hydrology

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Introduction

International co-operation in hydrology dates back already to the late years of the 1800s. Its important parts, measurements and observations of water level, lake temperature, frost, discharge, evaporation and precipitation were first closely related to the activities in geodesy, oceanography and meteorology. An international hydrographic and biological conference was held in Stockholm in 1899 and a conference with Scandinavian scientists in Helsinki in 1902. In the latter one, Theodor Homén described his lake studies how lake surface area, depth and wind influenced on temperatures especially in the hypolimnion. Even heat transfer was enclosed.

After the start of the Hydrographical Office in 1908, in accordance with its regulations, one of its duties was to co-operate with national and international equivalent institutes, organizations and private scientists. In the first phase, contacts were continued and created with Russian, Central European and Scandinavian hydrological institutions. Basis was made for example for literature exchange and exchange of hydrological data.

During 1930s activities were flourishing between the Baltic Sea countries. As an example, the Fifth Baltic Hydrological Conference was held in Helsinki 1936 with about 30 Finnish papers.

According to law and statutes from the year 1947, Finland had to inform the Soviet Union on the regulation of Lake Inari by giving the water level observations and also giving guidance on discharges as well as making models for forecasting for the regulation of the lake. Later on, also Lake Saimaa with its state was reported to the USSR.

With Sweden and Norway (the rivers Tornionjoki and Tenojoki) the Commissions on Bordering rivers have used hydrologic material with statute basis. Formal regular scientific co-operation with Nordic countries started 1955.

Up to 1958 the main international organization in hydrology was International Association of Scientific Hydrology (IAHS). It was part of the International Union of Geodesy and Geophysics (IUGG) under the non-governmental ICSU-family. The first IUGG congress in Finland was held in 1960.

After the involvement of hydrology as independent programme to WMO and UNESCO, both the operational activities as well as research clearly activated.

The most important UN conferences, which have led to the ongoing international programmes in hydrology of today have been:

- Water Conference, Mar Del Plata 1977
- Desertification Conference, Nairobi 1977
- Science and technology for Development, Wien 1979
- World Climate Conferences, Wien 1979 and Geneva 1990
- International Conference on Water and the Environment, Dublin 1992
- International Conference on Environment and Development, Rio 1992

One of the main issues in all of these conferences has been “Freshwater is a major environmental concern and a key to sustainable development".

UNCED, as well as requesting WMO (as leader) and UNESCO to take responsibility for water resources (surface and ground waters, quantity and quality) assessment activities, led to the establishment of a cohesive framework for all international activities related to water. Number of partners in this co-operation was more than twenty.

Governmental organisations

WMO is an intergovernmental organization with a membership of 195 countries and territories. It originated from the International Meteorological Organization, which was founded in 1873. Established in 1950, WMO became a specialized agency of the UN for meteorology, operational hydrology and related sciences. It is the authoritative voice of the UN as to the state and behavior of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting contribution to water resources.

WMO is playing the leading role in international efforts to monitor and protect the environment through its programmes:

- World Weather Watch Programme
- World Climate Programme
- Atmospheric Research and Environment Programme
- Applications of Meteorology Programme
- Hydrology and Water Resources Programme
- Education and Training Programme
- Technical Co-operation Programme

For instance, in collaboration with UN agencies and the NMHS's of member countries, WMO continues to support the implementation of relevant conventions such as the UN Framework Convention on Climate Change, the International Convention to

Combat Desertification, and the Vienna Convention on the protection of Ozone Layer and its Protocols and Amendments. WMO is instrumental in providing advise and assessments to governments on matters relating to the above Conventions. These activities contribute towards ensuring the sustainable development and well-being of nations.

The WCP-Water Programme, established in 1981, brings together water-related activities under umbrella of WCP with the aim of ensuring an effective input from hydrology to water-related studies of climate and also the effective use of climate information in hydrological studies and water resources projects. WCP-Water is co-ordinated by WMO and UNESCO and linked to other programmes such as those of UNEP, FAO, IIASA and IAHS. WMO and UNESCO organize jointly regular planning meetings for reviewing progress with existing projects and for developing proposals for future activities. One such project was the Second International Conference on Climate and Water in the Helsinki University of Technology in 1998. This Conference was also an input to the UNESCO and ICSU World Conference on Science for the Twenty first Century, held in Budapest in 1999.

