The History of Hydrogeology in Norway – Part II

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Introduksjon og sammendrag

Dette er andre del av en artikkel opprinnelig ment for en bok, "History of hydrogeology", som skulle inneholde tilsvarende artikler fra flere land. Bokprosjektet er foreløpig lagt på is. Del I av artikkelen, som omhandler utviklingen frem til ca 1950, ble presentert i forrige nummer av VANN.

Tidlige aktiviteter rundt boring av brønner for vannforsyning til gårdsbruk og lokalsamfunn ga med tiden en forståelse av hydrogeologi som vitenskap. Denne aktiviteten ble etter hvert utvidet og institusjonalisert av myndighetene. Siden 50-tallet var NGU den dominerende drivende kraft bak utviklingen av hydrogeologi som fagfelt i Norge, ofte i samarbeid med NVE og NLH. På 70- og 80-tallet ble det gjennomført omfattende grunnvannskartlegging med tanke på vannforsyning til kommuner flere steder I landet. Kartleggingen indikerte at 25 til 30 % av Norges befolkning kunne få sin vannforsyning fra grunnvann. Dette i kontrast til 13 % som faktisk benyttet grunnvann på den tiden.

Sentre for forskning og konsulentvirksomhet innenfor hydrogeology ble etablert i denne perioden samtidig som flere utdanningsinstitusjoner utviklet utdanningstilbud innenfor faget på alle nivåer, også doktorgradsnivå. De omfattende aktivitetene i fagmiljøer som Noteby og NGI var et klart uttrykk for en økende anerkjennelse av hydrogeologi som et viktig fagområde.

Abstract

The early development of hydrogeology was one of necessity. The art of drilling wells to supply groundwater to farms and communities gradually included an understanding of the science of hydrogeology. This activity was expanded and institutionalized by national authorities. Since the 1950's, NGU was the dominant driving force behind the expansion of hydrogeology, often working with NVE

and NLH. Major groundwater mapping programs were conducted during the 1970's and 1980's, supplying groundwater to large municipalities around the country. Results from studies indicated that 25 to 30 percent of Norway's population could be supplied with groundwater, in contrast to the 13 percent which was using groundwater at the time.

Centers of hydrogeology study, research and consulting were established around the country during the 1970's and 1980's when the higher institutions of learning began offering advanced degrees in hydrogeology. Activities at the large public consulting companies, notably Noteby and NGI, represented the expanding recognition of hydrogeology as an important earth science.

The Geological Survey of Norway

The new science of hydrogeology

In 1951 the Geological Survey of Norway (NGU), established in Oslo in 1858, began a new program led by Per Holmsen examining the results from well drilling by NDDC in Norway. In 1952 a well drilling register was established after the Danish pattern. By 1958 the number of registered drillings in bedrock had reached 3000. The average depth of the drillings was 40 m, but some reached as deep as 226 m; 90% of the drillings were in southern Norway.

Steinar Skjeseth, a paleontologist by trade, took over the new Hydrogeology Section in 1953, after NGU Director Føyn expressed his dissatisfaction with the mounting drilling costs, see figure 3. It was hoped that young Skjeseth was the right man to reign in the increasing costs of the burgeoning drilling program. However, Skjeseth soon proved to be more interested in developing the new science of hydrogeology rather than limiting the associated costs of drilling. The end result, nevertheless, was that the hydrogeology section at NGU, with its new leader, increased the focus on and raised the standards for the new science of hydrogeology in Norway.

By 1958 over 600 new wells were drilled annually in Norway. The knowledge garnered during the well drilling operations was deemed so important that a new initiative was taken to start the publication series "Notes from the water drilling archives". In all 14 separate monologues were published in this series, the last one being published as late as 1966 (Meddelelser fra vannborings-arkivet, Nr. 1-14).

Figure 3. S. Skjeseth (right) performing a pumping test in the field. Notice his attire which was considered appropriate at the time.

NGU moves – hydrogeologists stay behind

The decision to move NGU from Oslo to Trondheim was taken by the Norwegian Government on February 28, 1957. There was some indecision as to whether NGU should move to the Norwegian Institute of Technology (NTH) or to a new building that would be constructed at Østmarka in Trondheim. The Ministry of Industry finally decided on May 14, 1957 that NGU should be moved to the new building. In fall 1961 the move was completed, however not all of the employees moved to Trondheim. The Hydrogeology Section, with its five professionals, remained in Oslo. It was reasoned that since most of the well boreholes were drilled in southern Norway, it would be more practical to keep the section in Oslo, close to the action.

