On the Transition to the New Swedish Height System RH 2000

**Christina KEMPE, Linda ALM, Fredrik DAHLSTRÖM,
Lars E ENGBERG and Jakob JANSSON, Sweden**

Key words: Reference frames, levelling network, reference frame implementation

SUMMARY

Sweden consists of some 300 municipalities, all of them more or less having used their own unique height system. A new national height system, RH 2000, was implemented in 2005 by Lantmäteriet, the Swedish mapping, cadastral and land registry authority. Most of the municipalities are now changing to use the national height system also locally, to make more efficient use of GNSS in their own organization and to harmonize their data with the existing regional and national data. In this process, Lantmäteriet provides re-adjustment of the old local levelling networks in the new national RH 2000 frame, possibly with some supplementary measurements accomplished by the municipality. The article describes this transition process, seen in the light of the municipalities being self-governing to a large extent and Lantmäteriet, the national geodesy authority, only having an advisory role.

The preferred method results in RH 2000 heights for the benchmarks in the local height networks and a translation parameter for transformation of other height data. Except from this, the analysis of the local height network gives a good knowledge of the existing deficiencies. When the transition to RH 2000 is completed, more advantages are attained, such as using the same height reference frame in all parts of the municipality, a decreased risk of mixing different height systems and that data in a well-known high quality reference frame will be more attractive to external users.
The municipality will also have the opportunity to use GNSS technology for a wider range of applications where height determination is required.

On the Transition to the New Swedish Height System RH 2000

Christina KEMPE, Linda ALM, Fredrik DAHLSTRÖM,
Lars E ENGBERG and Jakob JANSSON, Sweden

1. INTRODUCTION

In Sweden there are some 300 municipalities, all of them using their own, more or less unique, height system. In order to harmonize local, regional and national data the local authorities are urgently requested to change from their old local to the new national height system.

2. BACKGROUND

2.1 Local height networks versus national height networks

The first height control networks for municipalities were established in the beginning of the last century. Most of them were in a very weak way connected to the national network prevailing at that time in Sweden; see section 2.2. Since then height control networks have been established in almost every urban area. Nowadays, we have 290 local authorities and almost every municipality has their own height control network and in some areas, there is more than one network because a fusion of two or more municipalities into one has taken place.

In Sweden, the responsibility for geodetic control networks is divided between the local authorities and Lantmäteriet, the Swedish mapping, cadastral and land registry authority. The main cause for this is different aims of the networks. The responsibility for Lantmäteriet has been to establish ground control for official mapping in small scales. The local authorities establish control networks for urban development.

Lantmäteriet is the national geodetic authority but has no power against municipalities and other authorities. Lantmäteriet cannot do anything else than give proposals and advice to the local authorities concerning their reference systems. Lantmäteriet is responsible for all national geodetic networks and the local authorities are responsible for their own networks.

The new national height system RH 2000 was introduced in 2005, to replace the preceding RH 70. The new system is more homogeneous than RH 70 and well adapted to Sweden's neighbouring countries and the European height system (Svensson et al., 2006).

2.2 Densification of earlier precise levelling networks

The first precise levelling in Sweden was performed in 1886-1905, resulting in the height system RH 00. The second precise levelling was carried out in 1951-1967, resulting in the height system RH 70; see Figure 1.

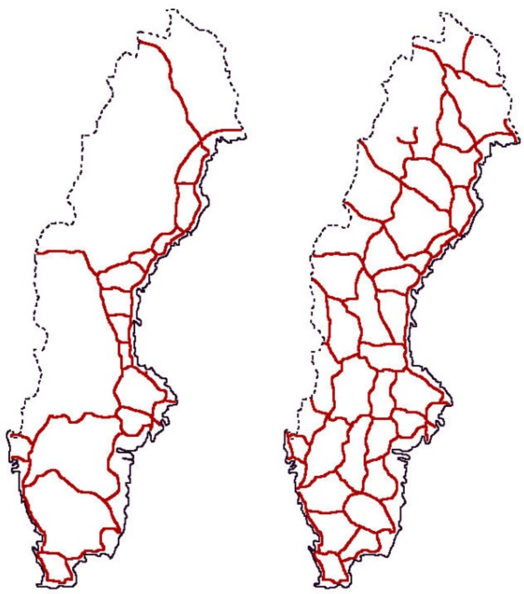

Figure 1: Levelling lines of the first (on the left hand side) and second (on the right hand side) precise levelling of Sweden.

