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Topographic Mapping in Denmark

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Introduction

The purpose of topographical mapping is to describe the landscape on a map. In Denmark topographical mapping have traditionally been defined, as maps in scale 1:10,000 – 1:100,000 published as series of map sheet covering the whole of Denmark. Maps in larger scale have traditionally been produced on demand covering small areas, and directly financed by the users.

Since the 1970's the municipalities and larger utility companies have taken the responsibility for financing the base maps in scale 1:1,000 – 1:10,000. The private sector produces these base maps. Since the late 1980's there have been digital maps with accuracy on 1 meter covering areas outside urban developments. These maps are different from region to region, and the copyright to the maps are owned by different municipalities and utility companies. The maps contain some topographical object, but they are not topographical maps according to the definition. Base maps in scale 1:1,000 – 1:10,000 are therefore not dealt with in this paper.

Topographical mapping has during the last several hundred years been a technical discipline including geodetic, surveying and printing challenges. Furthermore, topographical mapping has required cartographers with highly specialised handcraft skills.

During many years the topographical mapping has been limited to what was technical possible. However, the computer and surveying technology give many new opportunities for topographical mapping, which has and will continue to change the topographical mapping in Denmark. The new technology increases the sphere of application for many various users without increasing the expenses significantly. Moreover, the traditional cartographer skill is changing and is replaced by knowledge about computers and screen based communication.

In a historical perspective this paper describes the present and future national topographical mapping in Denmark. Kort & Matrikelstyrelsen (National Survey and Cadastre Denmark) – KMS – is responsible for the national topographical mapping in Denmark.

The national topographical mapping in Denmark has during the past 300 years followed the same development as the rest of the Western Europe. In the 18th and 19th centuries particularly France and Germany inspired Denmark concerning topographical technological developments. Land surveyors and officers from the Danish Army studied topographical mapping in France and Germany. The 20th century brought many technological innovations including the ways to produce and publish maps.

When NATO was established in 1949 it had a great impact on topographical mapping in Denmark. Map scales and map sizes were changed and the design of topographical maps had to follow the NATO Standardization Agreements.

In the last decade the use of computers have totally changed the production of maps. Moreover, the digital utilization of map products for GIS purposes is dominating.

User needs for topographical maps

Past need for topographical map products

Both the public and private sector use the standardized topographical mapping products produced by KMS. Compared with other countries in the world there are very few restrictions on using the topographical mapping products for civilian purposes.

The topographical mapping products available up to 1994 were limited to paper prints. The products included maps in scale 1:25,000, 1:50,000, 1:100,000, 1:200,000, 1:250,000, 1:500,000 and 1:1,000,000.

Denmark's area is app. 43,000 km² which gives possibilities to issue detailed topographical maps in books. Through the last 70 years different forms of topographical atlas in scale 1: 100,000 have been issued. The atlas is very popular and the last edition contains a place names index, road distance tables and some overview maps.

In 1994 KMS introduced a number of digital raster products in scale 1:25,000, 1:50,000, 1:100,000, 1:200,000 1:500,000 and 1:1,000,000. However, the digital products could not fulfill the continuous demanding marked for more topological, accurate and detailed maps required for e.g. GIS analysis, visualization, transport logistic, etc.

Present need for topographical map products

The Danish Defense has always been and is still the biggest user of topographical maps. The main products used by the Defense are still the printed maps in scale 1:50,000 and 1:100,000. Besides printed maps the Danish Defense uses different kinds of digital vector and raster data for many purposes.

The Danish Defense is building command and control systems, where maps and geodata are an integrated part of the systems. It is expected that these kinds of systems will setup new demands to the topographical mapping.

In order for KMS to revise it presents strategies for topographical mapping products, they undertook in 2000 a detailed customer survey of the present and future need for topographical mapping and geodata products for civilian use. The interviewees were divided in three groups, namely professional users, non-professional customers/NGOs and application partners with focus on IT-based business solutions.

