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GEODESY 2018

The Geodesy Strategy of Lantmäteriet

Our mission

is to meet society's need for a uniform, sustainable geodetic infrastructure and to ensure its availability and usage.

This is a translation of "*Lantmäteriets geodesistrategi 2018-2025*" into English. This translated report does only contain text, while the original Swedish version of the report also contains pictures.

Preface

By order of the Swedish government, Lantmäteriet (The Swedish Mapping, Cadastral and Land Registration Authority) is responsible for the national coordination of Swedish geodata, which includes the geodetic infrastructure. This lays the foundation for all other activities by clarifying which coordinate-, height- and gravity systems are to be used in Sweden. Thus, we are responsible for the national geodetic reference networks and work for a uniform national geodetic infrastructure. Geodesy is one of our key activities.

Geodata, that are data with some sort of connection to location, are becoming more and more important for society's development. The current Swedish Geodata Strategy serves as guide for all operators in Sweden when it comes to efficient geodata management. The Geodesy Strategy focuses on the national geodetic infrastructure and thus complements the national Geodata Strategy.

The national geodetic infrastructure and service are of great importance for efficiency in social and economic interactions and has undergone considerable changes in recent decades. The global geodetic infrastructure has become more recognisable due to increasing interest by the United Nations. Not least, we noted this in connection with the adoption of the resolution "Global Geodetic Reference Frames for Sustainable Development" by the UN in February 2015. This resolution reaches far into the national responsibility of each country. Lantmäteriet's geodetic operation must keep pace with the technological development and cooperate internationally within the field of geodesy to continue creating added value.

The main task of Lantmäteriet's Geodetic Infrastructure Department is to provide reliable geodetic reference networks for determination of location and gravity as well as perform geodetic measurements of the dynamic Earth. Such measurements contribute to research about climate change, natural hazards and other events affecting society. Furthermore, our national reference network SWEPOS efficiently supports positioning by modern satellite-based technology.

The Geodesy Strategy at Lantmäteriet extends until the year 2025 and is synchronized with the world around us. It is the successor to our earlier strategic plans "Geodesi 90", "Geodesi 2000" and "Geodesi 2010", all of which have contributed to drive Swedish geodesy forward.

Susanne Ås Sivborg

Director General of Lantmäteriet

The geodetic operation at Lantmäteriet

Lantmäteriet has a comprehensive geodetic operation organized within the Geodetic Infrastructure Department. In addition to maintenance of the national reference networks, there is a comprehensive development, research, advisory and support operation, including running and developing the reference station network SWEPOS. Lantmäteriet coordinates geodetic activities within Sweden and represents Swedish geodesy internationally. Important factors for success are to further develop the cooperation with sister-organisations, end users, service and technique suppliers, and education and research institutes, both nationally and internationally. Directions for the geodetic work at Lantmäteriet can be found in its instruction from the government.

The national Geodesy Strategy envisions an efficient geodetic infrastructure for Swedish geodata. Fundamental geodata are open, up to date, covering the whole country, standardized, of required quality, easy to access as well as efficient to use. The goals of Lantmäteriet for its geodetic operation harmonize well with the national Geodesy Strategy and give the foundation for its implementation.

The geodetic operation in Sweden

Geodetic operation in Sweden includes, apart from the Geodesic Infrastructure Department at Lantmäteriet, also the municipalities of the country, other governmental authorities (especially Sjöfartsverket (the Swedish Maritime Administration) and Trafikverket (the Swedish Transport Administration)), private companies as well as universities. Together we work, each one in its own field, to create a uniform and sustainable geodetic infrastructure and to allow their efficient usage. It is of utmost importance that there is geodetic competence available at all interested parties. However, the sector is limited in size, making a non-prestigious coordination and cooperation important.

The goal of Lantmäteriet is that we should work together, each with its own unique capabilities, to continue developing the unique geodetic infrastructure existing in Sweden. It is also our wish that we maintain the document series Handbok i mät- och kartfrågor (Handbook of surveying and mapping, HMK) together.

The national geodetic infrastructure

The importance of a geodetic infrastructure could be divided into the following three categories:

1. Geodetic reference networks are fundamental for spatial infrastructure by providing the basis for surveying and mapping.
2. A geodetic reference system is realized for accurate measurements and monitoring of global processes such as sea-level change and plate tectonics.

3. An infrastructure is extended in accordance with a very rapid technological development in positioning for industrial and mass-market applications.

The contribution of Lantmäteriet

The foundation of a geodetic infrastructure are reference systems, including their definitions, conventions, realizations and rules for usage. In Sweden, we have SWEREF 99 in plane and three dimensions, RH 2000 in height and RG 2000 for gravity, complemented by models for the geoid and land uplift as well as transformations. The reference systems are realized through reference networks, which can be passive or active. The passive reference networks are represented by markers; as an example, RH 2000 is realized by a comprehensive network of about 50000 fixpoints. The active national reference network for measurements with GNSS (Global Satellite Navigation Systems) is SWEPOS, which through the fundamental stations realizes SWEREF 99. Together with the other stations, this network constitutes, among other things, the national network-RTK service. By distribution of corrections the latter makes real-time positioning in plane, and though usage of a geoid model also in height, possible.

