CREATION OF NEXT GENERATION U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS

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ABSTRACT:

The U.S. Geological Survey (USGS) is 2 years into a 3-year cycle to create new digital topographic map products for the conterminous United States from data acquired and maintained as part of *The National Map* databases. These products are in the traditional, USGS topographic quadrangle, 7.5-minute (latitude and longitude) cell format. The 3-year cycle was conceived to follow the acquisition of National Aerial Imagery Program (NAIP) orthorectified imagery, a key layer in the new product. In fiscal year (FY) 2009 (ending September 30, 2009), the first year of the 3-year cycle, the USGS produced 13,200 products. These initial products of the "Digital Map-Beta" series had limited feature content, including only the NAIP image, some roads, geographic names, and grid and collar information. The products were created in layered georegistered Portable Document Format (PDF) files, allowing users with freely available Adobe® Reader® software to view, print, and perform simple Geographic Information System-like functions. In FY 2010 (ending September 30, 2010), the USGS produced 20,380 products. These products of the "US Topo" series added hydrography (surface water features), contours, and some boundaries. In FY 2011 (ending September 30, 2011), the USGS will complete the initial coverage with US Topo products and will add additional feature content to the maps. The design, development, and production associated with the US Topo products provide management and technical challenges for the USGS and its public and private sector partners. One challenge is the acquisition and maintenance of nationally consistent base map data from multiple sources. Another is the use of these data to create a consistent, current series of cartographic products that can be used by the broad spectrum of traditional topographic map users. Although the USGS and its partners have overcome many of these challenges, many, such as establishing and funding a sustainable base data-maintenance program, remain to be resolved for the long term.

1. INTRODUCTION

In 1884, the U.S. Congress authorized the U.S. Geological Survey (USGS) to systematically map the United States. In the early 1990s, the USGS completed first-time topographic mapping coverage of the nation. In 2010, during the 125th anniversary of the initial Congressional authorization of funds, the USGS is in its second year of a 3-year cycle to produce the nation's next generation of topographic maps. A natural question is how the task that initially took approximately 100 years to complete can now be accomplished in 3 years. The answers lie in new technology and creation, maintenance, and use of nationally consistent data maintained and updated by a network of partners.

1.2 Background

From the mid-1930s until the early 1990s, the USGS completed its largest scale, highest resolution topographic maps in the USGS topographic mapping series. These maps are in the familiar 7.5-minute quadrangle map format at scales of 1:24,000 and 1:25,000 (1:63,360 in Alaska). The number of quadrangles produced during this time is shown in figure 1(Moore, 2000).

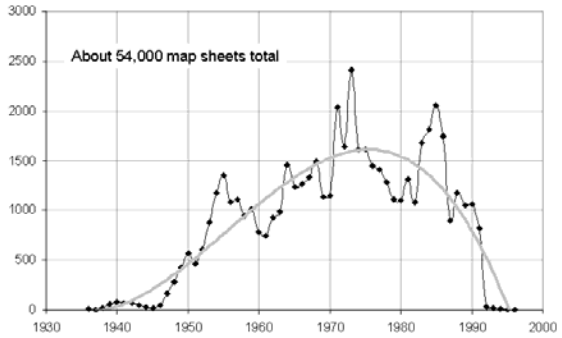

Figure 1. Number of primary series maps produced (vertical axis).

The maps in the 1:24,000 and 1:25,000-scale topographic map series contain a large number of features, as shown in the sample in figure 2 from the Hollidaysburg, Pennsylvania 7.5-minute quadrangle map, originally published in 1963, photorevised in 1972, and photoinspected in 1981. These features include Boundaries; Culture – Miscellaneous and Transportation; Drainage and Related Features; Foreshore-Offshore Features; Public-Land Survey Data; Vegetation; Reference Systems; and Relief and Related Features (Thompson, 1981).

Many of the features included in the original USGS topographic maps were collected or verified by USGS personnel in the field. Those features that were photoidentifiable were captured using photogrammetric methods beginning in the early 1930s, but many of the Boundaries, Cultural Features, and Public Land Survey System features required field collection and/or verification. In addition, the geographic names associated with these features required field work to collect and verify with local sources.

Approximately 770 hours of labor, on average, were necessary to produce an original, primary series (1:24,000, 1:25,000, 1:63,360-scale) USGS topographic map. The investment for completing coverage for the conterminous United States in this series is estimated to be at least $3 billion in 2007 dollars (Laurence Moore, written communication, August 18, 2010).

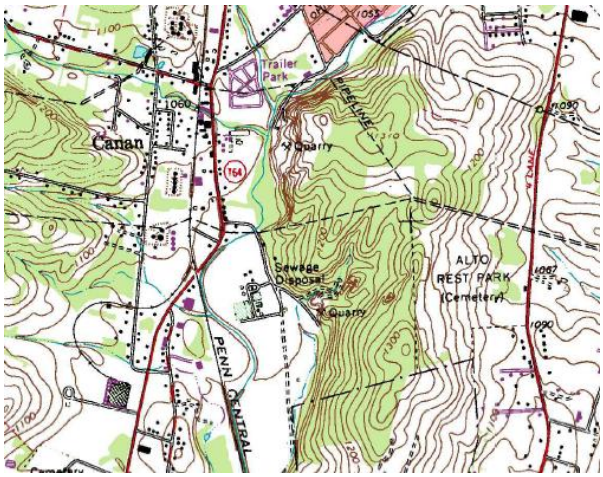

Figure 2. Sample of USGS Topographic Quadrangle 7.5-minute, 1:24,000-scale map from Hollidaysburg, Pennsylvania

Beginning in the 1970s and in parallel with the completion of primary map series coverage of the United States, USGS mapping scientists were developing data models and processes to collect and store map data digitally. Features were generally captured and represented as either raster or vector digital representations. Vector data products included the Digital Line Graph (DLG) and the Land Use Data Analysis Program (LUDA) (Usery, et al., 2010). Raster data products included the digital elevation model (DEM) and eventually the digital orthophoto quarter quadrangle (DOQ). Much of the information included in these digital data products was derived from the topographic maps. Conversion of this information from hardcopy format to digital products was a major effort for the USGS and its partners during the 1970s through the 1990's. Modern databases containing the successors to these initial digital data products still exist today (2010) and serve as the public domain base map information for the United States. Collectively, these databases comprise *The National Map*.

