Polish Cartographical Review
Vol. 49, 2017, no. 3, pp. 121–133
DOI: 10.1515/pcr-2017-0009

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NATO revolution in the Polish military cartography

Abstract. The article presents a review of contemporary Polish military topographic maps, with special focus on those in the scale of 1:50,000. They are basic maps used in all armies of NATO countries at tactical stages.

After the political breakthrough of 1989 Polish political elites saw the future of our country in the structures of Western Europe, but the Warsaw Pact still existed, and Soviet Army units were stationed in Poland and in the German Democratic Republic. All the Warsaw Pact countries used maps in the "1942" coordinate system and followed standardized rules of map elaboration. The article presents transformation of those maps into NATO standards, the first stage of which was elaboration of the, so-called, maps adapted to NATO standards.

At the end of 1990s there started elaboration of a new topographic map of Poland in the scale of 1:50,000. The project involved preparation of a level 2 map, in NATO nomenclature known as VMap Level 2, and simultaneously using the same base for to generate 580 sheets of a paper map in 1:50,000. Map elaboration finished in 2006 and in the following years the project was enhanced with publication of new maps based on high-resolution image data.

Since 2003 Polish cartographers have been participating in Multinational Geospatial Co-production Program (MGCP). Within the program high-resolution vector data is being prepared for selected areas of interest. They are mainly areas of current or potential military conflict, terrorist threat, ethnic or religious conflict, natural disaster, etc. MGCP data is not a ready product meant for direct usage, and without proper preparation it is simply unreadable. Therefore, special computer applications were developed to facilitate fast preparation of topographic maps in 1:50,000: MGCP Derived Graphic (MDG) and lately MGCP Topographic Map (MTM). Such maps differ from Polish topographic maps both in contents (to a lesser extent) and in graphic form (to a larger extent). They contain less objects, but include aerial information.

Keywords: Polish military topographic maps, maps in the NATO standard, VMap L2, MGCP, MDG, MTM

1. Military topographic maps adapted to NATO standards

The process of NATO-standard map elaboration in the Polish military was exceptionally complex, difficult and dependent on the political-military situation in Europe. After the political breakthrough of 1989 Polish political elites saw the future of our country in the structures of Western Europe, but the Warsaw Pact still existed, and Soviet Army units were stationed in Poland and the German Democratic Republic[1]. Several hundred million sheets of maps in the "1942" coordinate system covering not only Poland but also the so-called Western Theater of Military Activity had been kept in military storage and in individual military units. In such conditions the Topographic Department of the General Staff of the Polish Armed Forces suggested to the Minister of National Defense to gradually withdraw the maps in the "1942" coordinate system from use in the Polish Armed Forces and switch to those used in NATO. The key events which helped to reach that objective were the establishment of cooperation with the American Defense Mapping Agency in July 1992 and signing by the Minister of National Defense of Poland and the US Secretary of Defense of an agreement on cooperation with

[1] The Warsaw Pact was disbanded on 1 July 1991, and the Soviet military units withdrew from Poland on 17 September 1993. Poland became a full member of NATO on 12 March 1999.

the American Defence Mapping Agency (DMA)[2] and sharing of basic materials in the area of military topography, air and naval cartography, geodesy and geophysics, digital data and geodesic and cartographic materials.

As a result of that agreement the Polish Army received several dozen NATO standardizing documents, the so-called STANAGs[3], which made it possible to get acquainted with NATO requirements in the area of map elaboration. After the analysis of the documents it was determined that the main task would be to recalculate the points of geodetic control network from the "1942" coordinate system into the "WGS-84" coordinate system. Americans declared their help in reaching that objective. It was decided that a Military Basic Geodetic Network and a Military Detailed Geodetic Network would be established for the area of Poland in the "WGS-84" coordinate system. The next step, also with the American assistance, would be to perform gravity measurements at the points of the Basic Gravity Net.

Establishment of the basic geodetic network in the "WGS-84" coordinate system was performed with GPS metering and it started in 1993. Relations between the "1942" and "WGS-84" coordinate systems were defined on the basis of calculated and adjusted coordinates; the average error of transformation parameters was ± 0,26 m. In 1994 and 1995 the Military Detailed Geodetic Network consisting of 554 points was established. Measurement results made it possible to increase the precision of determining transformation parameters between the systems and provided a basis for connecting the military system with the EUREF-89 system used for civilian purposes.

Adaption of the "Partnership for Peace" program in Brussels in 1994 provided another impulse for adaption of NATO standards in the Polish Army. The program enabled the topographic service of the Polish Army to participate in conferences, geographic workshops and working groups of the Alliance as well as granted full access to technical documents related to the elaboration of new maps.

First it was decided to publish the maps adapted to NATO standards in the scales of 1:25,000, 1:50,000 and 1:100,000, and an operational map of 1501 series Joint Operations Graphic (JOG) in NATO standard in 1:250,000 replacing a previous map in 1:200,000. Such approach resulted from documents: "NATO Geographic Policy" and STANAG 3677 (2000) which set topographic and general maps in the scale series of 1:50,000, 1:250,000, 1:500,000 and 1:1,000,000. Continuation of publishing of maps in the scales of 1:20,000 and 1:100,000 resulted from the needs of Polish users, who were particularly accustomed to such maps. The first maps to be elaborated and published were adapted to NATO standards in the scales of 1:25,000 and 1:50,000 and covered the area of military training areas (Ustka, Biedrusko, Wędrzyn, Drawsko Pomorskie and Żagań-Żary), to be followed by maps of other areas. Until 1996 52 sheets of the map in 1:25,000 (out of the total of 2260), 306 (of 565) sheets in 1:50,000 and 96 (of 154) sheets in 1:100,000 had been published.