A part of the geodetic infrastructure thus includes the official geoid models and transformations produced by Lantmäteriet, including the models for land uplift. SWEPOS is unique from a global perspective because data are made available on the one hand for production surveying in form of detail measurements, machine control, and precision navigation, and on the other hand for scientific studies of motions of the Earth's crust. SWEPOS consists of two types of stations, where class A are the most stable stations that can be used, for example, for studies of geodynamic motions, while class B are simpler stations established on buildings that are mainly intended to be used in the network RTK service of SWEPOS. The geodetic infrastructure also includes the support of SWEPOS, the distribution of the observation data and post processing, and the digital geodetic archive.

We support a rational usage of modern geodetic infrastructure and surveying by guidance. This is mainly done through an updated website and the HMK-Geodesi document series, which is intended to be revised regularly. The revision includes feedback from readers and users from around the world and a well-established technique and method development.

The maintenance of the geodetic infrastructure includes, in order to secure their sustainability over time, both measurements for upkeeping of passive networks and continuous observations of the active network as well as analyses of these measurements.

The contributions of Swedish partners

The Swedish geodetic infrastructure also includes the globally important fundamental station Onsala Space Observatory as well as the Swedish tide gauge network for sea-level observations.

Onsala Space Observatory

Lantmäteriet has a strong and genuine interest in an extended cooperation with Onsala Space Observatory.

The goal of the observatory is to provide world-class observational resources for the Swedish and international societies. The department of Space, Earth and Environment at Chalmers University of Technology hosts the observatory.

Onsala Space Observatory is equipped with four large radio telescopes, which are used for astronomical observations both as single telescopes and together with other telescopes around the world. The latter technique is called Very Long Baseline Interferometry (VLBI). The VLBI technique is also used for geodetic observations to study the dynamics of the Earth's crust. The observatory also houses other equipment for space geodesy and gravimetry as well as a tide gauge.

The research activities include, among other things, measurements to determine Earth's crustal motions, measurements/studies of the changes in the gravity field caused by, e.g., the land uplift, as well as the Earth rotation parameters and the amount of water vapour in the atmosphere, mainly with the GNSS and VLBI. Onsala is one of the observatories with the longest records of Earth motion measurements. Observations of the movements of the continents (plate tectonics) are of high importance for, for example, the realization of the ITRS (International Terrestrial Reference System).

Observations of water levels

A valuable part of the geodetic infrastructure are water level measurements in Sweden by SMHI (Swedish Meteorological and Hydrological Institute) and Sjöfartsverket. While there are many long, continuous series of such observations in countries around the Baltic Sea, the Swedish time series are among the longest in the world. The official Swedish network for sea-level measurements consists of 55-60 stations today. SMHI has the responsibility for archiving the data from the stations as well as securing their quality (levelling and quality controls) while Sjöfartsverket is responsible for data collection and distribution to SMHI as well as running and maintaining the stations.

Additional Contributions

The Swedish municipalities contribute through their control networks in complementing the geodetic infrastructure in Sweden. These control networks are, and have been, the starting points for the Swedish property division. They have also been a prerequisite for the municipal primary inventory.

Finally, also service providers, through their own stations and services, contribute to the geodetic infrastructure. This is done in close cooperation with Lantmäteriet and its Geodetic Infrastructure Department.

The society's need for geodetic infrastructure

The use of GNSS has increased very rapidly in the last few years and today, it is unthinkable to go back to a situation without positioning systems. A geodetic infrastructure makes important contributions to society by providing the basis for the connection of information with a particular location. When everything is working, the world hardly notices the geodetic infrastructure. A good working geodetic infrastructure has great benefits for the society, with the majority being cost reductions for the users.

With the geodetic infrastructure as a basis, different operators in the society can, each by themselves, collect data, tied to a location, that later can be used, processed, and analysed together. Many different areas are today dependent on this infrastructure, for example:

- Positioning and navigation
- All types of construction work including that of transport infrastructure
- Mapping and sea surveys
- Collection, exchange, usage and securing quality of geodata
- Efficient usage of modern surveying techniques
- Measurements of water levels and motions in the Earth's crust
- Legally secure plan implementation based on documented and over time secure location information
- Laws, decrees, other statutes and verdicts that today contain coordinate and height information.

Much of our Internet usage is directly or indirectly based on a map, an air or a satellite image. Today we take for granted that with an Internet search we get information on where the closest store is. It should be possible to connect the location information to an application based on some sort of map application and thus we can obtain help in finding this place. By georeferencing the records, and our position being determined in the same reference frame, we can get help in reaching the target.

