New Survey Regulations for Israel

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SUMMARY

The Survey of Israel (SOI) is responsible for preparing and updating Survey Regulations for Geodetic Control Networks, Topographic Mapping, Cadastral Surveys and related activities. Licensed Surveyors in Israel are obliged to work according to those regulations. The last regulations were officially issued on June 1998. The need to update those regulations was felt mainly because of the latest developments in a number of surveying technologies. The state of the art technology of permanent GPS stations equipped with RTK capability of defining centimeter-level 3D positions in real time, dictated such an urgent need, as well as other developments (like LIDAR etc.) in topographic mapping technology.

Three teams of experts from the academy, the private sector and from the SOI prepared lately a first draft for new survey regulations. According to this draft, First Order Geodetic Control in 3D (Horizontal and Vertical) in Israel will be based on the array of 18 permanent GPS stations. The Plane Coordinate System for cadastral and engineering surveys will be in complete agreement with the GPS-based coordinates. The possibility of achieving centimeter-level accuracy for the cadastral boundaries leads to Legal Digital (coordinate-based) Cadastre. That is going to be quite a revolution with regard to the importance of boundary marks in the field. Another revolution is the decision of moving towards Ellipsoidal Vertical Control. The SOI shall no longer support First Order Precise Leveling networks. Countrywide orthometric heights will be based on the ellipsoidal heights network (GPS) combined with an Official Geoid Undulations Model. Orthometric networks may still exist, but not on a countrywide (seamless) base. They will be established wherever necessary (or be defined if they already exist) as "orthometric islands". The paper elaborates the process of preparing the new regulations including relevant discussions.

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1. INTRODUCTION

The Survey of Israel (SOI) is responsible for preparing and updating Survey Regulations for Geodetic Control Networks, Topographic Mapping, Cadastral Surveys and related activities. Licensed Surveyors in Israel are obliged to work according to those regulations. The last regulations were officially issued on June 1998. The need to update those regulations was felt mainly because of the latest developments in a number of surveying technologies. The state of the art technology of permanent GPS stations equipped with RTK capability of defining centimeter-level 3D positions in real time, dictated such an urgent need, as well as other developments (like LIDAR etc.) in topographic mapping technology.

Three teams of experts from the academy, the private sector and from the SOI prepared lately a first draft for new survey regulations. The external experts were chosen by a tender who considered their methodic proposals. The team's chairs were the responsible experts in SOI on the specific field. The whole work was organized by the chief scientist of SOI, whose duty is to update and prepare the survey regulations for authorization by SOI's Director General. Publishing of the regulations is done after they are signed by the Minister of Housing and Construction. The next step is to prepare much more detailed technical instructions, which are signed by the General Director of SOI. Updating of the so called "Manager's technical instructions" is done on permanent basis as long as it conforms to the regulations.

The next chapter concentrates on the proposed draft for the Geodetic Control Networks, which was authorized already by SOI's Director General. The drafts for Topographic Mapping and for Cadastral Surveys were not approved yet (July 15, 2006). This paper brings just a briefing of the proposed updating in Topographic Mapping; it brings some more information about those of the Cadastral Surveys.

2. GEODETIC CONTROL NETWORKS

The National Geodetic Control Network is defined as 3D control, i.e. every control point shall have horizontal coordinates (longitude, latitude and plane coordinates) and ellipsoidal height. The network is based on the Permanent GPS stations of Israel which constitute the higher order of the 3D control. The network is divided to a primary 3D class (named G class) and to two secondary classes: S for horizontal coordinates and E for ellipsoidal heights. In addition to the national network of ellipsoidal heights, it is permitted to maintain local networks of orthometric heights (H_L) or to measure control points of statutory (official) orthometric heights (H_S) based on GNSS measurements and official geoid undulations model (Steinberg and Even-Tzur, 2006).

