The production and use of a hydrographic flow-direction network of surface waters

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Key words: hydrographic, flow-direction network, surface waters

SUMMARY

Lantmäteriet, the Swedish mapping, cadastral and land registration authority and SMHI, the Swedish Meteorological and Hydrological Institute, are working together in a joint project called "The Hydrographic Network Project" with the overall goal to have new nationwide hydrographic products for customers ready in 2017. At the beginning of 2016, the first 15 main catchments areas were available as a hydrographic flow-direction network for customers.

The hydrographical information has lakes and streams in a network and shows how water flows from the water source to the outlet. The project work with main catchment areas to cover the whole of Sweden and the first map information has covered the southern parts of Sweden. Hydrographic information is produced in map scale 1:10 000 which is more detailed than the currently available Swedish hydrographic information.

To make "The Hydrographic Network Project" and its metadata available, standardized view- and download web services have been developed. Using standards makes it easier for end users to understand and combine other data with the network.

This project uses existing data made for cartographic use, which is not suitable for analysis and spatial calculations. The data is processed so it can be used for hydrographic network analysis.

The following products have been created for use in environmental and civil protection:

- Dispersal of pollutants and analysis of acidification and liming needs,
- Calculation of flood risks and impact in environmentally sensitive areas,
- Forestry and other infrastructural activities to see the potential effect on the landscape,
- Showing the effects of flow regulation and the impact on watercourses continuity,
- Migration of fish and other organisms and sediment transport.

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1. IMPROVING THE BASIC HYDROGRAPHICAL DATA IN SWEDEN

Lantmäteriet, the Swedish mapping, cadastral and land registration authority and SMHI, the Swedish Meteorological and Hydrological Institute, started in 2013 "The Hydrographic Network Project" (Lantmäteriet, 2016) in order to improve the possibilities to use the basic cartographical data in Sweden for hydrological mapping and analysis. The new hydrographic data will have better spatial resolution and precision compared with the existing database, SVAR, The Swedish Water Archive at SMHI, which is mainly built-up by features in the map-scale 1: 250 000 (SMHI, 2016).

Primarily the hydrographic data was delineated into map features representing lakes and streams as unique objects in a flow-direction network. Polygons representing surface water were delineated at inlets and outlets and at known locations of dam buildings. The delineated surfaces were categorized as standing waters or as running waters. Standing water objects in the new hydrographic database can be representations of lakes, ponds and other small surface waters e.g. man-made basins.

The basic data used is in map-scale 1: 10 000 which means that representations of small standing waters is a main part of that category. In the Emån catchment area, where the project activities started, the smallest surface water was 60 m^2 and 1 820 of 2 676 standing water objects were smaller than 10 000 m^2. In the Emån area 51 lakes larger than 1 km^2 were defined.

In the Swedish basic cartographical data, running water narrower than 6 metres is represented by a single line, not a surface. Lines were created in polygons of broader rivers and standing waters in order to build a network of lines representing the net flow-direction in the river systems and the catchment areas. These lines can be called centrelines or network links.

High resolution elevation data (Lantmäteriet, 2015) was used to define the water flow direction in the river systems. In standing waters the inflows and outflows were manually identified and connected with flow-direction in network links.

Technical challenges have been solved during the project, which is reflected in this paper. The basic cartographical data was adjusted to fit into a data model for delivery of GML-products according to the INSPIRE Hydrographic Data Specification (INSPIRE, 2014). It is also a challenge for a GIS-operator to decide whether a surface water area is standing water or running water. These two feature classes are different regarding water flow velocity within the water bodies, which is important for biology in the ecological systems as well as for using the water for different activities.

2. Production of the hydrographic flow-direction network

The methods for this project are based on the processes that Lantmäteriet provides for updating the basic cartographical data supported by SMHI's knowledge off hydrology. The production of the data is based on the main catchment areas in Sweden, which were defined by SMHI. The daily production take place at Lantmäteriet and the data is sent to SMHI for checks and validation, any suggestion or improvement are then updated at Lantmäteriet. The GIS operators at Lantmäteriet work with updating of the basic cartographical data on different production steps that are described below.

2.1 Create and update geometries

At SMHI the existing hydrographic database, SVAR is based on the Swedish General Map in scale 1: 250 000. After this project the information will be based on the basic cartographical data that is in the scale 1: 10 000. During the build-up of the hydrographic flow-direction network in the scale 1:10 000 the GIS operators at Lantmäteriet uses SVAR as a background for support and aid. The project produces hydrographic information based on the basic cartographical data, which is built up with orthophoto in the background (Figure 1).

There are many steps involved in the improvement of the basic cartographic data in order to make the data suitable for GIS analysis. At the start of the project the basic cartographical data had to be updated with new geometries to fulfil the requirements of the project.