The Hydrology and Water Resources Programme, HWRP, is concerned with the assessment of the quantity and quality of water resources in order to meet the needs of society, to permit mitigation of water-related hazards, and to maintain or enhance the condition of global environment. It includes standardization of all aspects of hydrological observations and the organized transfer of hydrological techniques and methods. This programme is closely co-ordinated with UNESCO's IHP.

Under HWRP is HOMS, the hydrological technology transfer system, first introduced 1981. It is based on a catalogue of hydrological technology contained in the HOMS Reference Manual. At the end of 1990s, this manual contained more than 450 HOMS Components. There are over 125 HOMS National Reference Centers in the world.

Regional activities under HWRP are implemented through a series of Working Groups on Hydrology.

UNESCO is one of the special organizations in UN-system. It is independent with its own statutes, own budget and decision making. There are about 180 member countries; the Headquarters are in Paris. This kind of special organizations work with UN organization through UN’s ECOSOC and participate to UN’s UNDP to help the countries of the third world.

The big scientific activities in UNESCO are:

- Geological Correlation Programme
- Man and Biosphere Programme
- International Hydrological Programme
- International Oceanographic Commission

In 1950 UNESCO launched a programme of the research of the world’s arid zones, in which hydrology played an important role. Because of the good results this

programme was followed in 1965 by the launching of the IHD, a significant contribution to our understanding of the processes occurring in the water cycle, the assessment of surface and ground water resources and the adoption of a rational attitude towards water use.

During IHD gaps were noted particularly on the solution of practical water problems, with man's influence on water resources, with urbanization, and with industrial pollution. It was thought that such problems could be tackled with international and regional co-operation. This led to IHP in 1974.The objectives of IHP became to develop a scientific and technological basis for rational management of water resources, both as regards quantity and quality.

UNEP belongs to the UN-family, having activities among others in water and soil conservation, watershed development and environmental monitoring, particularly in the fields of pollution and health.

WHO is a UN specialized agency having topics of major concern in adequate food, water and shelter. One of the best known research programmes has been the International Drinking Water Supply and Sanitation Decade, (1981–1990).WHO has also been responsible for the operation of GEMS-Water.

FAO is a UN specialized agency, which in research and development programmes has given priority to promoting environmental protection. This takes mainly place by developing approaches and technologies that increase agricultural production through rational management and conservation of natural resources.

IAEA, the International Atomic Energy Agency, priorises among others safe management of radioactive wastes. Wide-ranging programmes in Isotope Hydrology are focused on the development and use of isotope techniques for sustainable water resources.

The UN Regional Commission ECE has had activities in implementing the convention on the protection and use of transboundary watercourses and international lakes.

On the programmes of the European Union, water quality, quality standards, conservation and storage, techniques, climate related programmes, land-ocean interaction and magnified environmental issues could be mentioned among others.

Non-governmental international organisations

The most important hydrological organization under NGO's has been the IAHS, established in 1922. The work under IAHS is done through nine Commissions dealing with Surface Water, Groundwater, Continental Erosion, Snow and Ice, Water Quality, Water Resources Systems, Remote Sensing, Atmosphere-Soil-Vegetation Relations and Tracers. Widely known is the Hydrological Sciences Journal (from 1956) and the Proceedings and Report's (since 1924).

Other relevant organizations of NGO's are e.g. SCOWAR, IIASA, IGBP-BAHC, IAH, IAHR, ICID and ICOLD.

Organised hydrological co-operation in Nordic countries

There are three different forms of organized hydrological co-operation between the Nordic countries:

1. Nordic Hydrological Association

The main activity has been the publishing of the International Journal, Nordic Hydrology, and the Nordic periodical, Vannet i Norden (Water in the Nordic Countries). The Association organizes every second year on a rotational basis the Nordic Hydrological Conference. Association also participates in the organizing of smaller seminars, workshops etc. Membership to the Association is either individual or organizational.