What was the topographic map in 1:50,00 adapted to NATO standards like? The most visible change was in its size: two adjacent sheets of the previous map in "1942" system were merged into a so-called double sheet. Geographic range of the new map rose from 15' to 30' longitude and the range along the meridian remained unchanged (10' latitude). Coordinates of sheet corners, marked in black, still referred to the "1942" system. What was new was the addition of corner coordinates in the "WGS-84" system in blue, outside of the external frame. Another new element were outlets of graticule marked outside of the internal frame (every 5'). Coordinates of the sheet center were described in the "1942" system (fig. 1).

Merging of the two adjacent sheets brought about a change in sheet number. The system of sheet division of the International Map of the World used in the "1942" coordinate system was modified by adding pairs of figures or letters to the last segment of the sheet number (divided with a coma) which identified the adjacent sheets.

Another important element of the map in 1:50,000 adapted to NATO standards was the Military Grid Reference System (MGRS) built

[2] In 1996–2003 known as the National Imagery and Mapping Agency – NIMA, after 2003 as the National Geospatial-Intelligence Agency – NGA.

[3] STANAG (Standardization Agreement). In NATO, the agreement between Alliance members defining processes, procedures, terms and conditions enabling unification of military activity, technical procedures and military equipment.

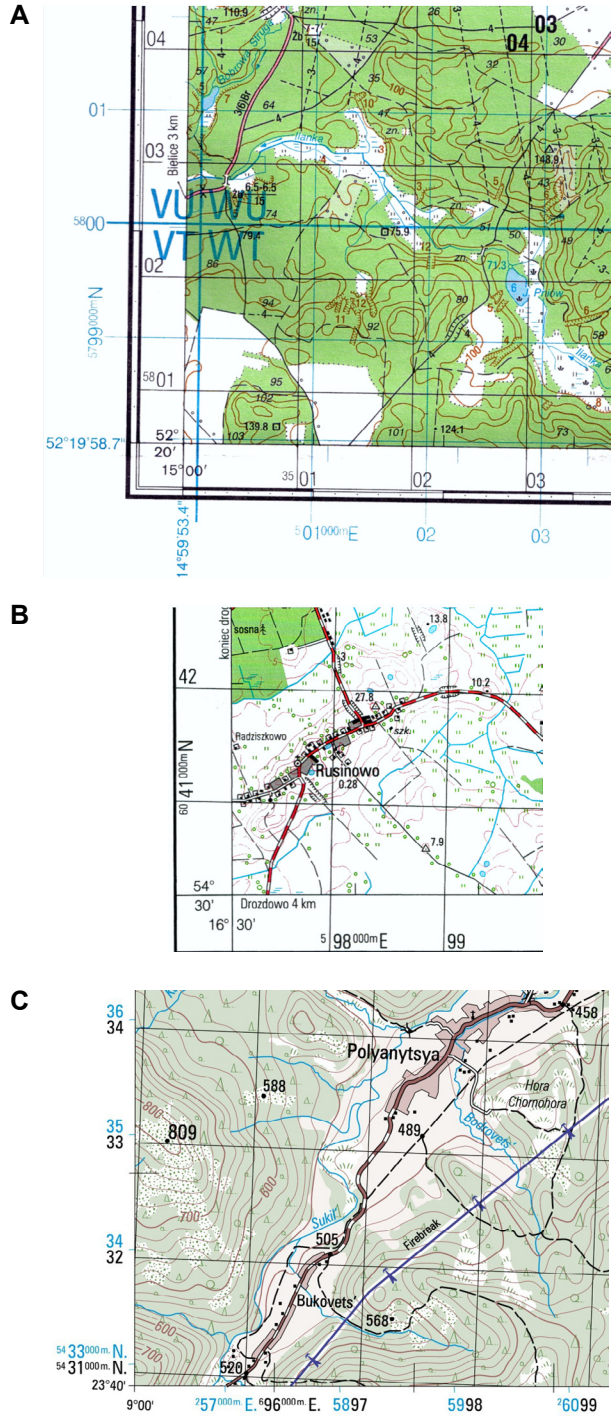

Fig. 1. Southwestern corners of military topographic maps in the scale of 1:50,000: A – map adapted to NATO standards, B – map in NATO standard, C – MDG map

on the UTM coordinate system which is based on the "WGS-84" ellipsoid and the universal transverse Mercator projection. MGRS reference system consists of a kilometer grid, grid coordinates placed within the sheet and outside of the external frame as well as identifiers of 100,000 m squares covering a particular sheet. All these designations were printed in blue. Black grid lines and designation of its coordinates from the "1942" system remained the same as in previous maps.