Figure 1: Orthophoto over an example area in Sweden.

The water areas, which were stored as large database objects in the base map data, were divided into separate hydrographic objects representing features with different hydrological characteristics. Lakes, small water areas and river reaches were delineated as map objects. As shown in Figure 2, the big lake in the middle and the streams were one database object but they were delineated into many different hydrography objects.

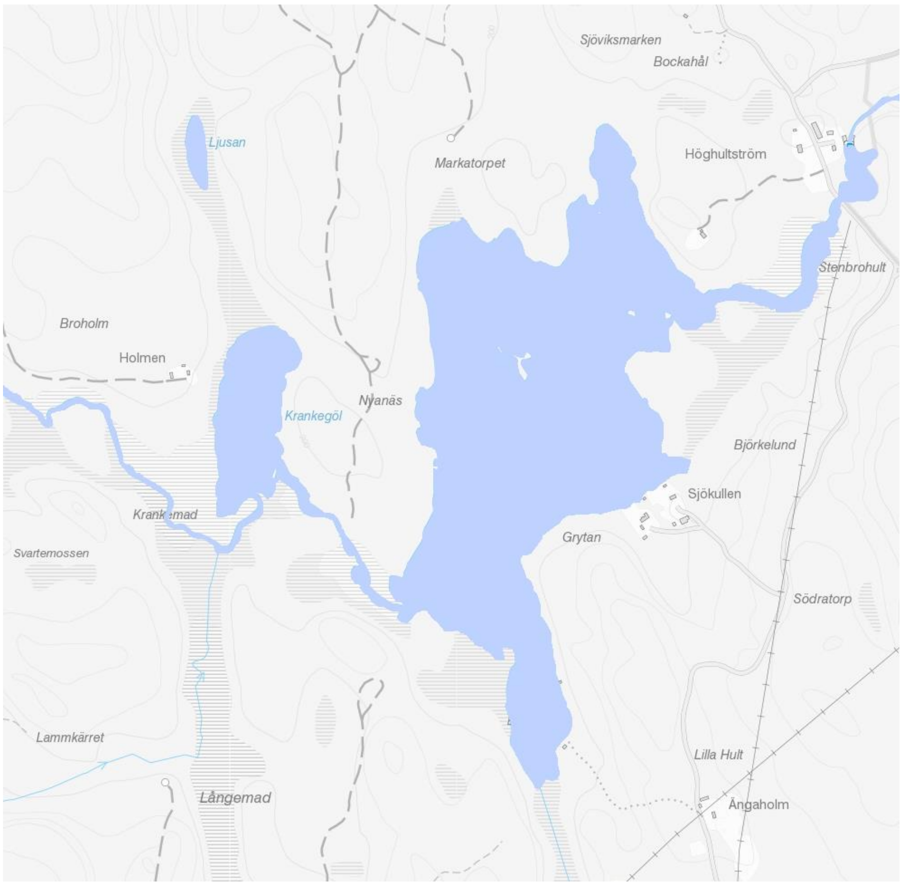

Figure 2: Hydrographic object prior to this project, water areas in blue.

The first step in the delineation process was to establish where a hydrographic object has its inlet and outlet. The GIS operators at Lantmäteriet create hydrographic objects from the database objects with help from SMHI. This is a complex task that sometimes requires additional information like orthophoto and elevation data. The next step is to determine if the water area is standing water or running water.

In the next step the GIS operators at Lantmäteriet create network links in the water areas to connect the polyline streams to each other to establish a flow-direction network (Figure 3). The network links in the water area are required to create a complete flow-direction network representing the flow of the water in the main catchment area.