The Hydrogeology Section was headed by Skjeseth and had five employees. Skjeseth was known as a driven professional, a gifted lecturer, intensive and outgoing. He continuously tried to transfer his own knowledge over to not only his fellow hydrogeologists, but other professional groups he came in contact with during his work. Skjeseth's enthusiasm often took over hand it is reported, being often a test in knowledge as well as endurance. Two things Skjeseth emphasized were: make observations and solutions together, and immerse yourself in the facts in order to understand the problem. By the end of the 1950's, Skjeseth and two other employees were working full time with bedrock wells.

In 1958 there were only 15 bedrock wells using casing. None of these 100 mm diameter wells used filters. In this same year two new wells were drilled in unconsolidated sediments: one for Rena Packaging Factory, and one at Sagtjernet for Elverum Municipality. Norsk Dypbrønnsboring successfully installed the wells using available material and equipment. The wells were drilled using an arm attached to a tractor which drove back and fourth. The work was extremely difficult in the rocky soil. But with the successful completion of these two wells, a new unique era began for Norwegian water supply that, especially for the eastern Norway region, lasted until 1985.

Drilling after water in bedrock became a common strategy for water supply by the end of the 1950's. At the farming exhibition at Ekeberg in 1959, the Hydrogeology Section participated by drilling a well to 70 m in order to supply water to the farmers at the exhibition.

In addition to constantly updating and analyzing the data in their drilled well register, from 1960 to 1970 NGU focused increased attention on finding the best locations for water wells. This resulted in groundwater being quickly accepted as a viable alternative to surface water. This new acceptance, for using groundwater produced from sand and gravel aquifers, applied not only to small country villages, but also to towns and cities.

In the Hydrogeology Section, the number of employees increased with the work load. A new move saw the section sharing offices with the hydrogeological section of the Norwegian Water Resources and Energy Directorate in the summer of 1977. The number of employees at this new "Oslo office" grew to 18 by 1984, 12 of these worked for Hydrogeology Section. By this time water supply studies had topped one hundred, with over half of these being conducted for the local municipalities.

Groundwater mapping

International Hydrological Decade

During the International Hydrological Decade (IHD), a program running from 1965 to 1974 conducted under the auspices of the United Nations, the Norwegian national IHD committee started groundwater level measurements in three "representative basins": Filefjell (high mountain terrain with a thin soil cover of till), Sagelva (a thick soil cover of till) and Romerike (lowland terrain with glacifluvial deposits). Particular emphasis was given to the Romerike area where groundwater was plentiful and of economic importance. NGU coordinated activities and was active in data collection and analysis. At the end of the IHD period, the Romerike drainage basin had all together three recording gauges, about 180 tubes and about 20 wells used for recording groundwater levels.

Hydrogeological mapping

In addition to NGU's consulting for the public, the production of groundwater maps gradually became an important activity at the survey. Hydrogeological maps, with descriptions, of Bergen (1115I) and Drøbak (1814II) at a scale of 1:50,000 were published in 1978 and 1979, respectively. These were color maps with bedrock geology where detailed fault analysis and registered data from drilled water wells gave the basis for the interpretation of expected water yield from bedrock locations. NGU performed test drilling in selected areas with unconsolidated sediments, and yields greater than that from bedrock were indicated on the maps. Because of the high cost of producing the maps due to extensive field and interpretation work, their production was ultimately discontinued by the survey.

Groundwater resource mapping

At about the same time, the survey began producing another series of groundwater resource maps called "Ground water in unconsolidated sediments" at M 1:50 000, the so called "blue series". Despite its title, this was a series of black and white maps, with descriptions, that synthesized the results from earlier groundwater surveys in unconsolidated sediments within map quadrangles. The earlier results were supplemented with new field assessments and exploratory drillings to characterize the potential groundwater quantity and quality in sand and gravel deposits.

The map text in the blue series comprised a general description of groundwater and a special section about the possibilities for extracted groundwater from unconsolidated sediments, along with short descriptions of the groundwater potential in the bedrock occurring within the map quadrangle. The area profiles also contained groundwater quality analysis, drilling profiles with grain size distribution curves for sampled sediments, and groundwater quantities extractable using 5/4" sand filter well points. A total of 41 groundwater resource maps were produced from 1976 to 1987. This mapping series is considered the best groundwater series that has ever been produced in Norway.