2. IHP-Hydrological Committees

The main function here is to encourage and stimulate regional co-operation between institutions across the national borders of the region. Joint projects are carried out within the Nordic Hydrological Programme. The activities in NHP have included working groups, expert meetings, seminars and research projects. The results of the NHP are published in the series NHP-Reports. The co-ordination of NHP has been done by KOHYNO.

3. Nordic Hydrological Institutes

NHI's co-operate in research and in operative hydrology. Under this umbrella, the main interests are the instruments and methods for hydrological measurements, collection, transmission, processing, storage and publication of basic data, hydrological forecasting, network design, specification of instruments and geographical information system.

All these Nordic organizational forms work under published statutes.

In international co-operation, one very visible activity has been the organizing of international and regional conferences in Finland.

Universities

In education and training, Finnish scientists have studied in USA, England, the Netherlands, Sweden and Russia. Finland has organized teaching, mainly in water management for African students.

The connections between Finnish and Estonian hydrologists were soon recovered after the Second World War. At first this happened by means of individual relations and later in the form of closer contacts with neighbouring professional and scientific organizations. The communication was enhanced after the opening of the regular passenger boat traffic to Tallin in the year 1960’s.

Regular connections with the Soviet Union in hydrology started in the year 1969, when the first UNESCO sponsored international higher hydrological course at Moscow

State Lomonosov University was set up. This post-graduate course was a Russian contribution to the International Hydrological Decade and International Hydrological Programme. Many Finnish experts attended the course, first of them was Reijo Porttikivi. Theme of courses varied from year to year, covering widely the field of hydrology and water economy. The instruction was completed by excursions, which were often directed to the Valdai experimental hydrological station and to the Baltic region.

In recent years, within the framework of cooperation in Central and Eastern Europe the Finnish Environmental Administration has initiated a systematic inventory of prospective ground water resources in the Republic of Karelia. The Karelian partner, Northern Water Problems Institute of Karelian Scientific Center, co-operates also in the development of GIS based data management of surface and ground waters, which was started by the Finnish experts.

At the end of 1990s started European Thematic Network of Education and Training for Environment-Water. This work is focusing on the relation between education and research within a perspective of lifelong learning. This network is represented in 26 countries by 71 institutions at its very start.

Annex 1. Acronymes and special terms used in this report

BAHC	Biospheric Aspects of the Hydrologic Cycle
Chy	WMO Commission for Hydrology
FAO	Food and Agriculture Organization
GEWEX	Global Energy and Water Experiment
HOMS	Hydrological Operational Multipurpose Subprogramme
HWRP	Hydrology and Water Resources Programme
IAEA	International Atomic Energy Agency
IAH	International Association of Hydrogeologists
IAHR	International Association of Hydraulic Research
IAHS	International Association of Hydrological Sciences
ICCE	International Commission of Continental Erosion
ICID	International Commission on Irrigation and Drainage
ICOLD	International Commission of Large Dams
ICSI	International Commission of Snow and Ice
ICSU	International Council of Scientific Unions
ICSW	International Commission on Surface Waters
ICWE	International Conference on Water and Environment
IGBP	International Geosphere-Biosphere Programme
IGCP	International Geological Correlation Programme
IGO	Inter-Governmental Organization
IHD	International Hydrological Decade
IHP	International Hydrological Programme
IIASA	International Institute for Applied System Analysis
IOC	Interngovernmental Oceanographic Commission
IUGG	International Union of Geodesy and Geophysics
KOHYNO	Co-ordination Committee on Hydrology in Nordic Countries
MAB	Man and the Biosphere Programme
NGO	Non-Governmental Organization
NOPEX	Northern hemisphere climate Processes land surface Experiment
REFLECT	Response of European Freshwater Lakes to Environmental ClimaTic change
SCOWAR	Scientific Committee on Water Research
SILMU	Finnish research programme on climate change
UNEP	United Nations Environment Programme
WCP	World Climate Programme

Annex 2. Ph. D. dissertation in hydrology

University of Helsinki

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