2.1 Horizontal Control

The primary objective of the horizontal control network is to serve the cadastral surveys. The ultimate goal of SOI is to define the cadastral boundaries with an accuracy of 5cm at 95% confidence level (Steinberg 2001). This goal will get its formal (legal) capacity in the new chapter of the regulations for cadastral surveys. This goal, as well as the available modern measuring methods and considering economic issues, dictated the structure and the accuracy of the horizontal control. As mentioned above, the National Grid (plane coordinate system) will be based on the permanent GPS stations of Israel (Steinberg and Even-Tzur 2004, 2005).

The primary class G is to be established and measured by SOI only. It consists of 3 levels as follows:

G0- the array of 18 (might extend up to 24 in the future) permanent GPS stations of Israel.

G1- an existing network of about 150 control points, built especially for geodynamics monitoring (Ostrovsky 2001).

G2 - a network of about 1200 control points with easy access, at a density of about 1 point per 20 square kilometers. A major part of those points are existing benchmarks which are suited for GNSS measurements.

Control points of the second class can be measured also by the private surveyors. This layer consists of 2 levels as follows:

S1- control points that are based on G class and are measured by GNSS methods only.

S2- control points based on the primary class G and/or on S1. Those points can be measured either by GNSS methods and/or by "classical" methods of EDM and angles.

A summary of the required accuracy for each level is given in Table 1.

Table 1. National Control Network Classification and Required Accuracy.

required accuracy (2σ) relatively to the nominal coordinates of the Permanent GPS Stations, in millimeters				Class/Level
Remarks		Vertical (ellipsoidal)	Horizontal	
by SOI only		5	3	G0
		10	6	G1
		20	15	G2
SOI & Private Surveyors		70	25	S1
		100	35	S2
SOI & Private Surveyors	relatively to the nearest G point	10		E1
		20		E2
		50		E3

As can be seen in Table 1, there is a requirement to define ellipsoidal height to every control point. This requirement is easy to achieve and is important for future works like topographic mapping or 3D cadastre.

A major issue in the new regulations is the decision to cancel the existing regulations about the dependency of the control points-level on a minimal distance between neighboring points. This regulation was quite a burden on the surveyors and SOI, whose duty is to approve their work, since it is not fitted to GNSS measurements. Another decision is that we shall have no more regulations for a maximal length of a traverse, number of legs, and the accuracy of the measured distances and angles. The only important parameter will be the accuracy of the adjusted coordinates. The instructions for achieving the required accuracy, as well as for the checking procedures and the computations (included of course the accuracy estimation) will be detailed later within the manager's technical instructions.

2.2 Vertical Control

The objective of vertical control within the scope of the survey regulations is to provide a framework on which surveyors can base and adjust their heights. The traditional approach to vertical control is as having orthometric heights, measured by instruments which are influenced by the earth gravity like levels or "total stations". Those heights suppose to give the distance of the point above the geoid along the plumb line, and "assure" running of water from a higher point to a lower one. Heights which are measured by GPS produce ellipsoidal heights which are of geometric nature, and do not "assure" running of water from a higher point to a lower one. The geoid undulations in Israel are between about 16 meters in the south and 24 meters in the north. The maximum slope between the ellipsoid and the geoid in Israel is about 10 centimeters per one kilometer.

Enormous work was done in Israel in order to establish an accurate and homogenous vertical control network based on precise leveling, without the ability to achieve the desired goal. It seems like endless Sisyphus work.

For usual engineering needs, the actual necessary accuracy of height differences should not exceed 10 millimeters to a distance of 100 meters, or in other words 1cm per 1km. It is very easy to reach this accuracy. However, due to the nature of leveling, in which one might make a gross mistake of 10cm in his work but will not find any abnormal disclosure once he conducted one-way leveling, this accuracy is not sufficient for orthometric control. A reasonable vertical control for usual engineering works consist of benchmarks whose local accuracy (including stability) is about 1-2 centimeters and the accuracy of the height difference between two benchmarks 1km apart is about 25mm. In order to achieve this accuracy we must measure and maintain a dense network of at least 2x2 km, based on the network of precise leveling, all over the country. This is practically an impossible mission. For this reason many municipalities established local networks of benchmarks. Height differences between neighboring benchmarks of two municipalities reach often up to 5-10 cm. The SOI have managed to bring orthometric heights to every urban area. Its accuracy, relatively to the higher orders of the leveling network (along main roads), is more or less 5-10

centimeters, depending on the distance and height difference from the higher order-benchmarks. It can be regarded as local networks just like those of the big municipalities.