A completely different context where information is connected to a position is in the climate and environmental debate, where sea-level change with time is discussed and where the locations of the observations need to be described. Soon it will be taken for granted that GNSS technology supports a user in seamless navigation between indoor and outdoor environments or as a support system for autonomous vehicles.

Already now, the position of a cellphone can be determined with an accuracy better than one meter and soon the development of autonomous vehicles will put higher demands on the real-time positioning. The geodetic infrastructure is here present without the user being aware of it – if it works!

The geodetic infrastructure is also an important part of the Swedish crisis readiness. Access to uniform coordinate and height systems secures the exchange of geodata between operators acting in crisis situations.

Uniform reference systems

All geodata in Sweden should have their location given in SWEREF 99 and RH 2000. This makes the data exchange easier and more efficient and secures quality. Uniform reference systems are thus fundamental for standardization of geodata. The adoption of uniform reference systems in Swedish municipalities and authorities is ongoing and should be finished within the next years.

The geodetic information in form of our national reference, coordinate, height, and gravity systems is freely available. Costs may only arise from the provision of the services.

It is difficult to assess what uniform reference systems offer in terms of efficiency. Just the fact that the users can be sure to get coordinates in a specific coordinate system and do not need to handle transformations makes the handling more efficient and reduces costs. The risk doing wrong is decreased and the quality is kept!

Uniformity on the European level is today governed by EU directives about geographic environmental information. This information called Inspire has defined that data exchange within Europe should be done in the European reference systems ETRS89 and EVRS. The Swedish reference systems SWEREF 99 and RH 2000 are Swedish realizations of these systems. By using them we thus also use the European systems and follow the European agreement.

GNSS-based applications with low measurement uncertainty

The usage of GNSS in Sweden is steadily growing. The need for the society is large and the future potential is even larger. GNSS usage with low measurement uncertainty will be easier to achieve. Today, it is foremost characterized by network-RTK (Real Time Kinematics), but the access to an accurate GNSS-position for anyone via, for example, cellphone is just some years away. In property registration, machine control, sea transport and agriculture the usage of GNSS makes a big difference.

Rough estimates indicate cost reductions of several hundred million Swedish crowns yearly for the users. This is still underestimating the savings. There is a big potential for the society. Some examples from different sectors and users are presented next.

Infrastructure projects

An active reference network in connection with bigger road and railway constructions has shown to reduce costs and increase efficiency. The entrepreneur has continuous access to the reference network and does not need to visit marked points. The access and reliability are large and leads to much timesaving.

Trafikverket has reported a cost reduction of 32 million Swedish kronor by the infrastructure project BanaVägiVäst but for entrepreneurs the savings are many times higher. This project was the first where Trafikverket used Lantmäteriet's network of fixed reference stations (SWEPOS) as provider for the reference network, and similar services have also been used by other infrastructure projects; Ostlänken – the high-speed railroad from Järna to Linköping – is the latest example of such a project. SWEPOS is again used as infrastructure for the positioning and machine control. The costs for the infrastructure are very low compared to the anticipated cost reduction for Trafikverket as well as their entrepreneurs.

Precision Agriculture

Agriculture is another sector where accurate positioning of machines can contribute to lower fuel consumption, less amount of fertilizer and other actions which together make the operation more efficient and give more profit. In the agriculture sector in Sweden cost reductions and increased profit of a few hundred Swedish kronor per hectare and year has been reported. Given that accurate positioning can be used for a large portion of Sweden's about 3 million hectares of farmland, the value is several hundred million Swedish kronor per year.

Seafaring

A bigger vessel in the Baltic Sea can gain 200000 Swedish kronor in increased profit each harbor visit if the vessel can be loaded so that it runs one decimeter deeper. Hence, extremely large profits are possible with support from better information about the ocean bottom conditions, the vertical position of the vessel and clarity of the reference system. Lantmäteriet participates in a bigger EU-financed project (FAMOS, Finalizing Surveys for the Baltic Motorways of the Sea), about mapping of the depth of the Baltic Sea, and contributes to the work with a common reference surface for the Baltic Sea as well as development of measurement methods.

Weather forecasts

In cooperation with SMHI and Chalmers, Lantmäteriet calculates the amount of water vapour in the atmosphere by using active reference networks in northern Europe. The calculation is based on GNSS observations of nearly 700 fixed reference stations and is used partly for meteorological weather models and partly for research about the change of climate with time.

Property registration

Thanks to GNSS use within property registration, surveys in connection to cadastral procedures are completed faster.

It should be added that it would be almost impossible to survey and mark borders on properties at inaccessible locations in sparsely populated areas of

the country, where marked datum points on the ground are missing, without GNSS technology and SWEPOS services.