Requirement of placing a symbol legend together with additional marginal information on each sheet was another novelty. Such extension of margin data was one of the reasons for increasing sheet dimensions. According to the NATO requirements the elements of marginal designation are bilingual or trilingual. It is always the national language (Polish), English and in the case of border sheets also the language of the neighboring country. The symbol legend of a map adapted to NATO standards is located below the southern frame of the sheet and contains a selection of main symbols appropriate for the map in "1990" standard. Symbols on maps of NATO countries are national, they are not limited by any STANAG provisions except the requirement of proper presentation of road classification. In the case of the marginal lettering of maps adapted to NATO standards blue color is used for description of information connected to "WGS-84" system and UTM projection (ellipsoid, projection type, grid coordinate system, vertical datum, grid type, ratio of calculating of "1942" system coordinates into "WGS-84" coordinates) as well as to the example of application of MGRS reference system. It should be noted that MGRS reference system bases on UTM and UPS[4] coordinates, but recording of MGRS coordinates differs from the recording of UTM (UPS) coordinates.

The so-called identification panel is a new element of marginal information on maps adapted to NATO standards. It consists in a frame containing three basic pieces of information about the map: series number, edition designation (edition number and coded initials of the agency responsible for that edition) and sheet number, e.g. Series M753, Edition 1-ZTSG WP, N-33-127-C,D, Sulęcin. Due to the lack of experience and incomplete knowledge of designation of map series published by NATO members, the Polish maps adapted to NATO standards had incorrect series numbers. For the scale of 1:50,000 instead of M755 the number used was M753, the same as for the American Topographic Line Map (TLM) for the area of Poland.

Implementation of topographic maps adapted to NATO standards in the Polish Armed Forces required a transfer of appropriate knowledge to their users. Therefore in 1996 there appeared several publications regarding the use of maps in NATO standards. The main of them was the guide *Wojskowe mapy topograficzne dostosowane do Standardów NATO (Military topographic maps adapted to NATO standards)* (1996). The publication contained information on the formal-legal bases, rules and stages of implementation of the "adapted" maps in the Polish Armed Forces, presented extended knowledge on NATO standards regarding horizontal and vertical datums, projection, military reference systems, map scales, map designation, required dimensions, marginal information, etc. Nevertheless, for several more years in some military units (particularly in rocket forces and artillery) maps in "1942" system continued to be used.

2. Military topographic maps in the NATO standard

In 1998, in the perspective of joining NATO, it was decided to stop the production of the map adapted to NATO standards in the scale of 1:50,000 and to start editing this map in a different standard. WOGiT (Military Geodesy and Remote Sensing Centre – now Military Geographic Centre) in Warsaw and 22WOT-K (22nd Military Topographic and Cartographic Centre – now 22nd Military Cartographic Centre) in Komorowo started digital elaboration of the military map of M755 series, using Intergraph's Modular GIS Environment (MGE) environment and equipment. Simultaneously, civilian companies which until then had been participating in elaboration of "adapted" maps on public procurements began to elaborate maps in the full standard.

It should be noted that M755 was not the first series of maps in NATO standard published by Polish cartographers. In the years 1995–1998 33 sheets of the operational map of 1501 se-

[4] UPS – Universal Polar Stereographic – set of plane coordinates for polar zones (over 84°N and 80°S).

ries (JOG) in the scale of 1:250,000 of the area of Poland were elaborated by updating British editions from 1980s.

In order to achieve full coverage of Poland with the map of M755 series in 1:50,000, 565 sheets had to be prepared. In most cases the basis for them were diapositives of the recently elaborated maps adapted to NATO standards, as well as single sheets of the last editions of maps in the "1942" system. Scanned diapositives underwent digital transformation into the "WGS-84" system followed by manual digitization of map contents (except relief) and semi-automatic digitization of relief. Frame, grid and margin data were generated using the MicroStation Development Language (MDL) application. Diapositives of six colors were generated in Map Publisher and exposed using MapSetter 6000.

Although the elaboration of the map in 1:50,000 was performed in Modular GIS Environment, using a relatively advanced GIS tool, the final product did not have the features of a true database. It was a purely cartographic construct, although the map project had characteristics of a database, defined number of features and assigned attributes. The database contained only the geometry of topographic features.

Transfer from the classical method of elaboration of the map in 1:50,000 into the digital method required that a full library of symbols and fonts had to be designed. In 1995 a new publication containing a new set of symbols (*Znaki…* 1995) was introduced for internal use within the Topographic Service of the Armed Forces. The set of symbols used before (on maps in 1:50,000 in the "1942" system and on "adapted" maps), which originated from Soviet cartography, was changed in the first edition of the M755 series map. The main change was the removal of about 120 out of 300 symbols appearing in the specimens of symbols (*Wzory…* 1986). The reduction involved mainly symbols referring to objects alien to the natural and cultural environment of Poland. Removed symbols referred such objects as e.g. mazar, mosque, Buddhist temple, salina, caravan trail, tidal marsh, geyser, tidal current, lava tongue, volcano crater, glacier, névé field, icing, palm grove, rice field.

Too detailed classes were merged into more general ones, and features in the new classes were differentiated by labels and explanations (often in the form of abbreviations). For example, *Wzory i objaśnienia…* from 1986 included four classes of features below with related symbols: overground oil pipeline, underground oil pipeline, overground gas pipeline and underground gas pipeline. The new symbols had only one class – pipeline with an optional labels "gas", "oil" etc.