2.2.1 Ellipsoidal Control

The team of experts came to the conclusion that there is neither practical possibility nor actual need to maintain a countrywide vertical orthometric control network. This conclusion follows the ideas about the future of vertical control as was expressed in Steinberg and Papo (1996,1998,1999). SOI will maintain vertical ellipsoidal height control network, measured by GNSS technique. As mentioned above, the nationwide vertical control is a part of the 3D geodetic control. The primary class G described in 2.1 is the same for the vertical control. The secondary class E for ellipsoidal heights, which can be measured also by the private sector, consists of 3 levels: E1, E2, and E3. Control points of this class will be measured by GNSS technique only, based on control points from higher levels.

The required accuracy for each level is summarized in Table 1 above.

2.2.2 Orthometric control

Although for many kinds of geodetic works (like photogrammetric mapping, large scale topographic mapping in open area, or heights that one gets automatically once he uses GPS in order to get horizontal positioning), we decided to continue with using orthometric heights in most of the works. We concluded that the transition to ellipsoidal heights only, is premature yet. For now, it seems impossible to explain, for example, a difference of 70cm between the heights of the Sea of Galilee (Lake Kineret) in its northern part relative to its southern one.

The orthometric heights will be used as having a local datum which will have to be noticed in every work. As was mentioned in the preface to this chapter, there will be a possibility for nationwide datum for orthometric heights (H_S) measured by GNSS and official geoid undulations model. Other orthometric heights of local nature (H_L) can be measured either by geometric leveling, trigonometric leveling or GPS based on local benchmarks, according to the required accuracy.

There are 5 levels of accuracy for orthometric height differences as summarized in Table 2 below.

It is worth to note that unlike the existing regulations in which the required accuracy is a function of the leveling length, D in table 2 is the horizontal distance between the points.

H_L1 and H_L2 can be measured by leveling (geometric or trigonometric) only.
H_L3 – H_L5 can be measured by GPS also.

Table 2. Vertical Local Orthometric Control Networks Levels and Required Accuracy.

maximal D in kilometers	required accuracy (2σ) of height-difference, in millimeters	Network-Level
20	$\sqrt{0.16+0.16D^2+4D}$	H_L1
10	$\sqrt{1.0+0.25D^2+16D}$	H_L2
1	$\sqrt{25+100D^2+100D}$	H_L3
1	$\sqrt{50+225D^2+225D}$	H_L4
1	$\sqrt{100+900D^2+2500D}$	H_L5

The accuracy of the "statutory" heights H_S (obtained by the official undulations model) is dependant on the accuracy of their ellipsoidal heights only, since the official model regards as "errorless". E1 will produce H_S1 and E2 will produce H_S2.

3. CADASTRAL SURVEYS

The existing regulations (from 1998) contain a chapter entitled "Surveying and Preparing Plans for Registration Purposes". Those plans for registration are mainly mutation of the cadastral parcels (re-parcelation) that are made in order to register changes of the cadastral boundaries and rights. According to the Planning and Building Law they have to conform to Town Plans. Exceptional are plans for "First Registration" in areas where the process of settlement of land rights was not completed yet (about 5% of the area of Israel). The modern Israeli cadastre was established in 1920 by the British mandate in Palestine, and was based on Torrens principles. The accuracy in which the boundaries are defined is quite heterogeneous as a result of the survey methods and equipment that were used. SOI have to check and approve each registration plan before it goes to the registration office at the ministry of justice (Forrai and Kirschner, 2006).