Trial mapping in Oppland and Finnmark

By the 1980's, NGU had received requests from numerous municipalities and property owners around Norway expressing an interest in focusing their mapping efforts more on the needs of the end users, for example using administrative boundaries rather than the limits of the map quadrangles in the M 711 series. The end users wanted to be able to give more input concerning the content of the maps.

In an answer to these requests, NGU decided to perform a sample mapping of the municipalities of Oppland and Finnmark. Each of these municipalities was contacted prior to the mapping in order to prioritize areas with a need for improved water supply. Afterwards, field work was carried out in each of the prioritized areas and test drillings were made on unconsolidated sediments with the potential for groundwater extraction. The bedrock in the prioritized areas was also surveyed and the potential water quantity was indicated based on bedrocks maps and existing results in NGU's well drilling archive.

Reports were made for all of the municipalities (26 in Oppland and 19 in Finnmark) with maps that indicated, for the prioritized areas, the location and description of unconsolidated sediments and bedrock with the potential for groundwater extraction. Data tables were also provided over bedrock wells. The disadvantage with the maps was the exclusion of proved and possible groundwater occurrences outside of the prioritized areas.

Groundwater in Norway (GiN) Project

Another project which had considerable impact on the hydrogeology in Norway was the "Groundwater in Norway" or GiN project (Ellingsen & Banks 1993). This project was initialized in 1989 by the Ministry of the Environment and then coordinated by NGU. The program included the development of new methodologies, index mapping, registration and evaluation of groundwater occurrences and pollution threats, in addition to new initiatives to inform municipalities and county administrations. 15 of Norway's counties participated in the project. The non-participating counties were: Oppland and Finnmark (which had already been mapped during their own project, as mentioned earlier), Møre and Romsdal (which had already been surveyed by the Sogn and Fjordane University College), and Oslo (which already had a good water supply).

Mapping in the individual counties was performed by a formal working group composed of:

- one hydrogeologist
- one specialist in Quaternary geology
- one specialist in structural geology

In addition to NGU personnel, hydrogeologists and geologists from Sogn and Fjordane University College, Telemark University College, the University of Bergen and several consulting companies were involved in the mapping.

The different local municipalities in the counties were also divided into A and B municipalities dependent upon the urgency of the need for local surveys. Field work was performed in A-municipalities, while in B-municipalities the mapping was performed based upon existing geological information at NGU. Mapping was performed in areas prioritized by the municipalities with the exception of the counties Østfold and Vestfold where a general evaluation was performed for possible aquifers.

Based upon the mapping performed in the individual municipalities, the possibility for groundwater supply from bedrock or available unconsolidated sediments in the areas was characterized as «Good», «Possible» or «Poor» according to the actual water need. Some of the locations classified as «Possible» were, after further investigations, found to have a lower potential for groundwater supply than first expected. At any rate, the results from the study concluded that 25 to 30 percent of Norway›s population can be supplied with ground- water, in contrast to the 13 percent which was using groundwater during the project period.

The GIN project was completed after four years and produced:

- 261 municipality reports covering 301 municipalities
- 15 county reports (summaries of the municipality reports)
- 13 GiN instruction manuals with practical information about finding and using ground water

A brief summary of the GIN project and a full list of reports and publications produced during the project period is given in NGU (1992).

NVE – from rain to groundwater

In 1961, the Norwegian Water Resources and Energy Directorate (NVE) began to re-organize their work with groundwater. Earlier groundwater observations had already been recorded by NVE in 1949 at Groset in Telemark. The assignments in the first years were mainly concentrated on regulation investigations. These studies mapped the influence of rivers on the surrounding groundwater regimes in order to evaluate the effect of the imposed regulation in the river basins on the local groundwater conditions. The methods developed by NVE to perform these studies included correlation analyses of the observed river levels with measured groundwater levels at selected observation points, as well as mapping of the groundwater in the affected areas.