These networks were not sufficiently dense and the coverage of the country was poor. When height control was needed for national small-scale mapping, these networks were densified by primary and secondary levelling lines of much lower accuracy.

The accuracy of the densification lines was sufficient for its purposes, but far lower than required for precise levelling or connection of local height networks. But since the benchmarks of these densification lines were the only points with heights available, they were nevertheless used for connection of local height networks. Depending on e.g. these poor connecting points, many local height networks are distorted.

2.3 The third precise levelling of Sweden

The fieldwork of the third precise levelling of Sweden – the base of the new national height system RH 2000 – lasted from 1979 until 2001. To understand why a new levelling was needed, it is illustrative to consider the earlier precise levellings; see section 2.2. The demands from the users for better coverage and accessibility had increased and the second levelling was mainly located along railroads, which made the benchmarks hard to reach. In course of time many benchmarks had also been destroyed. The aim of new third precise levelling was therefore to create a network covering the whole country, dense enough to allow all the local users to connect their measurements to easily accessible benchmarks; see Figure 2. (Svensson et al., 2006)

Figure 2: Levelling lines of the third precise levelling of Sweden.

2.4 Work on national and local level

The reference system used nationally must meet several criteria. It must be modern in such a way that positioning using modern technologies should be possible without destroying the high accuracy that modern instruments can achieve. The reference frame should make it possible to easily and efficiently exchange data with neighbouring countries as well as users within the country, which means that the connections to other reference frames must be well known or we should work in the same reference frame.

Locally, we nowadays have several hundreds of different geodetic networks. Lantmäteriet recommends the local authorities to tie their local networks to the national reference frame or – preferably – to use the national reference frame.

To help municipalities and other users, Lantmäteriet has developed routines to do the transition from old, distorted height systems to the new national height system RH 2000. When the transition is completed and the distortions of the local networks have been analysed, the municipality will have the opportunity to use GNSS technology and the national geoid model SWEN08_RH2000 (Ågren, 2009) for a wider range of applications where height determination is required.

The corresponding process of exchanging local plane co-ordinate systems for the new national reference frame SWEREF 99 is described in Kempe et al. (2006).

3. MEASURES TO TAKE, IN ORDER TO CHANGE HEIGHT SYSTEM IN A MUNICIPALITY

There are a few different methods that can be suitable for the transition to RH 2000 in a municipality; cf. the following sections. Lantmäteriet recommends re-adjustment of the old local levelling networks in the new national RH 2000 frame, possibly with some supplementary measurements accomplished by the municipality.

Irrespective of the method chosen, it is important to carefully inform all users – within the organization as well as external users – of the imminent transition to the new height system. Another essential action is to make a practice of labelling all height information with the reference frame used. It is not possible to see from a single height value, which height system it stems from. That is one of the reasons why the information activities are crucial.

3.1 Re-adjustment of the local height networks

The municipalities compile and deliver their old levelling data to Lantmäteriet, which can provide adjustment assistance as well as analysis of the networks.

The levelling data of the local height networks are normally of high accuracy, also in older networks. However, the heights of the benchmarks in the densified national networks were often of poor quality, thereby causing distortions of the local networks when used for connection to the national height network. In some cases, the poor connections forced the municipalities to use only one benchmark of the national network, to avoid distortion of the local network. This also leads to the fact that the level of different local height networks can typically differ by a few centimetres up to more than a decimetre, even though they are said to be established in the same reference frame; see Figure 3.