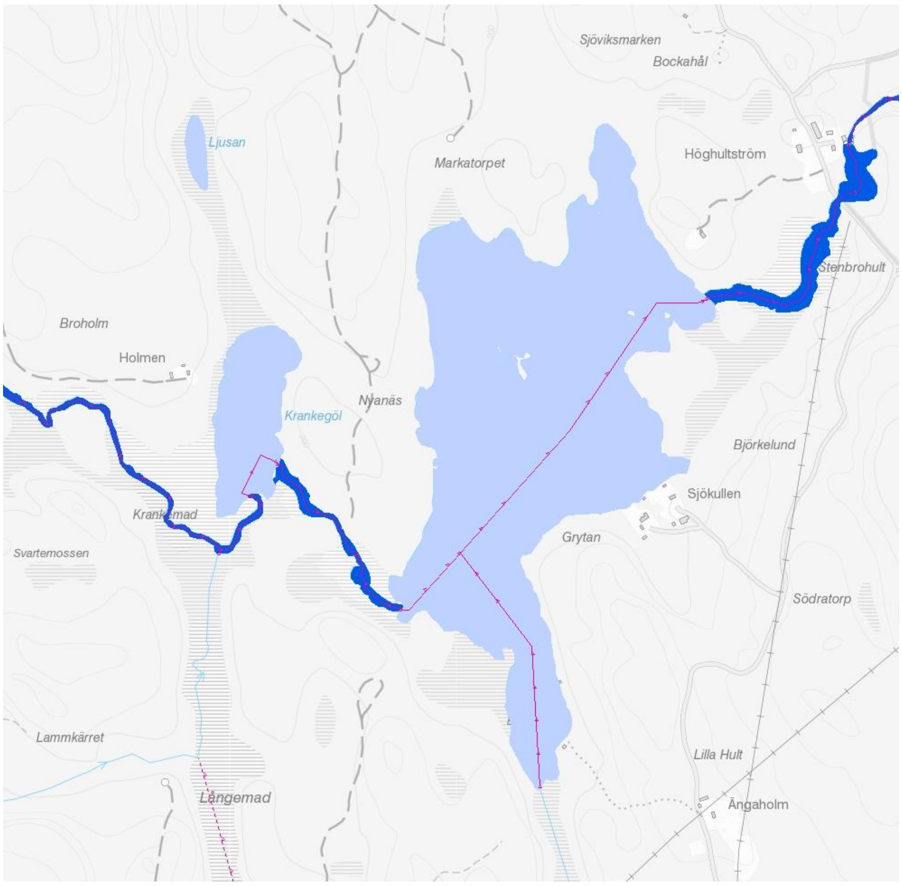

Figure 3: Hydrographic objects and network links in the water areas that represent the flow of the water. The pink lines within the water surface object represent the net flow-direction network.

2.2 Update attributes

The database objects had to be updated with attributes for unique IDs for the hydrographic objects. The following attributes were added to the basic cartographic data:

- Unique identifier for standing and running water.
- Unique identifier for water courses.
- Identifier for the main catchment area.
- Identifier for names of lakes and streams.

These attributes are mapped from the basic cartographic data from Lantmäteriet to the INSPIRE Hydrographic Data Specification (INSPIRE, 2014) and “The Swedish Water Standard” (Swedish Standards Institute, 2015).

2.3 Digitized direction of the polyline streams

One requirement of the project is that the polyline streams should have a digitized direction that matches the flow direction of the water. However the existing basic cartographical data did not have this requirement prior to this project. Some of the polyline streams have the right digitized direction but many of them have the wrong digitized direction (Figure 4).

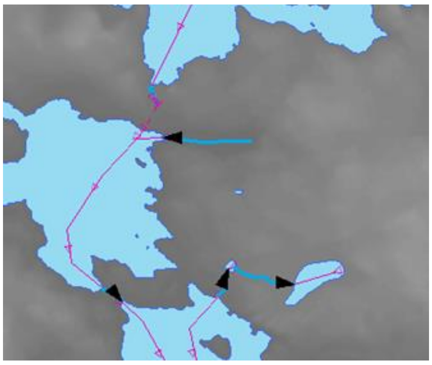

Figure 4: Polyline streams with wrong digitized direction. The black arrows illustrate the digitized direction.

This problem can be solved by manually selecting the lines one by one and flipping the digitized direction according to available elevation data. This method is time consuming and therefore a more rational method was used.

The new method is based on the use of the high resolution elevation data (Lantmäteriet, 2015) produced by Lantmäteriet. The elevation data has a resolution of two by two metres per pixel. The elevation from the elevation model is transmitted to the polyline streams. A large number of polyline streams are selected, the lines having an elevation value at the start point of the polyline stream that is lower than the elevation value at the end point of the polyline stream are selected and flipped at the same time instead of one by one (Figure 5).