Our reference systems – a part of the international systems

Our reference networks are not only linked within the Nordic countries but, more importantly, are also realizations of the European reference systems ETRS89 and EVRS. The three-dimensional reference system, ETRS89, is used in whole Europe and is maintained by the International Association of Geodesy (IAG) Reference Frame Sub-Commission for Europe EUREF and is accessible through EPN (EUREF Permanent Network), a research-driven network of continuous operating GNSS stations with known coordinates in ETRS89. EUREF has worked for common reference systems since the end of the 1980s. Thus, the national systems in Europe today are national representations of the international systems. With the support of EuroGeographics and the environmental directive of the EU, Inspire, this reference system is the backbone of all geographic and geodetic projects within the European territory, at national as well as international level. ETRS89 is, in turn, the European realization of the global reference system.

The national geodetic infrastructure of Sweden is thus a part of the international one. We continuously contribute with geodetic observations which are used for the global reference systems. The contribution from Onsala Space Observatory cannot be emphasized enough here. The operations of Lantmäteriet with data deliveries and analysis of geodetic data is significant for the international geodetic infrastructure, foremost to the European. All international contributions have by tradition been voluntary even if we can note some changes in the direction of formalizations through formal agreements.

The European height system EVRS is also maintained by EUREF. The system is constructed with national leveling and land uplift data to facilitate the exchange of height information within Europe. The development of an international height system is ongoing within the IAG. Like ITRS there is an international height system, IHRS, where H stands for height. IHRS will also be realized through reference networks. More and more international services and projects will deliver heights in an international height system. Important for us will be to develop and publish a relation between RH 2000 and this international height system.

The international work of the Department

Because our national reference system has such a strong international connection, our development is affected by the international one. Thus, international cooperation becomes important, necessary and a natural part of our daily work. Cooperation occurs directly through official tasks, for example representing Sweden in international organizations like the UN, but also by actively contributing to geodesy organizations like IAG.

There is a mutual dependence between national and international reference networks: The national networks are realizations of the international reference systems, which in turn need observations from the national networks. This dependence has been intensified during the last decades, and the development continues in the same direction. The work is based on voluntary participation (self-financing) from all the organizations involved. However, in the last couple of years we have seen a shift towards more formal agreements on UN and EU levels regarding international geodetic infrastructure. This change is expected to continue during the period covered by this Strategy.

Lantmäteriet will continue its commitment to the existing UN-related initiatives to ensure a sustainable geodetic infrastructure, primarily through the United Nations Global Geospatial Information Management Subcommittee on Geodesy (UNGGIM SCoG) as well as United Nations Office for Outer Space Affairs (UNOOSA) and its International Committee on GNSS (ICG). Furthermore, in 2015 the UN adopted the resolution "Global Geodetic Reference Frames for Sustainable Development" and we will contribute to its implementation in Sweden in as large extent as possible.

Lantmäteriet's international involvement will increase in the coming years and largely affect our operations. In addition to the recently mentioned UNGGIM SCoG, the most important cooperation partner is IAG and its subgroup in Europe, EUREF. It is also important to actively participate in other global or regional organizations in order to run an effective geodesy operation and supply skills in Sweden. An example is FIG, the international federation of surveyors.

The ambition for the Nordic cooperation is to raise NKG (Nordic Geodetic Commission) to a platform where our resources can be coordinated in more common projects and to strengthen the role of the Nordic countries in the European geodesy work.

The European Plat Observing System (EPOS) initiative will affect us. EPOS is a long-term plan, initiated and financed on EU level, to simplify access to and exchange of observations for research on European geodynamics. The observations of Lantmäteriet are an important input.

Over the years, Lantmäteriet has had an active and comprehensive service export. Through this Lantmäteriet contributes to develop the geodesy operations in the receiving countries, which is a prerequisite for international projects to be successful.

A dynamic Earth

Ensuring a sustainable national geodetic infrastructure is a challenge because the Earth is not a rigid body but is constantly changing under the influence of external and internal forces. The continental drift and earthquakes are known phenomena. In the Nordic countries we notice the land uplift, which is caused by the last glaciation. The Earth's crust, which was pushed down by the kilometer-thick ice, is on its way upwards to regain its equilibrium state.

The dynamic processes deform the Earth's crust causing the relative location of objects on the ground to change over time. Apart from scientific applications, this knowledge is of great importance in maintaining our national reference systems and for adaption to climate change. The land uplift has its maximum of 10 mm per year in the region around Umeå, while the horizontal component makes Sweden about 1 mm wider per year. After being stable over a long time period, the sea-level rise started to accelerate with the industrialization in the middle of the nineteenth century. Currently, the sea-level change along the Swedish coastlines is estimated to be a few millimeters per year.