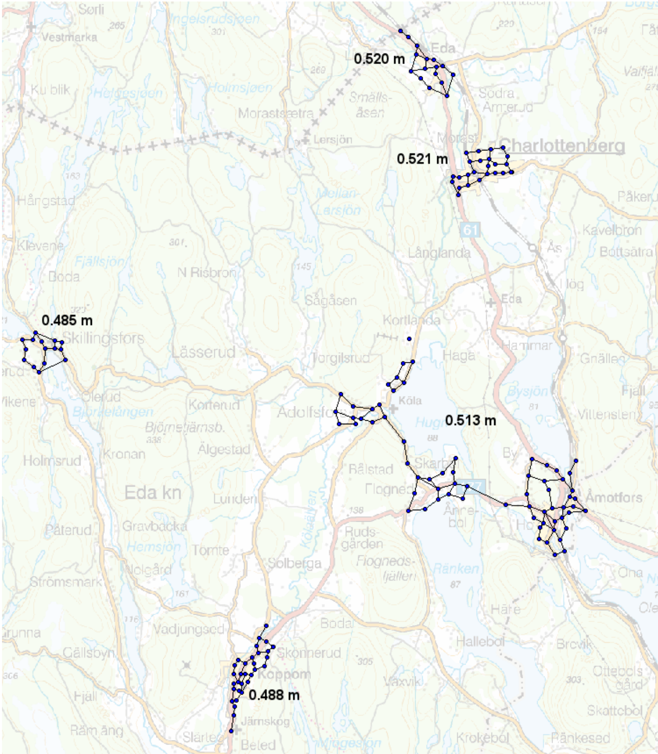

Figure 3: *The system difference to RH 2000 for the villages in Eda municipality. The local height reference frame in all of the villages is said to be the same.*

To re-adjust the local height networks, the old levelling data are connected to benchmarks with RH 2000 heights from the third precise levelling. This means that the municipality must be able to list their levelling data digitally, and deliver them to Lantmäteriet in a given format. Except from the levelling data, local heights and co-ordinates of the local benchmarks are required.

The data are stored in a database, and the network is drawn on a map to facilitate the search for gross errors; see Figure 4.

The next step is to find out which benchmarks of the local network are common with third precise levelling benchmarks. There are often already a number of common benchmarks, since local benchmarks to a large extent were used in the third precise levelling network. If supplementary connection points are needed, the municipality is recommended to perform these, in general short, levellings to obtain further connection points.

When the number and distribution of connection points is satisfactory, and the errors of the network have been evaluated and eliminated to an adequate level, the network is re-adjusted, using the RH 2000 heights from the third precise levelling as fixed.

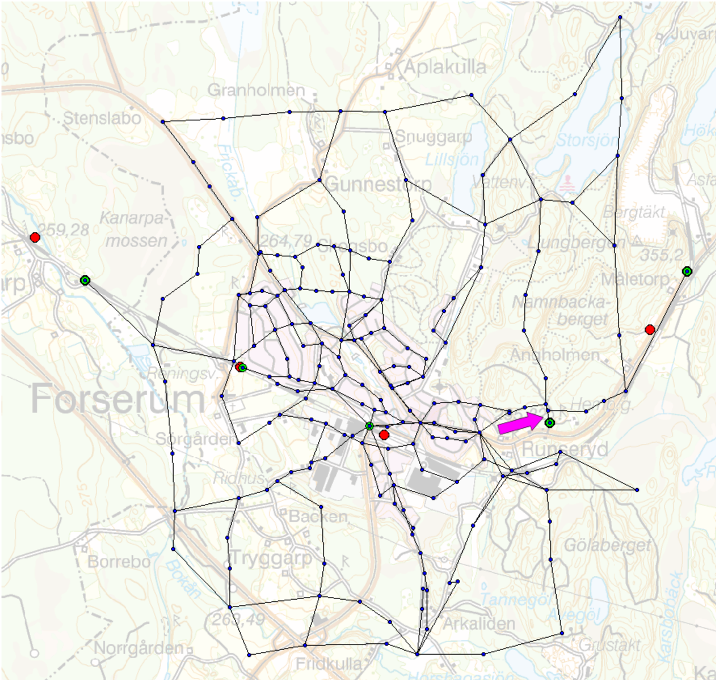

***Figure 4:** A local height network, with benchmarks (blue). The third precise levelling benchmarks are red and the benchmarks of the local network that are common with third precise levelling benchmarks are green. One supplementary connecting levelling was done (see arrow).*

The new RH 2000 heights of the local network are compared to the old local heights. Hereby a clear view of the distortions of the local height system is obtained. An average system difference – a translation – between RH 2000 and the local system can also be computed, for transformation of other height data than the high quality benchmarks.