The first surveys were performed in Østerdalen (Stor-Elvdal and Rendalen) in 1961 and required assistance from both NLH and NGU. In 1963 a new survey was performed in Lærdal, and others followed as the results of new plans to utilize more of the Norwegian waterfalls for hydroelectric power production. The growing number of groundwater surveys soon required additional administration in the Hydrologic Department. The Groundwater Office (GWO) was formed in 1961, but it was only in 1963 that the necessary resources were in place for the office to begin functioning properly.

During 1971 the possibility of large flooding after a period of large snow falls gave rise to the "Committee for run-off predictions" (UFT) with their secretariat placed at the GWO. The feared large flooding never did occur because a large part of the flood waters went to regeneration of the groundwater reservoirs along the rivers. The hydroelectric producers were so fascinated by what happened that they funded new research around run-off predictions. UFT remained active until 1977 after which their activities were transferred to the GWO.

During their period of activity, UFT developed and published a method to calculate the size of available groundwater resources from a groundwater magazine based on depletion curves constructed from water level observations at an observation point in the river basin (a water mark downstream from the groundwater magazine). UFT equipped and ran a large number of observation fields over the entire country, where records were kept for groundwater levels, ground frost depths, snow depths, air temperature, and runoff in the lower river basin. In coordination with record keeping at the GWO, these records were entered into the shared Hydrologic Department's data archives.

When the IHD period came to an end in 1974, the Norwegian Hydrologic Committee suggested the establishment of a National groundwater Network (LGN), combining the infrastructure established with IHD support with other existing activities. The national observation network was put together and completed by 1977 as they could use a number of the already established UFT stations. The observation program was increased to include measurements of groundwater temperature together with analysis of chemical parameters. Administration and budgeting for the LGN was given to NGU. NVE provided an engineer for the field work, a position which in 1984 was permanently itemized in the NVE budget for the LGN. NVE was responsible for all of the LGN data processing since they already had a fully operational data processing center for the storage and presentation of hydrologic data. Since then, important development and modernization of the LGN stations has taken place. By the end of the 1980's the network measured groundwater levels at approximately 80 measuring points in 43 different localities.

Agricultural University of Norway (NLH)

The pressing need to improve the water supply situation in Norwegian farming communities in the middle of the 1960's was one of the reasons for the establishment of a new Professorate in geology at the Agricultural University of Norway (NLH) in 1965. It was an easy transition for Skjeseth from NGU to fill this position and take responsibility for hydrogeology at NLH since he had already been teaching part-time classes on the subject for several semesters. Skjeseth's background from NGU contributed to the good working atmosphere that already existed between hydrogeologists at NGU and NLH

Skjeseth was an inspiration for his colleagues and worked tirelessly at championing the use of groundwater in Norway. His hundreds of visits in the field gave him an intimate insight into the hydrogeology of southeast Norway. Beside his professional duties, he conducted courses and held lectures for the well drillers and helped them in the field. The drillers saw Skjeseth as someone they could ask complicated questions from the field and receive back good, practical advice. For the general public Skjeseth published popular science publications and had a series on Norwegian TV about geology and groundwater in Norway.

Skjeseth's experience with hydrogeology was first incorporated into the basic geology curriculum at the college. Later the first formal education in hydrogeology began with the creation of the first undergraduate course in hydrogeology in the spring semester of 1977. Graduate courses were also added and the first hydrogeologist in Norway was graduated in 1978 after performing a detailed study of glacifluvial aquifers under marine clays. The first Norwegian doctorate in hydrogeology was granted in 1982 based on work in the Fetsund delta area (Ree, 1984). Life, however, was not easy for the new hydrogeology students working in the field. Drillers were not used to new techniques that involved pumping tests, wells were expensive and equipment had to be purchased or borrowed. One hydrogeologist recalls purchasing an old cable tool machine from the widow of an operator who had perished under the mast a few years earlier.

In the late 70's, well stimulation of crystalline aquifers became popular. In practice, this implied using considerable amounts of water pressure tolerant explosives. The spectacular geysers, shooting out from boreholes loaded with 20 to 40 kg of explosives, were impressive sights. The stimulation would often stimulate the yield, sometimes reduce the yield, and invariably render the water from the well unfit for human consumption for months!