A specific regulation in the 1998 regulations enlarges the validation of those regulations (for Registration Plans) to other relevant mapping products.

3.1 Legal Digital (Coordinate - Based) Cadastre.

The 1998 survey regulations and their adjunct "manager's technical instructions" contain a requirement to compute the coordinates of every boundary point as well as detailed instructions for its digital format (named SRV) which is suited to feed the cadastral LIS. However there is another demand for demarcation of every turning point of the cadastral boundaries. In case of disagreement between the coordinates and the mark in the field, the mark in the field is considered as the legal boundary, as long as it is regarded as the authentic boundary mark. Authorization of the authenticity of the boundary marks is the heaviest task

of the surveyors who prepare the registration plans and those who should approve their work. It is also a common source for boundaries disputes. However the requirement for demarcation of boundaries and the superiority of the boundary marks over their coordinates is needed as long as we do not have the possibility to achieve a desired accuracy in which we want to define the coordinates of the boundaries, i.e. a stable, accurate and homogenous control network and reference frame. This situation was already changed lately (Steinberg and Even-Tzur, 2005), and the new regulations for the geodetic control networks described in paragraph 2.1 above will accomplish its formal aspects. Proper EDM or GPS measurements of boundaries, based on the described horizontal control, will assure the desired accuracy of the boundaries definition.

A main issue in the new regulations is to assure the legality of the coordinate- based cadastre. There is still (July 15, 2006) a debate to be decided by the Director General of SOI whether the boundaries demarcation as a part of the plan for registration is optional or mandatory. It should be obvious that the superiority should be given to what was first, i.e. are the coordinates a result of measuring the boundary mark, or was the demarcation done according to the coordinates. Any how the new regulations and technical instructions should make sure that the demarcation and measurement of cadastral boundaries will be accurate and reliable.

3.2 Boundaries - Documentation Plans

As mentioned above, SOI is obliged to check and approve registration plans. The most important check is to verify the reconstruction of old (registered) boundary marks, or the authenticity of those which were found (see next paragraph). It is obviously also the main task of the surveyor who prepares the mutation plan, which is totally dependant on the old boundaries. Once it was found in the checking process that even one boundary turning point was not reconstructed in its proper place, the plan should be prepared again. A same thing happens once the supervisor found that an old boundary mark which the surveyor adopted as an authentic one is not authentic. That phenomenon is not a theoretic one. Reconstructing of old boundaries (and verifying of old boundary marks) which are based on old measurements is not an obvious job and it might be ambiguous. Therefore there is a growing surveyor's demand for early approval of the outer old boundaries of their plans. A similarly growing market-demand is to approve registered existing boundaries prior to building of wall-fences, or even in order to make sure that the distance from the boundaries to a new planed building is according to the minimal distance (so called "building-line") in the Town Plan. Boundaries disputes are decided in the court of justice (after very long time and high expanses), based on "expert witnesses" of private surveyors. It would make much more logic if it would be decided by SOI, which is responsible for the definition of the boundaries as registered in the Land Registry Office.

The draft for the regulations of cadastral surveys includes changing the name of the chapter to:" Preparing Plans for Registration Purposes and Plans for Boundaries-Documentation". The idea is that SOI will approve the reconstruction and actually the coordinates of registered boundaries upon optional requests. It will certainly be a heavy task to SOI which already has difficulties with the amount of mutation plans that are waiting right now to be checked and

approved (Forrai and Kirschner, 2006). However, I am sure that in the long run it will pay itself even in matters of checking time. It is an important thing to do and it is the right thing to do. Those approved Boundaries-Documentation Plans, will use also as a growing skeleton of Legal digital Cadastre as described in Steinberg (2001).