The change of the Earth's surface also means that our continental plate moves about 2.5 cm per year towards northeast. All these motions must be handled by defining our reference systems to refer to a specific epoch, i.e. a specific time. The coordinates of the reference systems (and gravity values) correspond to the situation at that time. Future positioning services with more global characteristics will challenge this way of thinking. All coordinates change. We must consider the fact that our position today is not the same as yesterday. Internationally, dynamic reference systems are currently discussed, and this question is actually much bigger than just being a geodetic problem. Geodata will more and more be used in combination with global positioning services and then geodata will be expected to show Sweden as it looks like at a specific time.

The postglacial land uplift in northern Europe, where Sweden is in the central part, is the area in the world with the best conditions to study how the Earth reacts to a former continental ice sheet. We do this with continuous GNSS time series and accurate, repeated gravity measurements. These observations attract the world's attention because they contribute to knowledge on how the Earth works. This knowledge is used in areas with current melting of continental ice, for example Greenland and Antarctica, to separate the effect of the current melting from the effect of the latest ice age and thus be able to make more accurate predictions for future climate-related sea-level changes.

Geodesy and climate research

What is climate actually and what is the difference between weather and climate? The short version is: "Climate is the average weather". In other words, climate data describe variations in the characteristics of the weather over a long time and over a larger area. Geodesy contributes to both weather forecasts and to climate research. Some effects of human influence on climate are higher temperature, faster melting of glaciers and sea-level change. In Sweden the effects of the global sea-level rise are reduced by land uplift. Therefore, accurate knowledge of the land uplift is required to be able to make reliable predictions of the effects of future sea-level rise in sensitive areas along the Swedish coast. Lantmäteriet today has expertise and experience connected to both land uplift and sea-level change. With our competence, together with other expertise nationally and internationally, we are an important player in the Swedish environmental and climate research.

Observations with a connection to a position on the Earth are a prerequisite to be able to conduct effective climate and environmental research. The international reference systems ITRS and IHRS then become common denominators.

GNSS-data from the SWEPOS stations are used to continuously calculate the amount of water vapour in the atmosphere. Water vapour sounds harmless but is one of the strongest greenhouse gases. In precise GNSS applications the influence of water vapour must be corrected, however, for weather forecasts and climate studies the gas is an important input parameter. What is noise for one person is valuable information for another.

GNSS-based positioning services today and tomorrow

During the last couple of years GPS and GLONASS have been modernized and Galileo was developed. The European system Galileo is included in the SWEPOS services since January 2018. Furthermore, the Chinese system BeiDou is being developed and will be available and useful for users in Sweden in a couple of years. New satellite systems make the technique even more useful for positioning in environments with limited visibility towards the satellites, for example in urban environment with high buildings or wooded terrain. The new satellite systems, in combination with new satellite signals from GPS and GLONASS, make positioning faster and more reliable. The combination of several GNSS is a field where much research is conducted and, for instance, Lantmäteriet currently (2018) has its own industrial PhD student.

Increased use

The GNSS technique is increasingly used, not only in detailed and cadastral surveys but also in sectors like machine control, agriculture, and for cable mapping. Thus, the SWEPOS network has been densified over time, swerving as foundation to reach lower measurement uncertainty and redundancy in the system. The great profit for a local user, like a municipality, yields when the technique use is combined with the introduction of the national reference systems and warranty of geodata's quality and way of work. As soon as new satellite signals and systems become available for measurements the surveying possibilities will increase and the measurement uncertainty for height measurements decrease.

Future needs for positioning are increasing and it is obvious that more and more users will be able to get an accurate position much easier. The cellphone industry has all the necessary technology for positioning with centimeter precision. We also note that self-driving cars are already today a part of the society. Accurate determination of the car's position will be demanded, and requirements will be put on us as service provider and as being responsible for the geodetic infrastructure, to ensure accurate and correct positioning.

Lantmäteriet in the front

In order for the GNSS technology to be used to its full extent by the users, Lantmäteriet needs to be one step ahead, preparing SWEPOS for handling new signals, having a close cooperation with the industry, as well as carrying out technology and method development and showing advantages and disadvantages of different methods. Lantmäteriet needs to continue monitoring the surrounding world to be able to take the right decision in a near future.

The geodetic infrastructure needs to be developed to be able to support future positioning, both through Lantmäteriet's own services or by someone else using our infrastructure. In the upcoming period, surveying methods that not directly use the Swedish geodetic infrastructure, like PPP (Precise Point Positioning), will be interesting for more users. Lantmäteriet should soon take a stand on developing an own PPP service for Swedish users. However, it should be pointed out that a technique like PPP demands a dense network of permanent stations to reach the expected performance. PPP gives positions in the current epoch but not primarily in the Swedish reference systems. SWEREF 99 and RH 2000 will still be our national systems in the foreseeable future, however, many users will want to make positioning in the current epoch, that is the way our dynamic Earth looks like at present. Network-RTK is the positioning technique to be used in the upcoming decade, but other techniques will be developed to support positioning, for example via cellphones.