Depending on the magnitude of the distortions, one system difference can be used for the whole network or municipality. If the distortions are large, it may be suitable to split the area into separate parts, for each of which a translation is computed; see Figure 5.

Using one or more translations is the most robust method for transformation of data. Other methods for transformation of data are utilized only in exceptional cases. To use e.g. an inclined plane transformation or a rubber-sheeting algorithm, plane co-ordinates are required for the objects to be transformed.

Finally, Lantmäteriet delivers the database, maps, adjustment – input data as well as results – and the height comparison with the resulting translation parameters, together with a written report.

The replacement of old local heights of the benchmarks, by the RH 2000 height from the adjustment, and transformation of other height data to RH 2000 is then done by the municipality or their consultant, e.g. the GIS system provider.

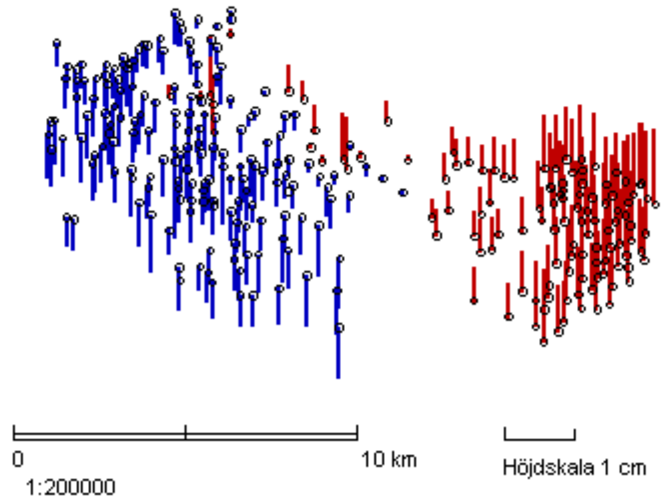

***Figure 5:** Initially, one translation was computed for this local network as shown in the figure. The vectors show the deviation of each point from the average system difference. When the distortions of the local height system became clear, two different translations were computed – one for the western part and one for the eastern part.*

3.2 Alternative methods

Of course there are cases where the levelling data cannot be recovered, or where the third precise levelling lines are too distant. Then there are a few alternative methods to be used, even though the method described in section 3.1 is the most favourable in the long-term view.

When the local levelling data cannot be recovered but there is a third precise levelling line available, a number of loops with local benchmarks can be levelled from third precise levelling benchmarks. Doing so will provide RH 2000 for these local benchmarks, but other benchmarks in local height network will not get RH 2000 heights. The translation – for transformation of other height data – that can be obtained by this operation will be uncertain due to the weak basis.

If the distance from the local height network to a third precise levelling line is too distant to justify connection by levelling, a number of the local benchmarks can be surveyed by GNSS technology, using the national geoid model to obtain RH 2000 heights for the benchmarks. The absolute RH 2000 position will be determined by the GNSS surveys, by applying the average system difference between the local height system and RH 2000 to one of the benchmarks. The original levelling data of the network can then be adjusted with minimal constraints. The RH 2000 heights from the GNSS surveys are not used as fixed, because this is likely to distort the levelling network. By using this method, the local height network can be seen as an RH 2000 network. The translation – for transformation of other height data – that can be obtained by this operation will be as uncertain as the height determination by GNSS technology.

If neither the levelling data can be recovered, nor is the third precise levelling available, GNSS technology can be used to obtain RH 2000 heights for a number of the local benchmarks. This will form the base for computation of an average system difference – a translation – between the local height system and RH 2000. This translation should be used only for transformation of other height data than the benchmarks in the local height network. The RH 2000 heights of the surveyed benchmarks should not be used for further levelling.