Based on the customer survey KMS defined new product series and category of maps derived from TOP10DK – the national topographical database in scale 1: 10,000 (please see page 10). The three categories of maps were defined and named MAP25, MAP50 and MAP100 (Just, April 2001). The number indicates the approximately scale and is developed to give the optimal functionality with an interval of the scale, e.g. a MAP25 can be used in a scale from 1:10,000 to 25,000.

For each category four product series with different functionalities are developed. Thus different topographical products are made available aimed at the customers needs. The following figure shows the possibilities of datasets divided into product series and category of maps:

Product series \ Category of maps	GIS data	Vector data	Raster data	Paper map
MAP25 Scale 1:25,000 (1:10,000 – 25,000)	GD25	VM25	RM25	PM25
MAP50 Scale 1:50,000 (1:25,000 – 75,000)	GD50	VM50	RM50	PM50
Map100 Scale 1:100,000 (1:75,000 – 150,000)	GD100	VM100	RM100	PM100

Figure 1. The matrix shows category of maps and product series with the users' priorities. The dark color indicates greater interest from the users.

Each of the categories derives from different kinds of datasets. The high ends ones are the GIS maps. These datasets have the full GIS functionalities and can be use for every day GIS task. They are suitable for planning, administration and analysis.

The vector maps contain reduced datasets from the GIS dataset. It is not possible to use it for GIS analyses, but it is sufficient for creating maps for visualization. It is not as complex and heavy to use as the GIS dataset.

The raster maps are the traditional maps used as background maps. Finally the paper maps are the traditional paper products.

The different users are interested in different datasets. The professional users particular in the public sector are interested in GIS data and raster data with the focus on the scales 1:25,000 and 1: 100,000. Many users on the semi professional market (private sector) do not need to have full GIS functionality, but they can use the vector dataset for geo-marketing, planning and administration. Vector data is particular used by the graphic business in order for them to present nice cartography. The non-professional customers/NGOs users want raster data and continue to use maps (Just, April 2001).

Future need for topographical map products

Since the customer survey was undertaken in 2000 it has become evident that map and geodata products should be made available as Internet services, which can be reached by end-user applications. This approach requires that the Internet services are accessible in an open, standardized way allowing utilization by application providers. For this purpose the Open GIS Consortium has provided the standards. The first Internet service that KMS is providing – the KMS Map Supply – KMS offers topographical and cadastral suite of products using the OGC Web Map Specification (WMS) along with supporting XML-based services for geo-coding (based on address, parcel-id. or name of geographical location) and for projection transformation.

The KMS Map Supply service was released in April 2002. The map supply service provides a geodata infrastructure that can be utilized in end-user applications, but it does not provide a solution in itself. Hence the success of the service is dependant on the availability of applications utilizing the service. Working with application partners and encouraging these partners to offer solutions utilizing the service is crucial for the success. (Hansen, 2002).

It is obvious that dissemination of maps on the Internet will change the use, because it becomes easy to download your own maps or use it in connection with WEB applications. Moreover, users will require current and accurate data and it requires KMS to consider alternative solutions to secure that the topographical mapping products always are kept up-to-date.

Production methods

Early topographic maps

The Royal Danish Academy of Sciences and Letters (established 1742) produced the first series of topographical maps covering Denmark. 17 map sheets in scale 1:120,000 were printed from copper plates in 1768-1825. The maps were measured by plane tables in scale 1:20,000 where simple triangulation were used.



Figure 2. Map in scale 1:120 000 produced by the Royal Danish Academy of Sciences and Letters in 1791

The maps produced by the Academy of Science did not fulfill the Army's need, due to it lacked information about elevations and the map should also show more details. It was decided to produce a tailor made map product for the Danish Army.

The Army as producer of maps

The Army's idea was to measure in scale 1:20,000 and issue the map with Lehmann's hill shading in scale 1:60,000. Zealand (the major eastern island in Denmark) was measured 1809-1841, but no maps were printed.

In 1816 "Den Danske Gradmåling" (The Danish Geodetic Surveys) was established. Its purpose was to establish a triangulation in Denmark and connect it to the neighboring

countries. The Institution also started a plane table measuring in Holstein in scale 1:20,000. A Danish national leveling was also carried out.