Lantmäteriet should provide data both in form of positioning services for end users and as raw data for redistribution via different providers. The cooperation existing today with users, instrument suppliers, Nordic sister-organizations, and universities, for the running. Development of SWEPOS shall continue. The ambition of Lantmäteriet w.r.t. SWEPOS is that the infrastructure should be able to receive and handle all the available GNSS signals and ensure that these can also be used to develop and improve Lantmäteriet's own services.

In order for Swedish users to be able to handle four different GNSS and the European support system EGNOS, it is required that Lantmäteriet is actively monitoring these different systems. Lantmäteriet continuously needs to monitor their status and quality to support the Swedish use of GNSS.

There are many different providers of accurate positioning services. Through a good cooperation with other providers of network-RTK we have agreed upon the importance of a strong common geodetic infrastructure as a basis, which is that of Lantmäteriet. Thus, other services are based on observations in real-time from Lantmäteriet's national geodetic infrastructure.

Lantmäteriet's coordination role today and tomorrow

Lantmäteriet has received a national coordination responsibility for the geodata field from the government, including the field of geodesy. The development of a successful use of the geodetic infrastructure is the result of

cooperation between the experts of Lantmäteriet and representatives of other governmental authorities, municipalities, private companies, and universities. Different from the situation in many other European countries we have, without governing laws, introduced new reference systems as well as a national reference network, SWEPOS, to the benefit of all users. This has been accomplished thanks to a good cooperation. Part of this is the reference group of SWEPOS with representatives from Lantmäteriet, other authorities, municipalities and private operators.

Impartial and objective advice

The municipalities and governmental agencies have limited competence within surveying technology, and at the same time GNSS technology is easy to access and gives great possibilities. The risk of uncertain results increases when the choice of surveying method is not always understood or prioritized. Impartial and objective advice about surveying technology and methodology can be crucial for the current application. An important document series in this respect is Handbok i mät- och kartfrågor (HMK) where the professional handling of surveying and mapping techniques is described. The purpose is to contribute to a more standardized handling of surveying and mapping matters in Sweden. The administration of these handbooks combined with support regarding control network strategy and technique and methodology development are very important areas. With the support of the HMK-documents we can contribute to that the surveying operation in the state and the municipalities obtains good results of high quality and usefulness. As part of this work, Lantmäteriet has established the HMK-Geodesi reference group with representatives from several different sectors. The role of the group is to support us in managing and developing HMK-Geodesi.

Cooperation group for geodetic infrastructure

As a result of the Swedish Geoprocess, the Samverkansgrupp Geodetisk infrastruktur (cooperation group geodetic infrastructure) has been established with participants from Lantmäteriet and municipalities. In the upcoming years the aim is to develop it to include all geodetic issues for public Sweden.

Focus has been on finalizing the introduction of SWEREF 99 and RH 2000 in the municipalities and at the authorities. Almost all municipalities have introduced SWEREF 99, however, the introduction of RH 2000 will need a few more years. The municipalities need support regarding how to work efficient in the future when it comes to maintenance of control networks, surveying technique and quality of the municipal control networks. The introduction of new reference systems, a densified SWEPOS together with a greater usage of network-RTK show that the municipalities and Lantmäteriet need to continue their cooperation regarding surveying strategies. The task of Lantmäteriet is to give the municipalities the support they need to actively take decisions in the preparation of a municipal surveying strategy, describing their long-term maintenance of coordinate and height systems including the control networks. Likewise, this also applies to Lantmäteriet’s own operation

and in particular to the maintenance of the real property register. What position quality do we need for border points? This question is already an important topic and will be even more challenging if we go towards a coordinate-based property registration.

The FAMOS project

In the last couple of years questions after a common reference system have become more important, with the Baltic Sea as a good example. The responsibility of Lantmäteriet for the national geodetic infrastructure is not only limited to land but includes sea and air as well. Together with Sjöfartsverket, Lantmäteriet is involved in the project FAMOS. Thus, the Baltic Sea is currently a natural part of our daily work. The focus is obtaining a reference surface for depth information coinciding with the zero level of RH 2000. Practically, this is accomplished by an improved geoid model (through additional gravity measurements) and GNSS methodology. We predict that the cooperation between Lantmäteriet, Sjöfartsverket and other authorities for questions involving the Baltic Sea will increase in the upcoming years.

We believe that the need for advice and support in different forms and via media will be at least as large in the future. The R&D operation together with practical experience are prerequisites for Lantmäteriet to continue being active in this area.