Znaki umowne… published in 1995 included not only symbols, their descriptions and graphic parameters, but also comments on their application. However, a general, editorial oversight of the new product was lacking. Because of that it was quickly decided to re-edit the existing specification, focusing mainly on the changes related to introduction of the new reference system and grid coordinate system, as well as the new format and color scheme of military topographic maps. The new specification (*Tymczasowe zasady…* 1997) was temporary, but it survived 14 years, supplemented with numerous annexes and additional guidelines. In 2011 it was finally replaced by a new specification (*Wojskowa mapa…* 2011a) and new specimens of symbols (*Wojskowa mapa…* 2011b), however referring only to the map in the scale of 1:50,000.

All military geographical products dedicated for usage in joint operations of the North Atlantic Alliance require an evaluation of conformity with Standardizing Agreements. American NIMA, basing on STANAG 2215 (2002), evaluated the military map in 1:50,000 published by the Topographic Service of the Polish Armed Forces. The result of the evaluation of the map contents was very good, there were also no objections to map's precision. However two remarks of the evaluators had major influence on the subsequent editions of the map. The first regarded decreasing the number of colors on the map. According to STANAG 3675 (2000) for land maps there should be five colors at the maximum (black – culture features, blue – hydrography, brown – land relief, red – road classification, green – vegetation). STANAG also allowed additional limiting of the number of colors by merging of some categories. It became obvious that violet should be completely removed and replaced with red (borderline, highway, expressway). Although the remaining five colors met the standard criteria, for the

sake of economy[5] it was decided to change the color of brown objects to red.

The second important change resulting from the evaluation of the map by the specialists from NIMA was the necessity of adapting the classification and presentation of road net to STANAG 2454 (2005). Until then road net classification on Polish military topographic maps, both "adapted" and those in NATO standard, considered the criteria of the number of lanes, their width and surface type. According to the above criteria the following classes were distinguished (except cart tracks and paths):

• Freeways, expressways (violet);
• main roads over 7m and 3,0–6,9 m wide (red);
• secondary roads over 7m and 3,0 -6,9 m wide (40% red);
• dirt roads, maintained (without color filling);
• dirt roads.

According to STANAG 2454 there are three types of roads:

• X type are roads suitable for use regardless of the weather, with hard surface, marked in red;
• Y type are roads suitable for use regardless of the weather, with loose surface, marked in red dashed line;
• Z type are roads suitable for use under fair conditions only, without color filling;

In this case adaptation to NATO standards involved grouping of existing categories into X, Y and Z types, showing it only in the English language legend.

Additionally, width ranges were modified according to the division used on TLM maps, according to MIL-T-89301A specification. The current road classification is the following:

• freeways, expressways (red) – motorway, double carriageway Highway – X type;
• main roads 7,4 m and over and 5,5–7,3 m wide (red) – all-weather road, hard surface – X type;
• secondary roads 3,0–5,4 m wide (40% red) – all-weather road, hard surface – X type;
• dirt roads, maintained (40% red, intermittent) – all-weather road, loose or light surface – Y type;
• dirt roads – fair or dry-weather road, loose surface – Z type.

Using red color on maps in NATO standard resulted in better graphic exposition of roads. Map designation of the sheet was also changed. Because of the requirements of digital processing the sheet numbers e.g. N-9-3-A,B or M-12-19-C-a,b were changed into N-09-003-A,B and N-12-019-C-A,B. In the sheet name the upper case letters were replaced by lower case (e.g. Komorowo instead of KOMOROWO), abbreviations were replaced with full names (e.g. Stara Huta instead of STR. HUTA). Cardinal directions were given in English.

3. Level 2 vector map (VMap Level 2) as the basis for editing new topographic maps in 1:50,000

At the end of the nineties, parallel to the preparation of analogue maps, a level 1 vector map (1:250,000) and a digital terrain model were being prepared in geographical units of the Polish Armed Forces. Gained experience made it possible to commence elaboration of a level 2 vector map for the area of the country, referred to as VMap Level 2 in NATO nomenclature. The project involved preparation of a continuous, digital geo-informational base for the area of Poland, which would correspond to a map in 1:50,000, and which would be the source for generating of 580 sheets of a printed map in 1:50,000. It was the biggest and at the same time the most difficult geo-informational project performed in the cartographic industry in Poland at that time, exceptionally complex technologically and demanding great cartographic knowledge. The project, which constituted a breakthrough in Polish cartography, was started in 1999.

It was a national endeavor, because NATO did not have a joint program of VMap L2 elaboration for area of interest of the Treaty, as was the case for VMap Level 1 (E. Sobczyński 2001, J. Pietruszka 2009). The practice in most NATO member states is that military vector elaborations of high resolution of information base on national databases are prepared by civilian cartographic authorities.

Information included in VMap L2 is largely similar to the contents of the military map in 1:50,000. The level of conformity can be evaluated at 80-90%. In the first phase the maps,

[5] The Topographic Service of the Polish Armed Forces at that time could use only two color offset press. Printing a five-color map required three runnings through the press (the same as for a six-color map). Printing four colors limited the labor requirement to two runnings.

prepared mostly by traditional methods, were the main source material for VMap L2. Therefore it was highly justified to adapt such an editorial direction, which would make it possible to update and generate the future editions of the topographic map from digital data. This was done. The project based on the NATO specification for VMap L2. Classes of features absent from the climate zone of Poland were eliminated. Extensions ensuring conformity with the instructions for preparing military topographic maps were added. At a later stage a technology was developed to elaborate the product using the method of vectorization, to prepare printing and publishing of future topographic map editions using digital methods and to transform digital data into distribution form.