The Danish Army was reorganized in 1842 and the General Staff was created. Only the General Staff's Topographical Department had to produce topographical maps. It was decided that the maps should be measured in scale 1:20,000 and have contour lines with an equidistance of 5 Danish feet (1,57 m). Cadastral maps were by use of a pantograph reduced to scale 1:20,000 as background for the measuring of the topographical maps. The maps were printed in scale 1:80,000.

It was a tedious process to engrave the copper plates for the maps. In 1857 it was calculated that all the copper plates would be completed in 1960 for the maps in scale 1:80 000. But there came an evolution or nearly a revolution, when photography and lithography changed production and printing of topographical maps.

The Army's second new measuring began in 1887, with described methods and clear objectives. Plane tables were used as before. Drawing on simple loose paper was changed to metal plates covered by paper. Place names were collected in the field and put on index cards. From 1889 the contour lines were measured with an equidistance of 2,50 m. Maps were issued in scales 1:20,000, 1:40,000 and 1:100,000.



Figure 3. Map in scale 1:20 000 produced in 1884

Around 1900 maps were issued in scale 1:10,000 with contour lines with 1,25 m equidistance for the Copenhagen area. These maps were restricted maps for use in the Army only. Fifty years later the prints came to public sale, and people interested in local history find great information in the 100 years old prints.

Denmark joined NATO in 1949. That resulted, among much other, in new map scales and new formats for printed maps. The new map scales were 1:25,000 (4 cm map) and 1:50,000 (2 cm map). The map in scale 1:100,000 changed format and the name was changed from General Staff Map to 1 cm map.

The area of a map in scale 1:20 000 covers 71 km² and the map in scale 1:25,000 covers 160 km². The numbers of map sheets were reduced from 835 to 405, when the scale was changed from 1:20,000 to 1:25,000.

Four maps in scale 1:25,000 are the basis for one map in scale 1:50,000, and four maps in scale 1:50,000 are basis for one map in scale 1:100,000. The map series 1:50,000 consists of 110 map sheets, and there are 33 map sheets in scale 1:100,000.