Geodesy research at Lantmäteriet

According to Lantmäteriet's instruction, research in the field of geodesy shall be conducted. The geodetic research operation of Lantmäteriet has its foundations in the maintenance, usage and sustainability over time of the reference systems as well as techniques and methods for positioning. Our research deals with, for instance, land uplift and other geophysical effects. It is orientated towards developing models for the changes of the Earth's crust and its effect on reference systems and our geodetic observations. The change in gravity, together with other observations, can describe the change of the Earth's surface and thus contribute to understanding how the Earth works. A close research cooperation established with the Royal Institute of Technology, Chalmers University of Technology, University of Gävle, University West and RISE (Research Institutes of Sweden AB) is an important part of the national responsibility held by Lantmäteriet.

Positioning and navigation are today a given for every user of a "smartphone". The technology development continues, and the possibilities are far from reaching its limitations. In the field of geodesy this development is characterized by key values like less, more, simple, faster, more accurate, more flexible, cheaper, and more integrated. The possibility for positioning at centimeter-level will be more easily accessible even for everyone. This also means that many of the current users of network-RTK will be using substantially cheaper services via the mobile operators. Accurate positioning via mobile units based on technique using GNSS will put demands on quality

control, traceability and handling of reference systems. The development and modernization of GNSS will make new surveying methods possible. We must observe the cutting edge of this development to be able to counsel the users. The reference systems on land, at sea and in the air will be seamless in a completely other way, which put demands on securing their availability and sustainability. We also think that the contribution from geodesy to the environmental and climate research will be clarified and strengthened.

Lantmäteriet will continue to conduct active research connected to our field of responsibility. Examples of planned research until the year 2025 are:

- Continue to conduct R&D regarding theories and methods for geoid modelling as well as phenomena affecting the geoid like melting of ice and ocean volume changes and their influence on the shape of the sea surface
- Officially get national responsibility for gravity measurements
- Continue to conduct R&D regarding geophysical-based models for land uplift
- Further development of theories and methods for implementing deformation models of the Earth's crust and models of gravity change
- Make R&D-contributions to decrease the uncertainty in our geodetic infrastructure
- Continue to conduct R&D about applied GNSS – for instance regarding the effect of more satellite systems, to increase the availability and decrease the measurement uncertainty
- Be active in the method development for most effective use of new technology and new combinations of modern and traditional techniques
- Participate in R&D dealing with space weather to secure lower measurement uncertainty when measuring with network-RTK
- Develop methods to denote the quality and reliability of the surveying systems, in order to help the users to have control over their surveying processes
- Continuously train one or two own industrial PhD students.

Our key activities

Lantmäteriet shall continuously:

- Ensure that the geodetic infrastructure, including competence, is of the right quality and extent for foreseeable needs
- Maintain and update the geodetic reference systems SWEREF 99, RH 2000 and RG 2000 on land, at sea and in the air
- Make sure that Sweden has a geoid model corresponding to the user needs
- Conduct decisive absolute gravity measurements
- Continue the densification of SWEPOS in accordance to the established plan, to secure the availability and develop the use of GNSS in real-time
- Ensure an infrastructure that makes development and modernization of the GNSS usage possible
- Carry out R&D-work for the maintenance and sustainability over time for the reference systems as well as method and technique development for positioning
- Actively follow and support the development in the field of GNSS as well as in the geodesy field in general
- Contribute to the international geodetic cooperation through data deliveries and active participation in working groups
- Actively participate and when required initiate standardization work within the geodetic field
- Actively participate in internal and external projects, like FAMOS and within NKG
- Have an active support and advisory operation
- Have a dialog with the municipalities to understand their needs
- Maintain and further develop HMK-Geodesi
- Develop methos and conduct external monitoring to support, e.g., the revisions of HMK-Geodesi
- Monitor the development of IHRF and asses the need of a transformation between IHRF and RH 2000
- In the period 2020-2024, work on the review of the boundary between Sweden and Norway
- Maintain and develop the courses offered within the field of geodesy.

In 2018 we need to focus on:

- Take decisions on new maintenance plans for RH 2000, consolidation stations, RG 2000 and tide gauges
- Clarify our cooperation with Onsala Space Observatory
- Take a decision on our strategy for contributions from SWEPOS to international interests like the Global Sea Level Observing System (GLOSS), EPOS and others
- Develop directives regarding the contribution to climate research from the Geodetic Infrastructure Department

- Make sure that a transformation to the current ITRF-epoch is continuously available
- Develop the work for the reference group of HMK
- Develop support for GNSS measurements with the Galileo system
- Evaluate the GPS signals L2C and L5

In 2019 we need to focus on:

- Conduct new maintenance plans for our passive and active national networks
- Establish an industrial PhD student working with VLBI at Chalmers University of Technology and an industrial PhD student working with geoid modelling at the Royal Institute of Technology
- Take a decision concerning the direction w.r.t. InSAR and the geodetic infrastructure in Sweden in the perspective that EU-GMS (Ground Motion Service) will be implemented. A pre-study will be carried out highlighting advantages, disadvantages, competence, costs etc.
- Make a revision of HMK-Geodesi
- Publish a report about future positioning services based on SWEPOS and uniform reference systems
- Investigate the users need and form for procession certification
- Make sure that Lantmäteriet becomes responsible for gravity in Sweden, including the national measurement area
- Develop our knowledge about models regarding ice history.