For all standard vector products in NATO the following elements are the same: the system of spatial reference, the distribution format and the coding method of semantic features. The standard system of spatial reference includes the "WGS-84" horizontal datum, the Mean Sea Level (MSL) vertical datum and a geographic projection.

Geographic coordinates of geometric elements are marked in degrees with decimal extensions. To achieve a different format or set of displaying coordinates one has to use an application for data presentation.

The remaining elements of the standard for vector products are defined according to the Digital Geographic Information Exchange Standard (DIGEST) digital standard of data exchange, created by Defence Geospatial Information Working Group (DGIWG). Part IV of DIGEST „Feature and Attribute Coding Catalogue" including a list of encoded classes of geographical features and attributes important from a military point of view plays an important role here. The same encoding scheme named with an acronym FACC was after slight modifications also applied in VMap L2.

The distribution format of VMap L2 is VPF, the theoretical basis of which is the second part of DIGEST – *Theoretical Model, Exchange Structure and Encapsulation Specification*. Transforming the data into this format is a complex and costly process. Here the stress is put on diagnostics and elimination of errors and geometrical anomalies, building proper topology and data integration control. All this predisposes the digital VMap L2 product for various analyses. Commonly used GIS applications, e.g. ArcGIS, MGE, Erdas Imagine, Geomedia, ArcView have interfaces for VPF format, which allows direct reading and presentation of data.

Elaboration of VMap L2 for the area of Poland took place in the years 2000–2005. Since 2003 the project was joined by the Surveyor General of Poland and marshals of several voivodships (provinces). From "cartographic outlet" resulted a topographic map of M755 series in 1:50,000 which was another edition basing on previous symbols and the temporary specification.

In 2006 works on the new version of a vector map, the so-called VMap L2+, were started. This time the source of data for its preparation were not military topographic maps, but rather a digital orthophotomap. As a result the new map sheets have more precise location of terrain objects.

At that time the interest of civilian services (Surveyor General of Poland and voivodship marshals) in maintaining VMap L2 and VMap L2+ libraries diminished. It was related to the start and development of the projects of the Topographic Base of Data (TBD) and the database of Topographic Objects (BDOT10). Currently only the military updates the vector database and publishes the paper military topographic map in 1:50,000.

Until 2011 elaboration of military topographic maps followed a temporary specification, and the new specification of 2011 referred only to the map in the scale of 1:50,000. Although it preserves the structure of its predecessors, it is also significantly different. Most of all it does not refer to the technology of map elaboration. Cartographic technology applied in map preparation should ensure proper, precision and quality in compliance with the specification. The current instruction, unlike previous ones is rich in illustrations, charts and appendices, which facilitates its use in editorial cartographic and reproduction works.

The specification introduces new features and corresponding symbols. 12 new symbols were added and three more were modified. The newly added features marked on the contemporary topographic map of M755 series are, among others: destroyed building (earlier only labeled as "zn."), helipad, wind turbine, major protected cultural heritage site, sports field, stadium, ski jump, landfill, tramway line,

ski lift. Symbols of three objects were modified: important pass, other pass and embankment or levee. The new specification returns to placing number characteristics of features on map.

4. Other military topographic maps

The military topographic map of M755 series in 1:50,000 is not the only map published by the Polish military geography. Military operations abroad, including mainly participation in the mission in Afghanistan made it necessary for the Polish units to be provided with detailed topographic maps of those areas. At that time several tens of thousands of soldiers from over 40 countries participated in the operation of International Security Assistance Force (ISAF) commanded by NATO. It was obvious that cooperation of such diversified coalition must be based on a single, detailed and current map. The area of Afghanistan was fully covered in the scale of 1:50,000 only by Soviet maps in the "1942" system elaborated in 1980s and American Topographic Line Map (TLM) maps. They both presented the topographic situation from at least twenty years before, and the first did not meet NATO standards. A new map was needed, which would conform to standards, be current and published quickly. For this purpose the data from the Multinational Geospatial Co-production Program (MGCP), in which military geographers from over 30 countries had been cooperating since 2003, was for the first time used on a large scale. Within the program high resolution vector data of selected areas of interest are being prepared (J. Pietruszka 2009). They are mainly areas of current or potential military conflict, terrorist threat, ethnic or religious conflict, natural disaster, etc.

Vector data in the MGCP program are collected on the basis of the newest commercial satellite scenes with resolution below 1 m. Most data is obtained with the information density corresponding to the maps from 1:50,000 – 1:100,000 scale range. MGCP data does not contain information on land relief, political and administrative borders or nautical data. Other data, impossible to gather from satellite scenes are complemented from bases maintained by NGA (Shuttle Radar Topography Mission – SRTM, Geographic Names Data Base – GNDB, Automated Air Facilities Intelligence Files – AAFIF[6], Digital Vector Obstruction Files – DVOF[7]).

MGCP data is not a ready product meant for direct usage, and without proper preparation it is simply unreadable. Its aim is to facilitate fast publication of detailed topographic maps.