The field of hydrogeology at NLH expanded during the 1970's and the 1980's. The Norwegian Farming Science Research Council (NLVF) gave research grants for studies on water supply within the small farming communities and later for studies of water in the unsaturated zone. A new position for a professor, working within several areas of hydrogeology and specializing within hydrochemistry, was added at NLH in the 1980's. In 1984 an assistant professor position was also added at NLH to perform research work in hydrogeology. The Norwegian Hydrologic Committee (NHK) was an important driving force behind the granting of research positions at NLH and received their funding from the state controlled Concession Fund. Employees were persistent in their efforts to obtain funding for hydrogeological research at NLH. NHK was later incorporated into the Research Council of Norway (RCN) where interest for hydrogeologic research diminished after the 1980's.

In spite of the lower funding by RCN, cooperation between NLH and the University of Bergen (UiB) began in the middle 1980's. By 1987 a new national field course in hydrogeology was organized with practical support by NGU at Kaldvelladalen south for Trondheim. The two week field course soon became popular with aspiring hydrogeologists and eventually included the University of Oslo as well as the Norwegian Institute of Technology.

Jordforsk – georesources and pollution research

In 1977 NLVF was of the opinion that farming research was poorly organized and they created, after initiative from Skjeseth, a "Steering committee for agricultural research". The committee began to perform so much original farming research that by 1981 it received from NLVF status as an independent institute with the name of GEFO ("Institute for georesources and pollution research"). In the late 1980's GEFO was merged with the Norwegian Soil and Peat Company and reorganized as a foundation. Jordforsk, as the new group was known, was run as an independent research institution in Ås with less grants from The Research Council of Norway.

Public consulting sector

Locating water supply wells in the rural areas always was an important activity for the Hydrogeology Section at NGU. The number of these projects neared an all time high towards the late 1970's. By this time NGU had performed about 500 assessments. Most of these concerned water supplies for single family dwellings, mountain cabins and farms; the evaluations were mostly performed for well drillers and private persons, as well as some large municipal water supply projects.

Many of these groundwater projects were located in unconsolidated sediments, with the project leadership being provided by NGU. They were responsible for choosing the locations and performing the follow-up studies. This led to the establishment of a number of large public groundwater supplies, as in the case of Kongsvinger, Elverum, Lillehammer, Voss and Hønefoss. Some smaller ones were also established in Odda, Kautokeino and in most of the population centers in Gudbrandsdalen.

Over the years, the requests for help from the state hydrogeologists employed by NGU began to decrease for a number of reasons:

- water well drillers began using hydraulic fracturing to increase borehole yield
- the appearance of a new generation of water well drillers who often were better educated in their profession
- consulting firms with well qualified hydrogeologists began to offer their services in the market.

Noteby

In 1975 the Oslo based consulting engineering firm Noteby established a Hydrogeology Group to meet the growing demand for hydrogeological consulting skills in the market. This was a daring move, in direct competition with the governmentally employed hydrogeologist at NGU. The company employed some of the first students with dedicated training in hydrogeology. Most of these employees came from the new program for hydrogeology at the Norwegian Agricultural College and from the geology department at the University of Oslo. Projects mostly involved development of groundwater sources and sanitary/industrial landfills in Norway.

By the late 1970's, Noteby had increased their activities so much in Africa that they transferred six hydrogeologist to Kenya. Groundwater studies in East Africa and especially Sudan were performed for the Norwegian Agency for Development Cooperation (NORAD), the Swedish International Development Cooperation Agency (SIDA) and the United Nations Development Program (UNDP) well into the 1980's.

NGI

Groundwater has historically created geotechnical challenges in Norway. During the last century new techniques have been developed to prevent leakage and subsidence problems near tunnels and open excavations. The Holmenkollen tunnel is a classical example of this type of subsidence (Holmsen, 1953). The construction was started in 1912 with sections still being completed in the 1970's. The Norwegian Geotechnical Insitute (NGI), a private foundation established by a government resolution in January 1, 1953, was engaged to determine the geologic conditions and to monitor pore pressures and follow up on the subsidence problems. With assistance from Noteby, they were responsible for the schemes for artificial infiltration of water.

Since the creation of NGI, the institute has also worked extensively with the construction of dams for hydropower. With over 250 dams in Norway, there has been considerable research around the development of these structures. This research has led to new ideas about dam siting, construction material and requirements needed to control groundwater flow and seepage.

By the 1980's, hydrogeology was an integral part of NGI's consulting activities in working for national and international clients within the areas of water supply, natural hazards, environmental protection, oil and gas, building and construction, and transportation.

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