4. CONCLUDING REMARKS

By analysing the local height system, good knowledge of the existing deficiencies is obtained. When the transition to RH 2000 is completed, more advantages are attained:
- The same height reference frame is used in all parts of the municipality
- The risk of mixing different height systems is decreased
- Data in a well-known high quality reference frame will be more attractive to external users
- Data exchange between different producers/users is facilitated

When the transition is completed and the distortions of the local networks have been analysed, the municipality will have the opportunity to use GNSS technology in combination with the national geoid model SWEN08_RH2000 (Ågren, 2009) for a wider range of height determination applications.

REFERENCES

Kempe C, Alfredsson A, Engberg L E, Lilje M, 2006, Correction Model to Rectify Distorted Co-ordinate Systems. FIG XXIII International Congress, October 8-13 2006, Munich, Germany.

Kempe C, Eriksson P-O, 2007, Lantmäteriets arbete med kommunala plan- och höjdsystem. MätKart 2007, Uppsala, Sweden (in Swedish).

Olsson P-A, Eriksson P-O, 2005, Nationella höjdsystem – historik. Lantmäteriet, PM, Gävle (in Swedish).

Svensson R et al., 2006, The New Swedish Height System RH 2000 and Geoid Model SWEN 05LR. FIG XXIII International Congress, October 8-13 2006, Munich, Germany.

Ågren J, 2009, Beskrivning av de nationella geoidmodellerna SWEN08_RH2000 och SWEN08_RH70. Lantmäteriet, Rapportserie: Geodesi och Geografiska informationssystem, 2009:1, Gävle (in Swedish).

BIOGRAPHICAL NOTES

Christina Kempe
Ms. Kempe graduated in 2000 from the University of Gävle as a Mapping and Surveying Engineer (BSc.). She is since then working at the Geodetic Research Department of Lantmäteriet, mainly with reference frame and co-ordinate system issues. For the past few years she has been supporting the municipalities in their transition to the new national reference frames SWEREF 99 and RH 2000.
Ms. Kempe is a member of the Swedish Map and Measuring Technique Society.

Linda Alm
Ms. Alm graduated in 2005 from the University of Gävle as a Geomatics Engineer (BSc.). After graduation she was hired as a teacher at the university. Since 2010 she is working at the Geodetic Research Department of Lantmäteriet, with reference frame and co-ordinate system issues, mainly supporting the municipalities in their transition to the new national reference frame RH 2000.
Ms. Alm is a member of the Swedish Map and Measuring Technique Society and the Swedish Cartographic Society.

Fredrik Dahlström
Mr. Dahlström graduated in 2005 from the University of Gävle as a Geomatics Engineer (BSc.). He is since 2009 working at the Geodetic Research Department of Lantmäteriet, mainly with reference frame and co-ordinate system issues. For the past few years he has been supporting the municipalities in their transition to the new national reference frames SWEREF 99 and RH 2000.

Lars E Engberg
Mr. Engberg obtained his Master's degree from the Royal Institute of Technology in Stockholm 1973. He has been working as a lecturer in Geodesy at the School of Surveying for many years. Between 1989 and 1996 he was at the City Surveying Department in Stockholm and responsible for the establishment of an improved reference network in Greater Stockholm. Since 1996 he is working at the Geodetic Research Department at Lantmäteriet. At present, he is involved in a national project aiming to implement the new reference frame SWEREF 99 as a national standard. He is also engaged as an international adviser.
Mr Engberg is a member of the Swedish Association of Chartered Surveyors, the Nordic Geodetic Commission as well as the Swedish Cartographic Society.

Jakob Jansson
Mr. Jansson graduated in 2011 from the University of Gävle as a Surveying Engineer (BSc.). He is since then working at the Geodetic Research Department of Lantmäteriet, with reference frame and co-ordinate system issues. Mainly he supports municipalities in their transition to the new national reference frame RH 2000.
Mr. Jansson is a member of the Swedish Cartographic Society.

CONTACTS

Ms. Christina Kempe
Lantmäteriet
Geographic and Land Information – Geodetic Research Department
SE-801 82 Gävle
SWEDEN
Tel. +46 26 633856
Fax +46 26 610676
Email: christina.kempe@lm.se
Web site: www.lantmateriet.se/geodesi