Time is the decisive factor in editing a map from MGCP data. Crisis situations (political, social, economic, and mainly natural) demand quick reaction. Elaboration of a current topographic map in a normal cartographic process, basing on standard specification and templates, requires a lot of labor and time, often of many months. In the case of crisis time is limited, from several hours to a few weeks. A project of the MGCP Rapid Graphic (MRG) "fast map", authored by the parties involved in the MGCP program, was the answer to such requirements. Since the word "rapid" referring to maps had connotations of low quality, it was decided to change the name into "map from MGCP data" MGCP Derived Graphic (MDG). The new map evolved directly from the standard American topographic map published by NGA, known as TLM.

In 2009 the Geographic Service of the Polish Armed Forces realizing the MGCP program practiced a method of elaboration of such maps. MGCP data received from NATO partners for the area of Ghazni, for which the Polish military contingent was responsible, was transformed into cartographic features. On the basis of SRTM2 data land relief was elaborated (contour lines, scarps, spot heights, shading), names verified, province borders introduced, neatlines, grid and all margin information generated. Data obtained from the Allied Joint Force Command (JFC) Brunssum command, verified at the warfare theater, served to supplement information about bridges and culverts. This way an MDG topographic map of the U711G series in the scale of 1:50,000 was prepared within a very short time. Following sheets of MDG maps of N701G, U711G and U712G series covering the area close to the national border have been prepared since 2014.

MDG Maps differ from Polish topographic maps of M755 series both in contents (to a lesser extent) and in form (to a larger extent).

[6] Digital base of information on airfield facilities.

[7] Digital base of aeronautical obstacles.

Sheet orientation is vertical and dimensions (for our geographic latitude) are 20' W-E × 15' N-S[8], while M755 maps are horizontally oriented and their dimensions are 30' W-E × 10' N-S. The size of printed map sheets after cutting is, 558,8 × 736,6 mm and 840 × 640 mm, respectively. MDG map has only one frame which limits its contents while M755 map has two frames: internal – determining contents range, and external – limiting the so-called inter-frame field with grid descriptions and road/railway objectives.

Map annotations (marginal information) is almost the same regarding the information range, but differently located or presented in a different form. The main difference results from the fact that all notes in marginal information of MDG are in English. On the M755 map marginal information is bilingual (Polish and English) or trilingual (additionally the language of the country covered by the sheet). Additionally, marginal information of MDG maps includes a elevation guide diagram with four elevation bands (low, medium, high and highest) and the maximum ten height points (including the highest and the lowest on the sheet). Other elements of marginal information on MDG maps, which are absent on M755 maps, are conversion scale of feet into meters and information about readability of the map in red light or red and blue-green light. Additionally, for each pair of longitudes and latitudes creating the frame of an MDG map, information about terrain dimension of 1" is given (e.g. *One second of latitude equals 31 m*).

The range of topographic contents of both maps is similar. Differences result from smaller informational range of MGCP data which results in a smaller number of features on the MDG map. The main difference regards the method of presentation of topographic contents. MDG map is in five colors (black – cultural features, railroads, roads; green – vegetation; blue – hydrography; dark brown – land relief, roads, built-up area, cultivated land; dark blue – aeronautical features and obstacles), while M755 map is printed in four colors. Unlike on the MDG map, aeronautical features and obstacles as well as built-up areas are marked in black and red replaces dark brown. Also, on a map of M755 series cultivated areas are not presented. Apart from a larger color set a wide range of rasters and patterns are used on the MDG map, significantly larger than on the M755 map.

Definitely less symbols of point features are presented on an MDG map. Their insufficiency in comparison to an M755 map is compensated with the use of a point symbol of located objects which substitutes symbols of such features as chimneys, towers, masts, lighthouses, mills, windmills, tombs, monuments, etc. The signature is accompanied with a label, which often leads to excessive density of labels on the map. Specification used for MDG maps elaboration does not allow label abbreviations, therefore their concentration in one place can significantly impair map legibility, e.g. on a M755 series map concentration of three objects (water tower, transformer substation and brick plant) would be labeled *w.w., pod. el.* and *cg.*, and in the case of MDG – *Water tower, Transformer substation* and *Brick plant*.

Aeronautical information presented in a separate color[9] of symbols is of special significance on the MDG map. Presented are land aerodromes, water aerodromes, helipads, aprons, stopways, runways, taxiways, hangars and

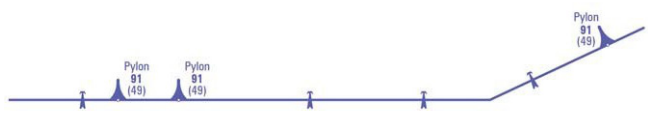

Fig. 2. Power line pylons as aeronautical obstacles (MDG)

[8] TLM specification defines that for 50°-61° latitude a map sheet dimension should be 22,5' W-E × 15' N-S. Change of W-E dimension results from the organization of MGCP data, which are collected in cells of 1° × 1°. To fully utilize data from a single cell for MDG map preparation, W-E and N-S dimenisons must be divisors of 60'.

[9] Dark blue, also called aero blue CMYK 75,70,1,0; Pantone Blue 072U.