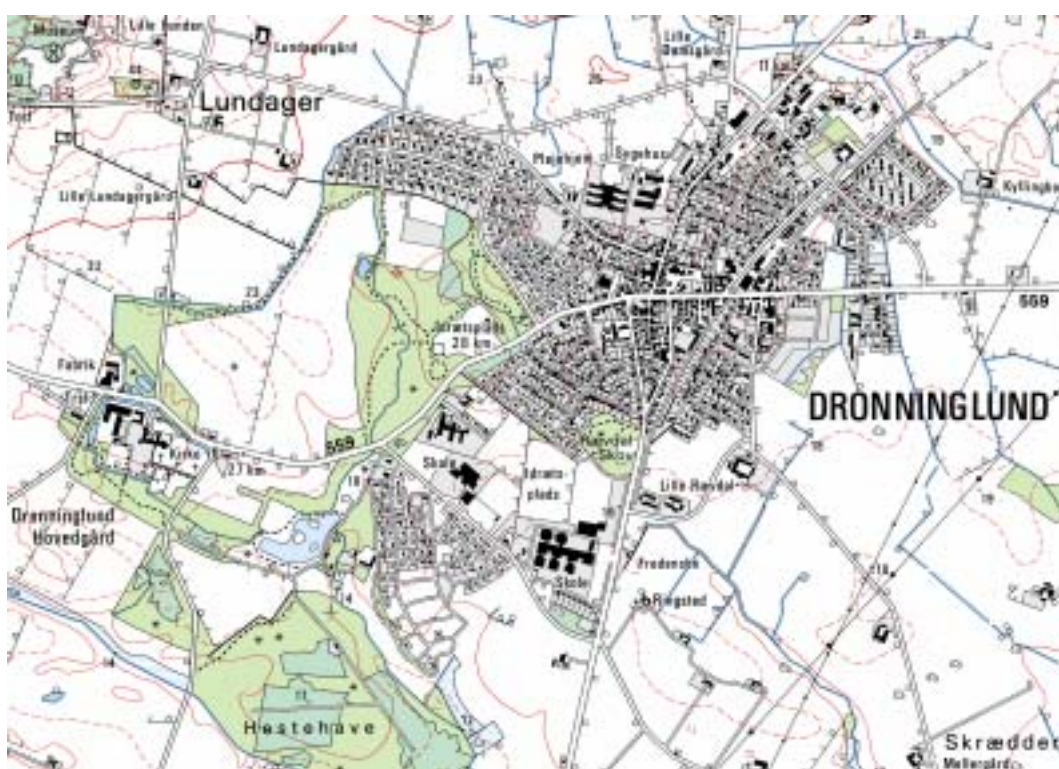


Figure 4. Map in scale 1:25,000 – 4 cm map produced in 1987

The maps in scale 1:25,000 and 1:50,000 have been updated every 10 years after thorough field inspections. The frequency for updating the maps in scale 1:100 000 are 6 years.

Photogrammetric measuring

In the middle of the 1960's photogrammetric measuring of Denmark in scale 1:10,000 began. The drawings were on plastic sheets and field inspections were performed together with check of place names. New contour lines were measured by

photogrammetry for the Danish west coast only. In the remaining of Denmark the former contour lines were fitted to the new measuring. In most of Jutland the 5 feet contour lines (from around 1870) were interpolated by hand to 2,50 m contour lines.

Scribing and peeling

The glass and plastic scribing technique was from the middle of the 1950's used for the contour lines. In the 1970's the drawing of maps by pen and ink came to an end. The scribing and peeling on plastic sheets took over. It caused more standardized maps and quicker production. The place names on index cards were computerized and it was quick to search out place names for a specific map.

The computers takes over

In the beginning of 1990's the scribing and peeling technique was replaced by the computer technology. All plastic sheets, around 15 for each map, were scanned and stored as individual raster files. The maps in scales 1:25,000 and 1:50,000 have been updated by superimposing orthophotos on the raster maps.

All raster files for the maps in scale 1:100,000 are converted to vector files. All the vectors are attributed and stored in a database. The 33 map sheets are updated regularly after field inspections.

GIS – new requirement and possibilities

Development of computer technology to handle maps and other geographical related information increased the possibilities and application of data, which had up to then been impossible. In the 1980's the ideas were focused on utilizing computers to handle digital drawings. In the late 1980 the GIS concept was general accepted and the users of maps began to define the future requirements for maps in a GIS environment. These requirements have had great impact on the topographical mapping in Denmark since.

With the GIS concept there were new requirements to the topographical mapping both from the Danish Defense and the civilian users. With digital technology it was for the first time realistic to assume, that it is possible to use the same data to fulfill different requirements without increasing the expenses significantly.

As described above the computer was adopted in the topographical map production in the earliest 1990's. Basically the analogue production was merged to computers at that stage. With the requirements from the Danish Defence and civilian users based on the GIS concept, there was a need for reviewing the topographical data collection and the topographical map production.

Database for multiple purposes

The vision born at that time was to create one topographical database, which could fulfil both military and civilian requirements for digital and analogue products. The idea was to create one large-scale topographical database, which could be used for multiple purposes in GIS systems. Furthermore, the database should be used to produce other topographical products in smaller scales.

The objective was to create a production system for the topographical products, where the information only was collected once and stored and maintained in one single database. The whole concept was a very big change from the traditional topographical mapping, where each scale had its own information collection and maintaining workflow.

In the first half of the 1990's KMS undertook thorough investigation of the establishment of a large-scale database. It was decided in 1995 to commence production of a topographical database in scale 1:10 000. The topographical database was named "TOP10DK".

TOP10DK – the topographical database in scale 1:10,000

TOP10DK was produced from 1995 until 2000 and it covers the whole of Denmark. The production of TOP10DK was based on aerial photographs. The TOP10DK is updated every 5 years.

The users require current data, where the database always is kept up-to-date. This is not realistic with updating procedures based on aerial photographs, and for that reason other models for updating the TOP10DK database is taken into consideration. The main idea is to update the most important objects like roads and houses based on information from municipalities.