3.3 Reconstruction of Registered Boundaries

As was mentioned above and is detailed in Steinberg (2001), the accuracy in which the boundaries are defined is quite heterogeneous as a result of the survey methods and equipment that were in use along some 80 years. The accuracy changes from few centimeters in modern surveys up to 2meters in areas where the only documentation is the block sheets scaled 1:2,500. Usual computation of boundaries coordinates, in the old Israeli grid on which their measurements are based, brings an accuracy of few decimeters. According to the existing regulations, reconstruction of the old boundaries should be done by coordinates-transformation from the old Israeli grid to the new one, based on measuring (in the new system)of at least three old control points, or boundary marks, or authentic objects, that were measured in the same system with the old boundaries. An r.m.s of 15cm in each direction (Y,X) is o.k. Although the boundaries were marked in the field, we can rarely find an authentic one or a near-by control points that were used for the original measurements. It is more likely to find some objects as old buildings that survived the accelerated development of Israel. Discrepancies of half a meter and even more were found in neighboring large mutation plans. Plenty of research works were conducted in Israel (see e.g. Gavish and Doytsher (2002), Fradkin and Doytsher (2002), Croitoru and Doytsher (2003)) in order to learn about the accuracy of the original cadastral surveys and in order to improve the boundaries-reconstruction accuracy. Right now (July 2006) SOI is conducting a very large research that is spread over 60 registration blocks in four different locations. This work is done by chosen expert private surveyors, with the goal to reach the best ways for reconstruction of old boundaries and define them as Legal Digital Cadastre.

A special set of technical instructions will be dedicated to reconstruction of old boundaries, based on the massive research that was (and is) done. The most important thing is to enable achieving of consistent results by every surveyor. The technical instructions must consider consistent computation process of the old filed books and field sheets (which contain additional distance measurements) and their adjustment process with the accurate new measurements of authentic boundary marks or objects. It will also have to relate to the location of existing substantial fences with regard to the ellipse-error of the adjusted boundary points coordinates, as suggested in Steinberg (2001) for Approximate Legal Digital Cadastre.

4. TOPOGRAPHIC MAPPING

The chapter of topographic mapping in the existing regulations is very detailed and includes plenty of technical issues. This is going to be changed through focusing on the main issues like the required accuracy in every product, and its content. The detailed specifications will appear in the adjunct manager's technical instructions. Those instructions will relate to the up-to-date technology. The newly proposed regulations present a compromise between the fully

automated, fully digital advanced mapping technologies and the still popular traditional, manual, analogue, and paper based mapping procedures. Just like in the existing regulations, every topographic mapping should be tied to the geodetic control network. The new approach described in chapter 2 of this paper will influence the topographic mapping regulations as well. That is true also for cadastral boundaries which appear in the topographic mapping.

5. CONCLUSION

The Israeli Survey Regulations published in June 1998, reflected its preceded technology innovations. It was the first time to mention GPS measurements in the survey regulations as well as digital photogrammetry, orthophoto and GIS. The new Israeli grid, which is based on a new datum, a new projection and a new coordinate system, has been adopted by the mapping community. This grid is considerably more accurate and consistent than the previous one, and enables significantly better handling of a nationwide spatial data. The rapid technological progress, and the continuous transition from graphical maps to digital information is clearly demonstrated by a long list of the professional issues, which have been regulated in 1998 but had not even been mentioned in the previous version, published in 1987. In order to avoid a large gap between the regulations and state-of-the-art future technology, detailed technical instructions were published in conjunction with the regulations. Naturally, these instructions follow the regulations; however, they may be modified by the Director General of SOI, in particularly when new technology comes in. Such a modification enabled quick response to new technology without a need to change the regulations themselves frequently. However, some conceptual revolutions (like transition towards 3D geodetic control network and coordinate-based cadastre) that were enabled by the state-of-the-art technology of Permanent GNSS Stations, dictated the need for new regulations. There are still some issues to be decided and a lot of work to be done in writing the technical instructions. We shall probably leave an open door for introducing future 3D cadastre in the technical instructions. The new survey regulations will hopefully be published by the beginning of 2007.

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