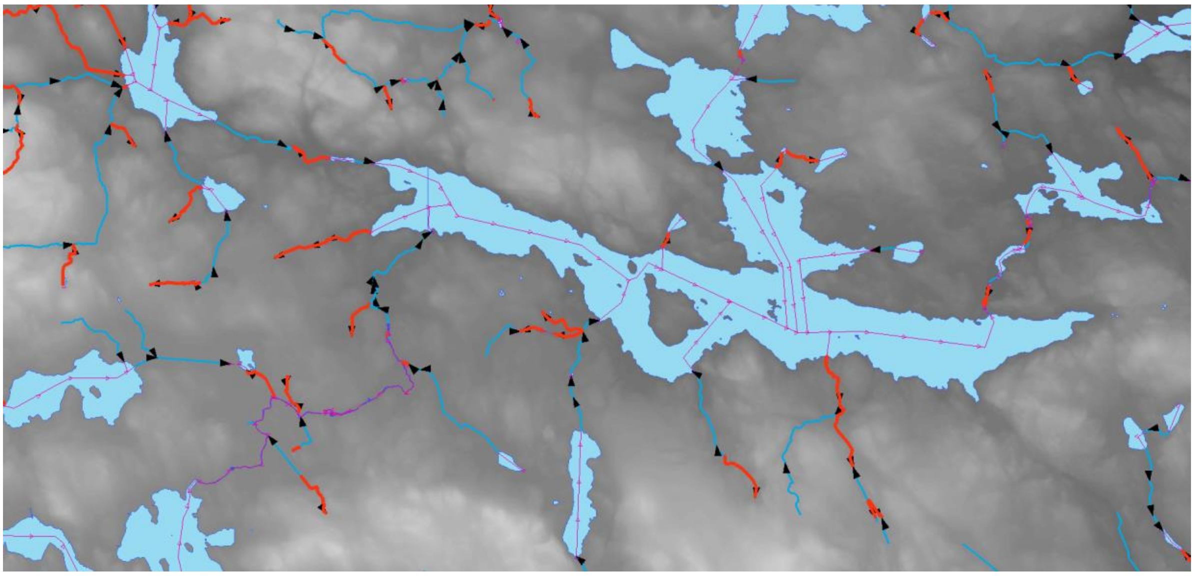

Figure 5: Polyline streams with elevation transmitted from the elevation data. The red polyline streams have a digitized direction that doesn't match the flow direction according to the elevation data.

This method does not find every polyline stream that has the wrong digitized direction. The reason for this is that the geometries of the polyline streams are sometimes wrong and do not match the elevation data. These streams are located by placing a point at the outlet of the catchments area and search upstream that point. If the search stops then the polyline stream has the wrong digitized direction. The digitized direction of the stream is corrected and a new search upstream is performed until all the polylines in the main catchment area have the right flow direction.

3 The usage of the hydrographic data

3.1 Trace upstream and downstream in the flow-direction network

The flow-direction network produced in this project can be used for tracing in the flow-direction network. For example if a user finds pollution in a lake a search can be performed upstream that lake (Figure 6). The same procedure can be performed if the user knows that the pollution come from a specific lake and wants to knows which streams downstream that can be affected (Figure 7).

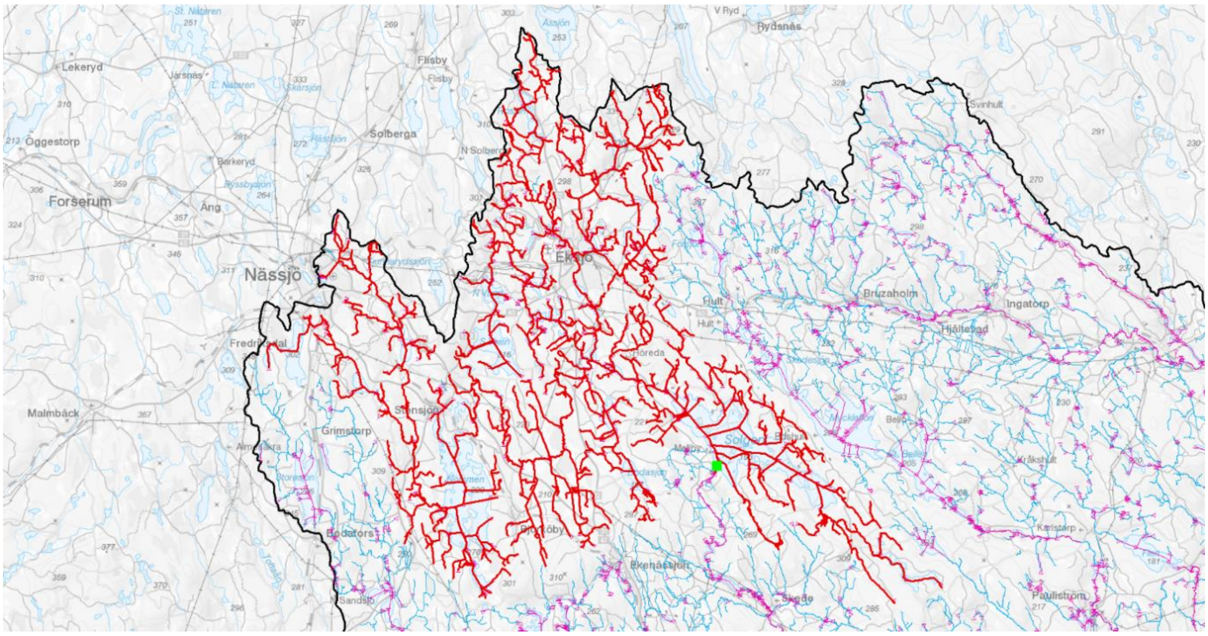

Figure 6: The red lines show the streams upstream the lake, where the green square is the start point for the search. The black line is the water divide for the Emån catchment area.