TOP10DK is a well-defined and well-structured topographical vector dataset with an accuracy of 1 metre or better. All TOP10DK registrations are made on the basis of aerial photographs and is subsequently controlled in the field. TOP10DK is based on meticulous specifications in terms of what is to be registered and how it is to be registered. The registrations are all subject to a strict completeness check and topological check to ensure that the rules specified are complied to.

The geometrical part of TOP10DK includes 46 themes. There are x, y and z coordinates stored for every point. Each object has an unambiguous number with associated attribute information.

In TOP10DK there is attached information about which instrument, with which accuracy, by which operator, etc. the point was measured. The information is not related to the object, but to every point in the object, e.g. every vertex in a road centreline. With such information it is possible to check, which points have been newly measured and which stemmed from previous measurement.

Beside the geometry part of TOP10DK the database includes place names. To each text the database contains geometry information describing which objects the text relates to.

Model for deriving product from TOP10DK

Since 1996 TOP10DK has been used to produce different kinds of large-scale products. Due to the structure of TOP10DK it is simple to produce topographical/cartographical products in large-scale (1:10,000 – 1:25,000). The production of MAP25 is scheduled to be completed 2002.

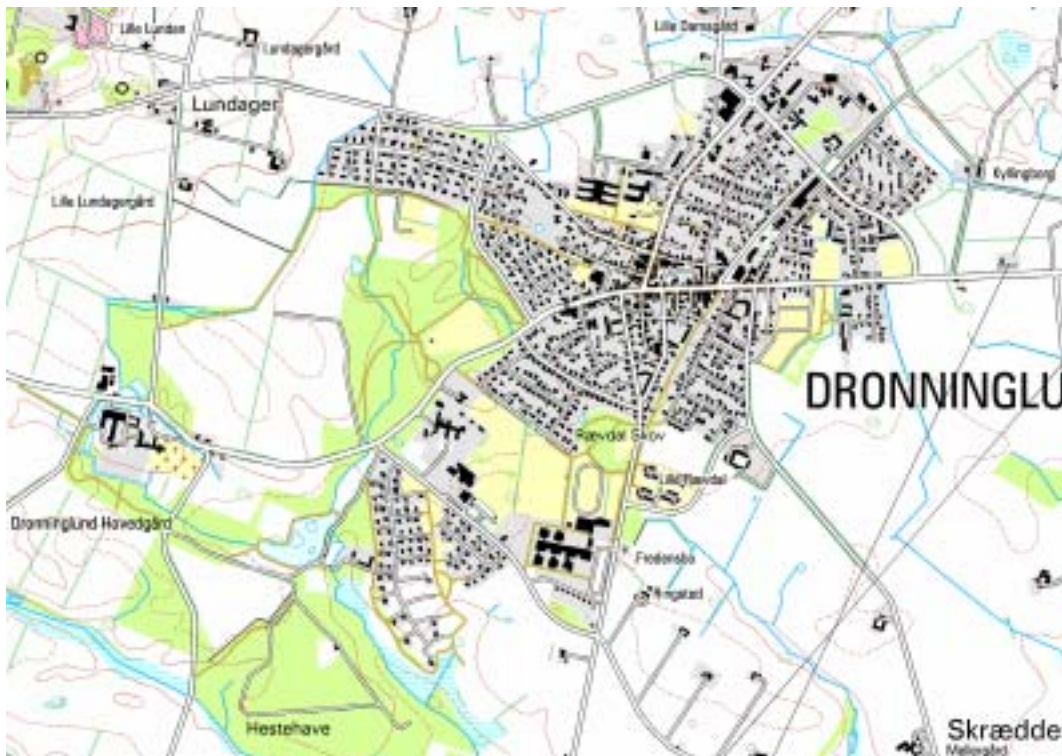


Figure 5. Example of MAP25 produced in 1999

In 1995 when the production of TOP10DK began, the technology was not developed to derive data or map sheets in 1:50,000 and 1:100,000 from a database in scale 1:10,000. Consequently, it was not realistic to base the topographical map production on TOP10DK. Instead it was decided to focus on producing the database and keep the existing workflow for doing the topographical map production to the Defence in scale 1:50,000 and 1:100,000.