In 2020 we need to focus on:

- Take a decision on the direction regarding dynamic and semi-dynamic reference systems
- That all public clients and trustees of geodata should have introduced SWEREF 99 and RH 2000
- Publish a relation between RH 2000 and IHRF XX
- Have established a global GNSS analysis as support for EPN and GNSS analysis with NKG
- Develop support for GNSS measurements with the Beidou system.

In 2021 we need to focus on:

- Conduct a pre-study about mass-market applications connected to SWEPOS
- Evaluate the sensitivity of SWEPOS to external signal disturbances and how one can use SWEPOS to monitor disturbances on GNSS
- Make a study about densification of the sparser areas of the SWEPOS network, to obtain more redundancy
- Establish a model for financing the geodesic infrastructure at the Onsala Space Observatory
- Complete the work with the update of SWEREF99
- Make a management plan for RG 2000

- Evaluate transponders and corner reflectors for SAR/InSAR
- Participate in the development of a Swedish InSAR-service

In 2022 we need to focus on:

- Implement BeiDou in the SWEPOS network-RTK service
- Complement the geodetic infrastructure with signals/reflectors for SA/InSAR
- Investigate how to provide information about integrity to the SWEPOS users
- Evaluate the possibility of a PPP-service based on SWEPOS
- Participate in the calculation of a new geoid model for the Baltic Sea which will serve as a common reference surface for charts in Baltic Sea Chart Datum 2000 (BSCD2000)
- Investigate the possibilities of simple RTK-receivers

In 2023 we need to focus on:

- Prepare SWEPOS for supporting precise GNSS-applications for the mass-market
- Implement information about the reference frame in the data streams of the SWEPOS real-time services
- Modernize the SWEPOS postprocessing calculation service
- Update the transformations between SWEREF99 and ITRF2020 as well as RH 2000 and IHRFXX
- Established global GNSS-analysis as a support for EPN and GNSS-analysis conducted within the NKG
- Establish national metrological laboratory for gravity in Sweden

In 2024 we need to focus on:

- Start a densification of the sparser parts of the SWEPOS network, to improve the redundancy
- Work with a new Nordic/Baltic land uplift model
- Participate in the creation of a new Nordic/Baltic geoid model
- Finish the review of the boundary between Sweden and Norway

The situation 2025

Reference systems and infrastructure

YEAR 2025:

- Sweden has a sustainable, unbounded, coherent geodetic infrastructure on land, in the air and at sea with uniform, globally adapted reference systems
- SWEREF 99, RH 2000 and RG 2000 are the national reference systems for position, height and gravity and are used by all municipalities and authorities with Geodata relation

- Lantmäteriet has a national geodetic infrastructure including own GNSS-based services based on which other service providers can build their own services
- With the support of transformations and models, it is possible to effectively work in ITRF and IHRF at the current epoch as well as to access our geodata in these frames at the current epoch
- We have ensured the sustainability of our reference systems by continuous time series analysis and modelling of land uplift and other geodynamic effects
- We have ensured the lifespan of SWEREF 99, for instance by continuously developing the active reference network
- We have ensured the survival of RH 2000 through active maintenance of the passive reference network
- We have a seamless geoid model of high and known quality both on land and at sea.

The users

YEAR 2025:

- GNSS is the dominant technique and the combination of many different surveying techniques has been highly developed
- Accurate positioning and navigation in real-time have obtained an increased and widened usage and are a given both indoors and outdoors for everybody
- Everybody has access to the Swedish reference systems – within seconds, everywhere and all the time, without being aware of it
- We have ensured the access to our reference systems and our information through services, in form of positioning and archive services
- Our national geodetic infrastructure allows services for the mass market in form of positioning on the centimeter level in real-time
- There is a mass market for systems based on accurate GNSS integrated with other sensors, for example in autonomous vehicles
- The complexity of construction, surveying and property registration has accelerated, and everything is handled in three dimensions.

The role and status of Lantmäteriet

YEAR 2025:

- Lantmäteriet continues to conduct research in the field of geodesy
- Lantmäteriet has strengthened its coordination role by focusing also on supply of competence and being an innovation center
- Lantmäteriet has continued responsibility to ensure a national geodetic infrastructure
- Lantmäteriet actively participates in building the international geodetic infrastructure to ensure our national reference systems and to contribute

to the realization of the UN-resolution on “Global Geodetic Reference Frame for Sustainable Development”

- Lantmäteriet has an active coordination and advisory role on geodetic surveying techniques and reference systems, both nationally and internationally
- Lantmäteriet has strengthened its role both nationally and internationally, in the fields of geodynamics as well as environmental and climate research