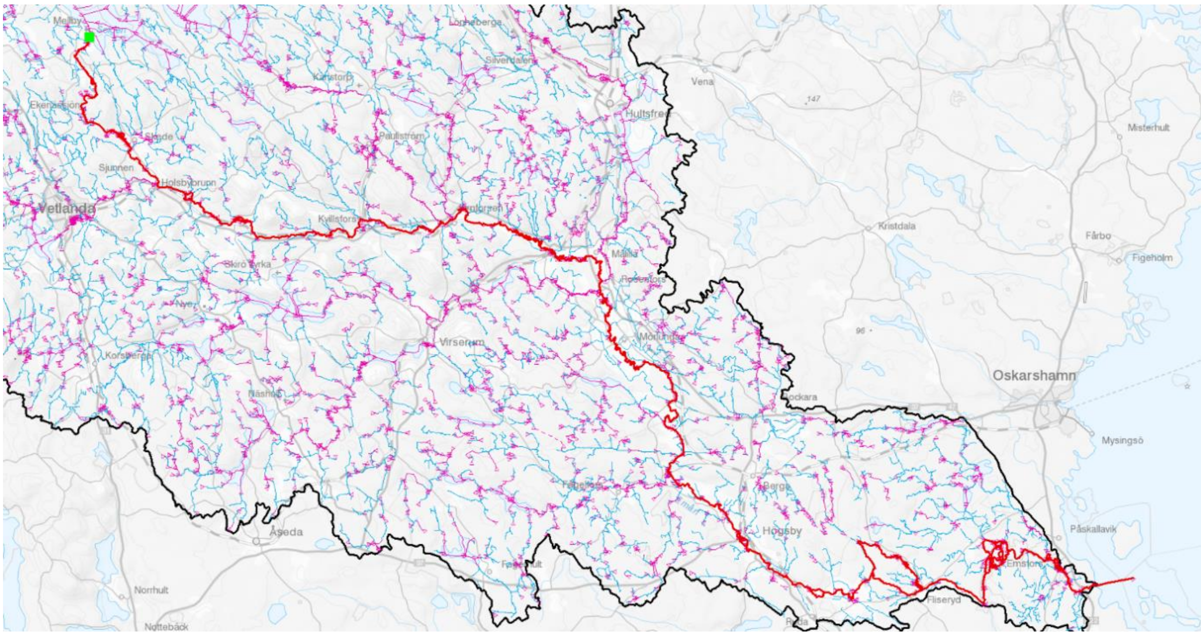

Figure 7: The red lines show streams downstream the lake, the green square is the start point for the search.

3.2 Comparison Between SVAR and ”The Hydrographic Network Project”

The information produced in “The Hydrographic Network Project” is more detailed compared to SVAR. Figure 8 shows the streams in the main catchment area for Emån in SVAR. The streams have a combined length of 1 615 kilometres. Figure 9 shows the streams in the main catchment area Emån which were produced in “The Hydrographic Network Project”. The streams have a combined length of 4 580 kilometres.