In 1999 KMS refocused on deriving product from TOP10DK in different scales. Based on figure 1 KMS has defined a conceptual model with base datasets, derived datasets and products:

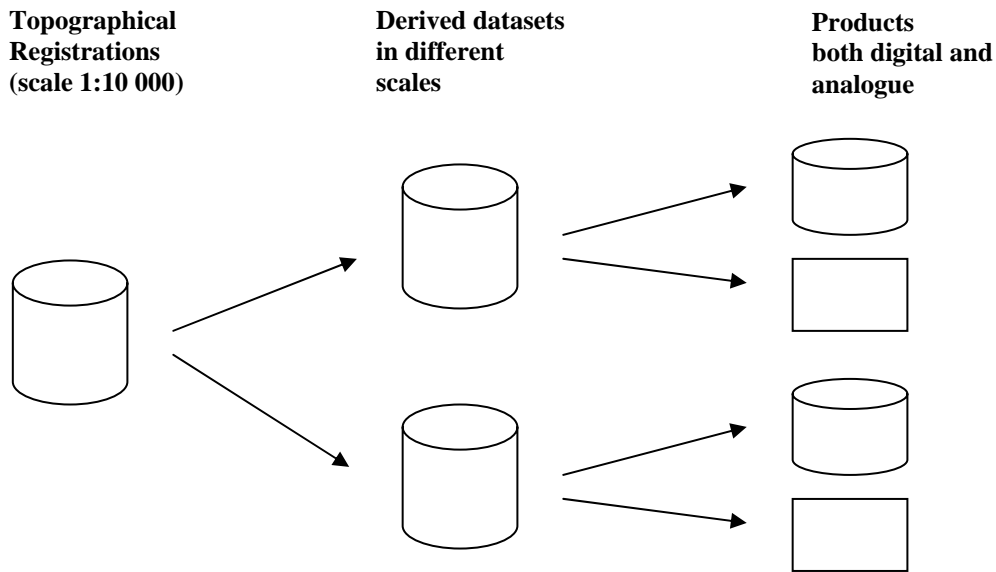


Figure 6. Conceptual model for the topographical databases

There is defined a database model to store the different kinds of products in order to handle the conceptual model. In the database the geometries for the topographical map products are structured according to the following object model (Bengtsson, 2001):

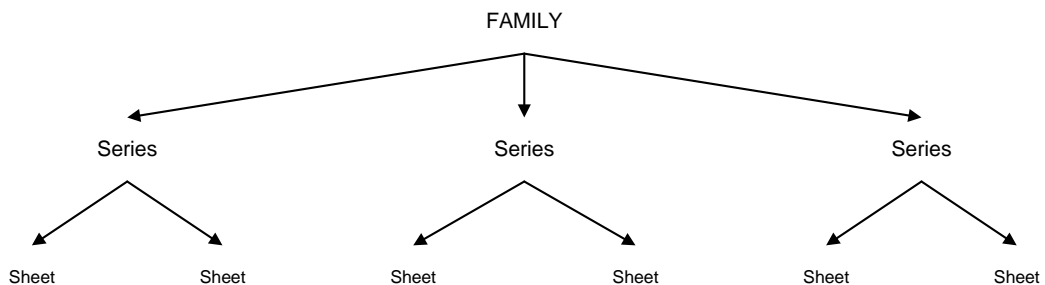


Figure 7. Database model for storing derived products

The **Family** contains derived topographical geometries and geometries for name placement according to a defined scale. These geometries can be used as the basic for further manipulation/generalisation in the production of vector and raster products in this scale.

The **Series** contains derived topographical geometries and geometries for name placement that either is geometries inherited directly from the Family or/and are geometries, which have been further manipulated/generalised for this Series.

The **Sheet** contains only topographical geometries inherited from the Family or the Series. It can contain it's own geometries for name placement.

In order for updating the derived datasets when the TOP10DK have changed, the database is designed to handle references between the derived object and the TOP10DK object(s).