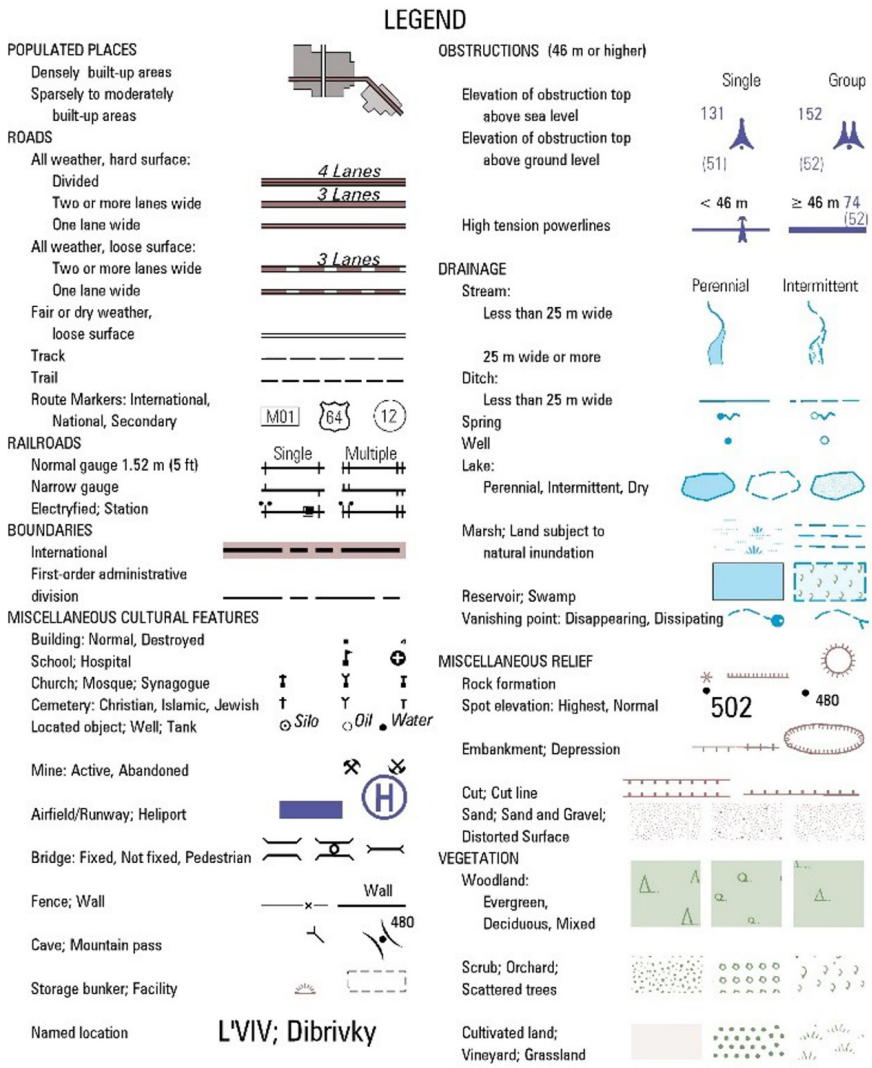

Fig. 3. Legend symbols (MDG)

aeronautical obstacles, including power lines, telecommunication lines, cableways and pylons. Each feature over the height of 46 m (AGL) is presented with a separate symbol of aeronautical obstacle accompanied with its heights (AGL and AMSL) and descriptor. If the feature presented on an MDG map with an individual symbol qualifies as an aeronautical obstacle, its symbol is changed into a general aeronautical obstacle symbol (fig. 2).

On M755 maps the above features are treated with less attention, a symbol of an aeronautical obstacle does not exist, outstanding buildings are only presented with a slightly modified symbol. Other tall features do not change their symbols, they are only accompanied with information about their height (from 50 m AGL). Aeronautical features, power lines, telecommunication lines, cableways and pylons are not distinguished on the map in any way.