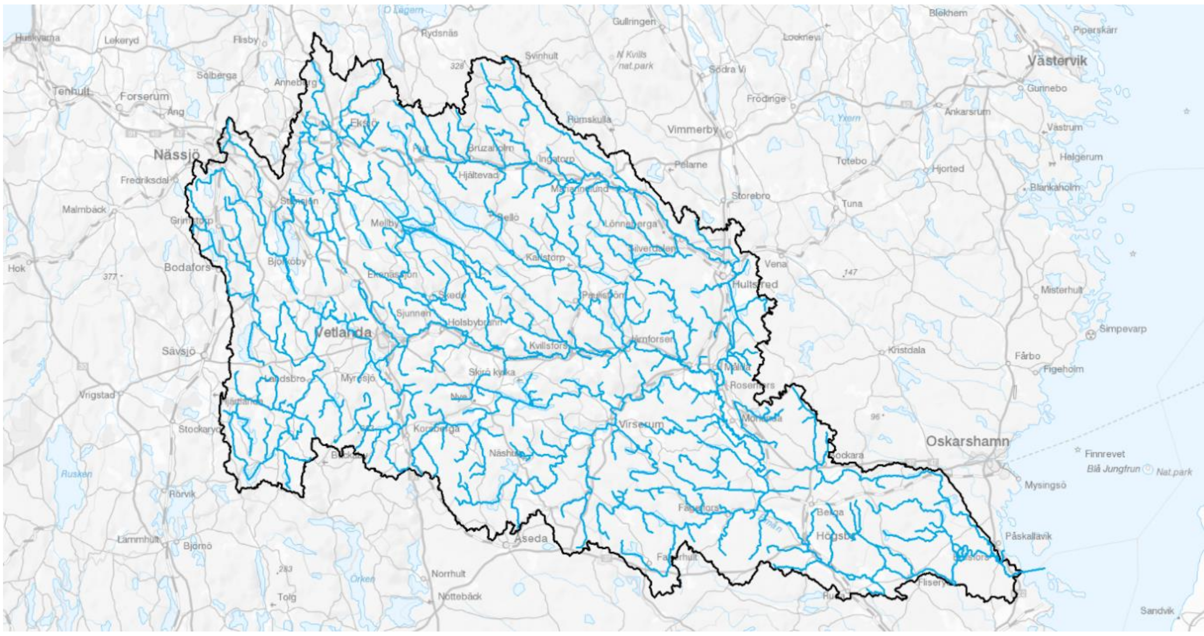

Figure 8: Streams in the Emån catchment area in SVAR.

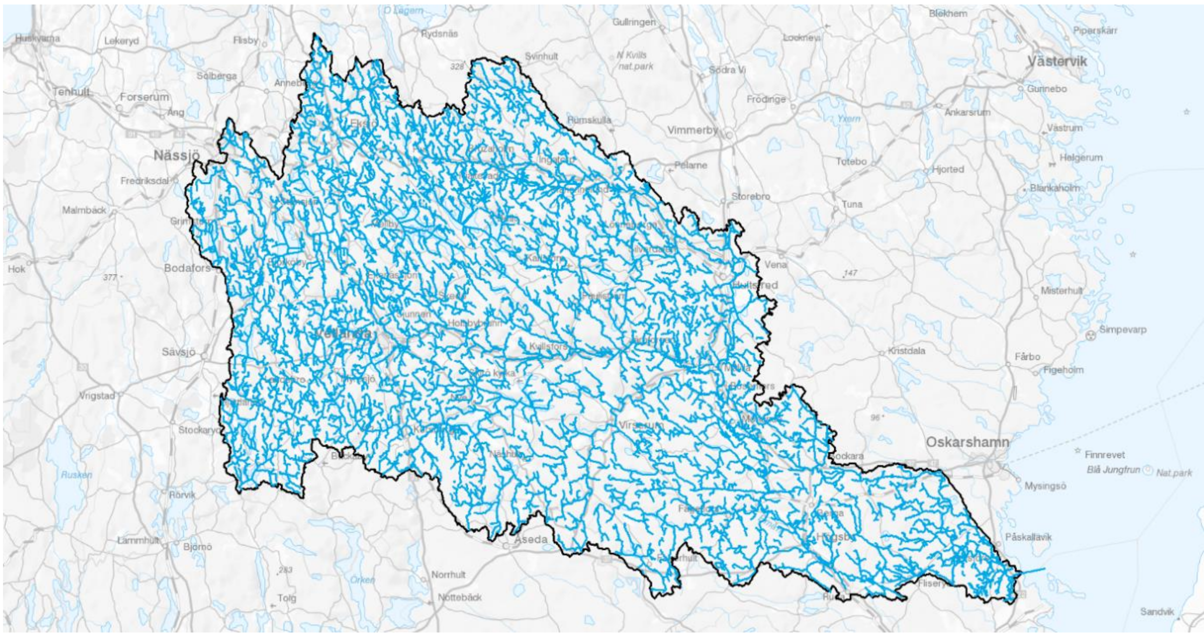

Figure 9: Streams in the Emån catchment area in “The Hydrographic Network Project”.

In the SVAR-database version 2012_2, there are 570 objects in the Emån main catchment with a combined area of 280 square kilometres representing standing and running water (Figure 10). In "The Hydrographic Network Project" there are 2900 objects in the Emån main catchment with a combined area of 280 square kilometres representing standing and running water (Figure 11). The estimated total water surface area has increased by 20 square kilometres and the amount of objects more than doubled in the detailed data from "The Hydrographic Network Project".