Deriving data in smaller scale

It will still take time before KMS has a fully automated and robust production, which follow the concept described above. In 2001 the first maps in scale 1:50,000 to the Danish Defence was produced from the TOP10DK database in scale 1:10,000. The biggest challenge is to automate the generalisation. The production in 2001 gave some promising results, and showed that it is realistic to have a topographical map production to follow the concept within a few years.

The next step is to use the experiences from deriving product in scale 1:50,000 on product in 1:100,000.

Organization of the topographical mapping in Denmark

Geodetic Institute

In 1928 a new civilian institution, The Geodetic Institute, was founded as a part of the Ministry of Defense. The Institute took over and continued the work performed by the General Staff's Topographical Department and the Danish Geodetic Surveys (Den Danske Gradmåling).

Until the late 1980's the topographical mapping was primary based on the Defence's requirement combined with the technical possibilities. The Institute carried out all development, test and production.

The topographical maps were and are still used for many different civilian purposes by professional and none professional users, albeit it was not intended for them. The Defence financed nearly 100% of the expenses for the map production.

The National Survey and Cadastre (KMS)

Among the most important reasons for restructuring the organisations involved with mapping financed by the public sector in the middle of the 1980's were:

- coordination of mapping in Denmark
- planned new investments in expensive technology
- a wish to add organisations to contribute financially to the production of maps
- minimizing production expenses having public mapping in one organisation

A new agency was founded in 1989. Cadastral maps, sea charts and topographical maps were going to be produced by KMS. The goal was to establish databases with digital maps, which could be used for many different purposes.

KMS should continue to receive founding from the Government. However, approximately 1/3 of KMS income had to be generated from sale of maps and geodata products. During the 1990's KMS has created databases for topographical, cadastral map and sea charts, which are for public sale.

KMS was an agency under the Ministry of Housing and Urban Affairs, but was in 2001 transferred to the Ministry of Environment. Until a couple of years ago KMS particularly focused on creating digital databases for topographical, cadastral and hydrographical purposes. The huge work is completed and KMS vision is to create the best possible advantages for the Danish society from the digital databases as an integrated part of national infrastructure.

New models for co-operation

When the Danish Defense was responsible for the production of topographical map all work from information collection to printing of the maps was carried out by the Geodetic Institute. There are two main reasons, namely:

- a question of national security
- the production required unique technology and handcraft skills

When KMS was founded in 1989, the political attitude for co-operation with the private sector changed. The national security aspect was less important and the production techniques did not in the same degree require specific skills. KMS had to identify economical and technical solution for topographical mapping, which includes both in-house production and production by the private sector. Private companies, for example carry out all the work with data acquisition to the topographical database TOP10DK, after public tenders.

With the computerized production new possibility for co-operation has become possible. The base maps for municipalities and utility companies have traditionally been technical base maps in scale 1:1,000 – 1:10,000. Such technical maps comprise many objects, which are to be found in the topographical database. A Committee has identified common objects in the topographical database and the technical base maps. It can in near future be possible to share data and get the benefits from common production.

Conclusion

The responsibility for the topographical mapping in Denmark has changed through the years. In the beginning the 20th century it was the Army's General Staff that produced the maps. The civilian institution the Geodetic Institute under the Ministry of Defence took then over. When KMS was founded it became a part of the Ministry of Housing

and Urban Affairs. In 2001 the KMS was transferred to the Ministry of Environment. The name of the resort Ministry renders the general interest in topographical maps. Put differently, from being maps for primarily the Defence, the topographical maps have become an integrated part of national infrastructure.

Previously maps were produced as separate series of map sheets in different scales. Today topographical maps are derived from one single database.

The Danish Defence, private sector and public will to some degree continue to use printed maps. However, dissemination of maps on the Internet will change the use, as it becomes easy to download your own map. The challenge for KMS is therefore to consider what to do with paper maps in the future – should KMS continue to have storage of printed maps or will all paper maps in the future be plot on demand. It is obvious that the future will bring more and more customized topographical maps.

Production of topographical maps and geodata are expected to be more and more integrated by sharing data, and setting up common productions. The goal is to get both an improved and a less expensive (topographical) mapping.

From a users point of view topographical maps and geodata will be an integrated part of national geodata infrastructure hopefully to benefit for the whole Danish society.

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