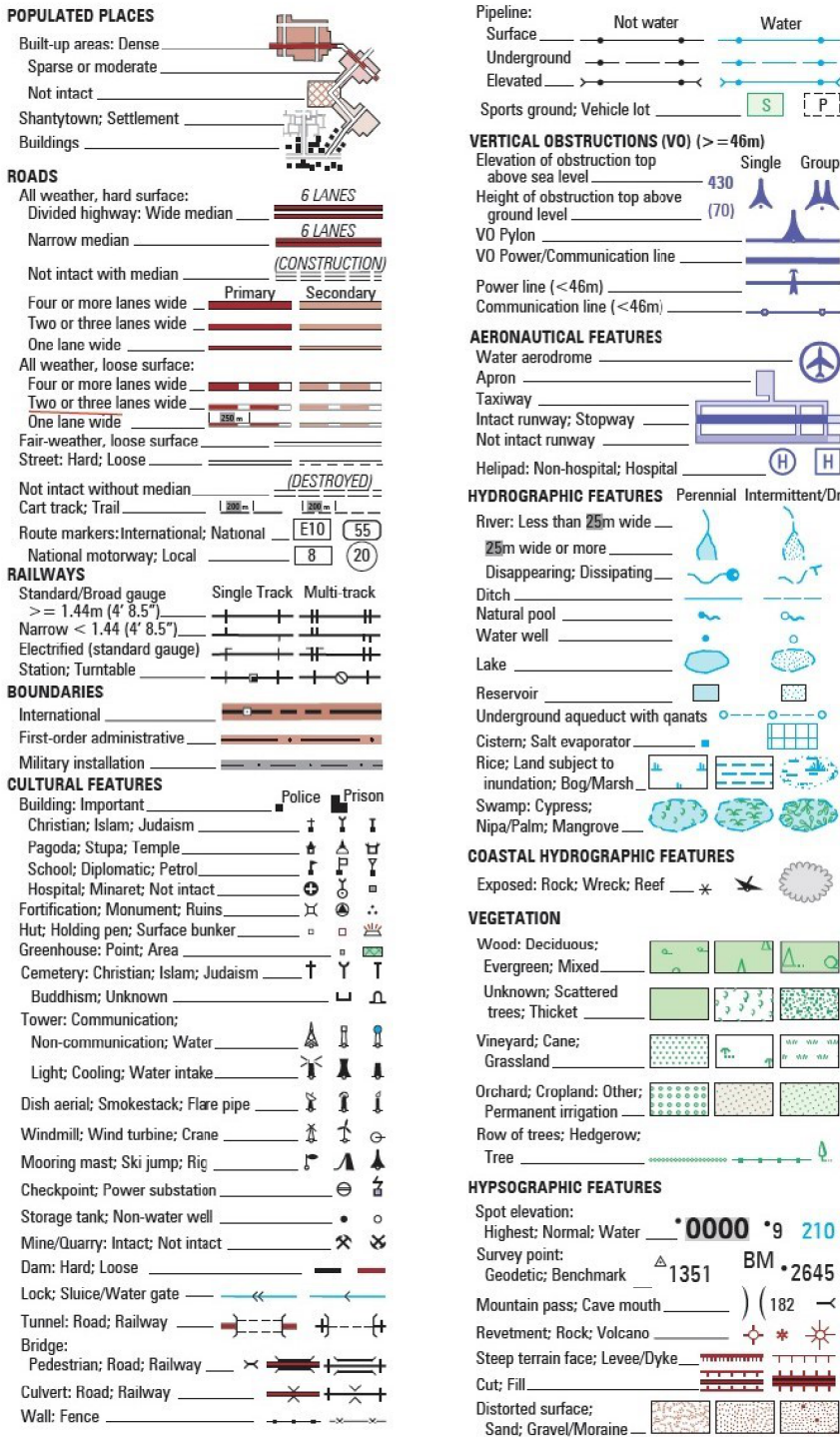

Fig. 4. Legend symbols (MTM)

At the same time, an MDG map has a very limited set of numeric characteristics. Apart from AGL and AMSL heights mentioned above, which refer to aeronautical obstacles, the map presents only the number of road lanes (e.g. 2 Lanes) and the number of railway tracks (e.g. 3 Tracks).

The MDG map had originally been elaborated using MIL-T-89301A and MIL-T-89306 specifications referring to TLM maps in the scales of 1:50,000 and 1:100,000. It was only in 2012 that special guidelines were issued to adapt those specifications to the requirements of MDG (*Standard Product…* 2012). Next step towards formalization of map elaboration was the establishment by DGIWG of the standard for MGCP data presentation in 2015 (*DGIWG 109…* 2015). The new standard, as well as NGA's replacement of MIL-T-89301A and MIL-T-89306 specification with new documents (*Data Product…* 2015) and *de facto* creation of a new map simply called the Topographic Map (TM), resulted in the edition of the first full specification for maps generated from high resolution MGCP vector data (*Data Product…* 2016).

Since the MDG map was elaborated basing on the specification of the TM map, it was renamed MTM (MGCP Topographic Map). The main feature differentiating MTM from MDG is the number of point features increased from 98 to 115 and as a result smaller number of labels and an increased legend of symbols (fig. 3 and 4).

The analysis of the current trends in elaboration of military topographic maps in the scale of 1:50,000 shows that they develop in the direction of simplification and generalization. These are the opposite of the solutions adapted for the Polish civilian map in the scale of 1:50,000 in the "1992" system. The civilian map, despite its level of detail, does not contain information for special air forces and unmanned aerial vehicle, but contains information about tourist trails which are of secondary importance for the structures of management of national security.

The geographic service of the Polish Armed Forces is currently at the stage of completing the MDG project and at the same time implementation of the technology adapted to the MTM map project.

5. Conclusion

Achievements of Polish military geography in the last 20 years are immense. Within a few years it managed to edit topographic maps in the new system of spatial reference conforming to the NATO standards for the area of Poland. It should be noted that only between 1999 and 2003 almost 3000 different maps were elaborated in the total number of 20 million sheets, and at the same time 150 million sheets of maps conforming to Soviet standards were withdrawn from use. Simultaneously with the preparation of analogue maps digital geographic products for automated command systems and new training aids have been developed, and training on the usage of new maps has been conducted within the Polish Armed Forces. These achievements were best summarized by the former chief of the General Staff of the Polish Armed Forces, general Franciszek Gągor (2009, p. 6): *Poland… is the first of the countries which joined NATO after 1999 to ensure full conformity of its own geographic materials with NATO standards. This level was achieved even before the official date of joining the Alliance.*

Despite such achievements some questions about the future present themselves:

- What next with Polish military topographic maps and in which direction a cooperation with civilian service in elaborating them will develop?
- Will the military decide to elaborate a new MTM map for the area of the country, in the light of allied NATO forces stationing in Poland?
- What will happen to the map of M755 series and the update of VMAP L2+?

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