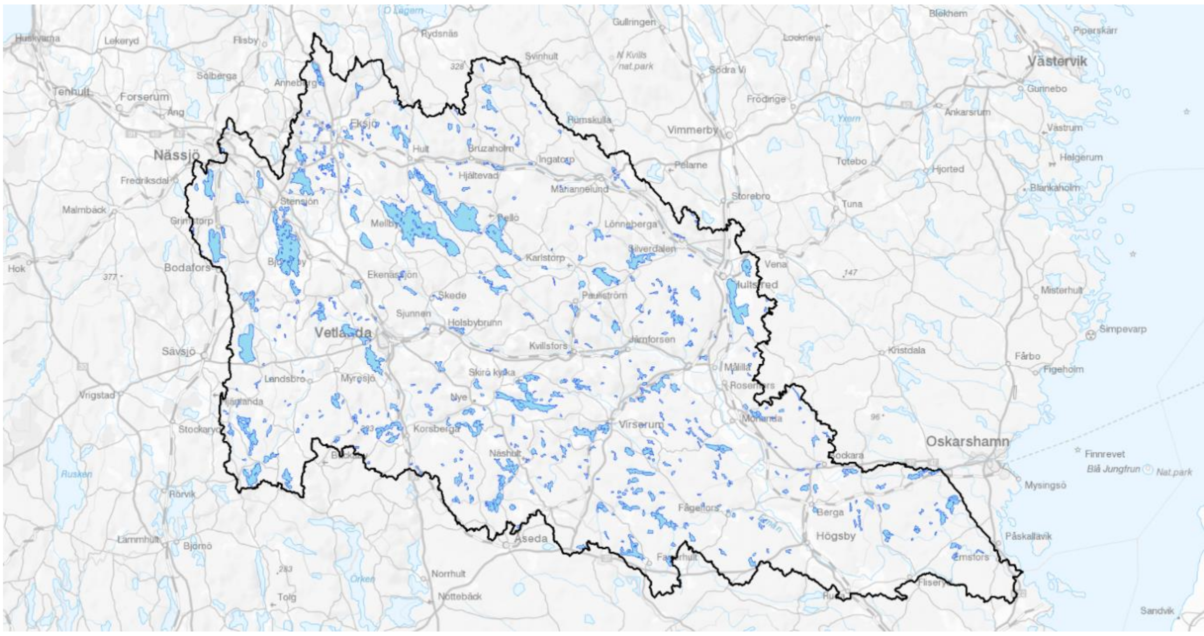

Figure 10: Standing and running water in SVAR.

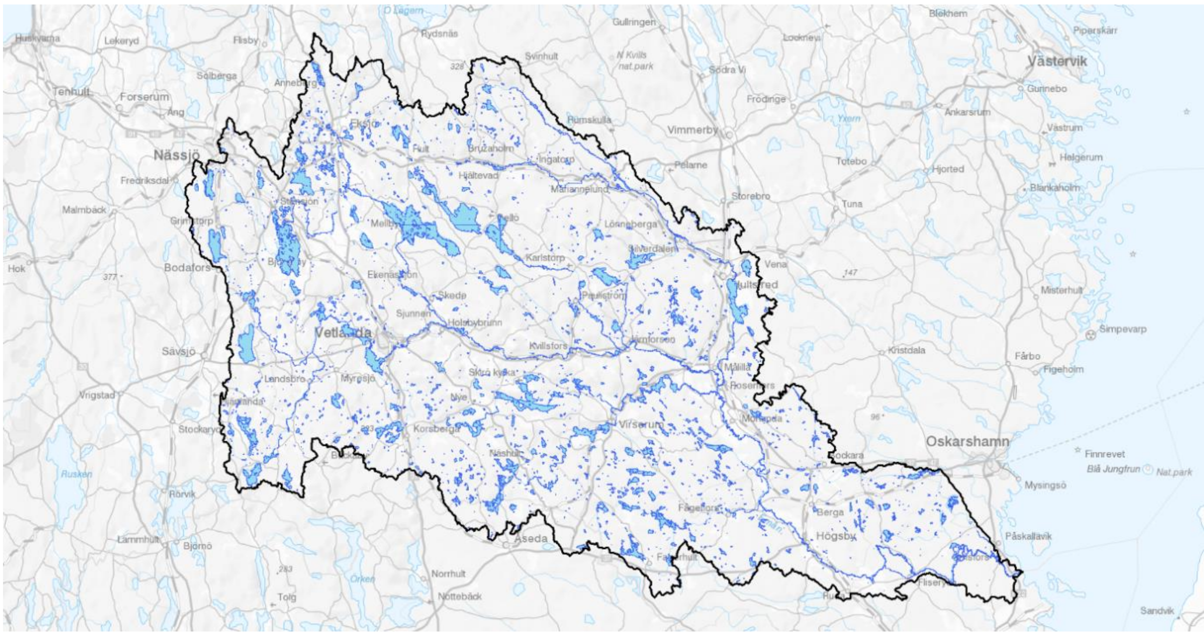

Figure 11: Standing and running water in "The Hydrographic Network Project".

The data in “The Hydrographic Network Project” is more detailed and accurate than the data in SVAR (Figure 12).

Figure 12: The blue single line from SVAR is generalized. The white centreline is data from “The Hydrographic Network Project” that is more accurate and lies within the watercourse in the orthophoto.

3.3 The hydrographic flow-direction network products

Four web services have been produced that meets the requirements of “INSPIRE Hydrographic Data Specification” (INSPIRE, 2014) and “The Swedish Water Standard” (Swedish Standards Institute, 2015). The services provided are:

- Inspire Hydrographic Physical Waters
- Inspire Hydrographic Network
- Swedish water standard Physical Waters
- Swedish water standard Logical Network

These products will cover the whole of Sweden by the end of 2017. Data for download is available per main catchment area. In January 2016 data for 15 main catchment areas were available for customers. The delivery format for the services is Geographic Markup Language, GML (Open Geospatial Consortium, 2012). In the future the hydrographic data within the main catchment areas will be updated and published twice a year.

During 2017 the Geographic Markup Language products will be tested by potential users in Sweden. The production according to the standardized specifications was successful. Applying the standards “INSPIRE Hydrographic Data Specification” and “The Swedish Water Standard” in practice had some challenges where we had to decide whether we wanted to follow the standard or make the data useful for the end users. For example in Inspire the data should only be Swedish data. But if the end user should get sensible data to work with we incorporated foreign data in the hydrographic flow-direction network to get the whole picture of the hydrographic flow (Figure 13).

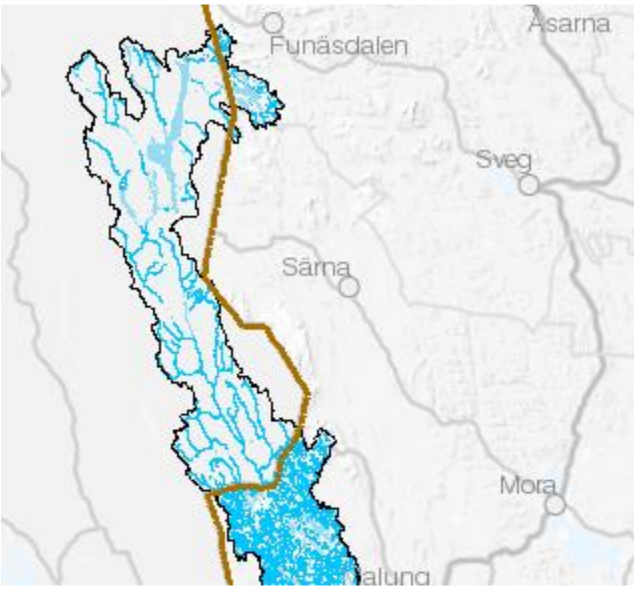

Figure 13: The hydrographic flow-direction network product of Inspire hydrographic data specification over the main catchment area Göta älv including data in Norway. The brown line is the national border between Sweden and Norway.

4. Conclusions

The need for good hydrographic data with a coherent structure is important in many sectors. Good hydrographic data enable assessments within the environmental sector and in climate adaptation work. By creating a hydrographic flow-direction network the social benefit increases. Describe the water flow in a way that can be performed with GIS analysis gives the user opportunities to anticipate and handle the consequences and impact on the environment.

It is essential to understand that the products being produced in this project are components in a hydrographic flow-direction network and serve as a base for different kinds of analysis and it is up to the end users to connect their data to the network. Lantmäteriet and SMHI are government agencies and our government commission is to provide the GIS community with basic cartographic data. The data in "The Hydrographic Network Project" can be used for several environmental and civil protection issues. These usages are not something that Lantmäteriet or SMHI has tested; this is something that the GIS community will have an opportunity to do with the data from "The Hydrographic Network Project".

The basic cartographic data is stored in a dynamic database that is updated on a daily basis by the GIS operators at Lantmäteriet. The hydrographic information is updated with new objects that do not have unique attributes. It is important to locate these new objects and update them with the correct attributes. It is a complicated task for an ordinary GIS operator to update these hydrographic attributes so one of the biggest challenges is to keep these data up to date with high quality. It is desirable that a GIS operator with knowledge of the hydrographic data updates these attributes.

The expectation for this project in the future is to cover the whole of Sweden with this hydrographical data. This will hopefully enhance the usage of the hydrographical data and lead to better environmental and civil decisions. In order to enhance the usage of these data it is important to promote these data for the GIS community. Therefore a roadshow is about to take place in different cities in Sweden where Lantmäteriet and SMHI will lead training and information about the data in the project.

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BIOGRAPHICAL NOTES

Rickard Hallengren has a Degree of Bachelor of Science in the main field Geomatics at University of Gavle, Sweden, received in 2013. He has since then worked as a GIS engineer at Lantmäteriet – the Swedish Mapping, Cadastral and Land Registration Authority.

Håkan Olsson has a Ph.D. in Limnology and is experienced in using hydrographical data in analysis of ecological status and hydromorphological alterations in aquatic environments. He has since 2002 worked as water environmental expert at the Swedish Meteorological and Hydrological Institute.

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