In 2001, the USGS produced a report titled, "*The National Map:* Topographic Mapping for the 21st Century" (U.S. Geological Survey, 2001). The report included several key directions for the USGS' mapping program in the future. The first was the idea that the USGS, as the nation's civilian mapping agency, should lead the maintenance of a set of consistent, updated, base spatial data for the United States. These data should be maintained through partnerships between public and private sector stakeholders. The data would serve as the source for modeling and analysis, as well as derived products. One significant statement in the report was that "The USGS will continue to provide a standard set of digital data products and high quality paper topographic maps derived from *The National Map*" (U.S. Geological Survey, 2001). This statement became the driver for the creation of the US Topo product.

2. THE US TOPO PROGRAM

In November 2008, the USGS embarked on a program to create an updated series of topographic maps derived from *The National Map* databases, thus following the path established in the 2001 report. At the time of the US Topo program's inception, the United States Department of Agriculture's (USDA) National Aerial Imagery Program (NAIP) was following a 3-year cycle of acquisition of 1-meter or better orthorectified imagery for the continental United States(U.S. Department of Agriculture, 2010). Since one of the key layers to be included in the next generation mapping product was to be an orthorectified image, program leaders decided to aim for a 3-year update cycle for the US Topo products following the NAIP cycle of acquisition. Each year, the USGS would create updated map products for one-third of the nation's approximately 55,000, 7.5-minute quadrangle, primary scale series products. Thus, roughly 18,333 maps would need to be produced each year to meet the program's goals. The content of the product would be derived from *The National Map* databases, with the addition of the NAIP imagery. The process would strive to be automated, with a minimum of data editing at the time of product creation. The fundamental assumption with this process was that the acquisition and maintenance of the data would be performed before the addition of the information to the map product. The feature content would initially be minimal with the gradual addition of features as data became available and of sufficient quality to add to the map products. The goal of the program would be to eventually reach the same level of feature content as included in a traditional USGS topographic map product. This would be dependent on the availability and quality of the data sources.

2.1 The first year of the US Topo program: "Digital Map-Beta"

The first year of the 3-year cycle beginning in late 2008 was a ramp-up year in many respects for this program. The initial product contained limited content, as described in ""Digital Map-Beta"; 7.5-Minute Quadrangle Maps in GeoPDF; Draft Version 0.0.25" (U.S. Geological Survey, 2009), including:

- a NAIP orthorectified image; typically 1-2 meter ground sample distance, leaf-on, preferably current to within 3 years, preferably true color;
- Interstate and Federal highways, state routes, local roads in urban areas where cartographic considerations permit, all available roads in rural areas. Note that in 2009, the primary source for roads was the U.S. Census Bureau;
- airport names from the Geographic Names Information System (GNIS);
- geographic features and populated places from GNIS as cartographic considerations permit;
- names of hydrographic features from the National Hydrography Dataset (NHD);
- national boundaries;
- map collar and grids, including a 1,000-meter Universal Transverse Mercator (UTM) grid drawn and labeled in conformance with the U.S. National Grid (USNG) standard, corner coordinate labels and 2.5-minute ticks and labels, State Plane Coordinate System ticks; and

- Federal Geographic Data Committee (FGDC) -compliant metadata.

The file format for this product, initially called the "Digital Map-Beta," was a layered GeoPDF. Users with freely available Adobe® Reader® software were able to view, print, and perform simple geographic information system-like functions using the product. An XML format file containing FGDC-compliant metadata was attached to each GeoPDF file.

The goal for the first year of the program was to complete one-third of the continental United States with the "Digital Map-Beta" product, with a slight reduction in the goal because of the late start of the program in the production year. The states to be completed in fiscal year 2009 (October 2008 to September 2009) are shown in figure 3 in yellow.

Figure 3. US Topo Work Plan

The gray areas in these states are managed by the United States Department of Agriculture (USDA) Forest Service (USFS). The USGS maintains an agreement with USFS to show only USFS roads over their lands. During 2009, the two agencies worked together to devise a plan to add USFS roads to USGS map products in these areas; however, the process was not mature enough to add these roads during the first year of the program. Thus, the USGS did not produce products over USFS lands in 2009, but chose to defer production in those areas until USFS roads could be shown.

Because of significant start-up issues related to large volume production of Digital Map-Beta products, the goal of completing one-third of the continental United States was not met in 2009. The USGS was, however, successful in producing 13,200 of these products and making them available for free download through the USGS Map Store at http://store.usgs.gov by September 30, 2009.

2.2 The Launch of the US Topo Product

During the second year of the US Topo program, significant feature content was added to the product. Most notably, contour lines and labels were added to depict the shape of the terrain. These contour lines were generated by software using source data from the National Elevation Dataset (NED) (U.S. Geological Survey, 2006). Hydrography or surface-water features from the National Hydrography Dataset (NHD) (U.S. Geological Survey, 2010) were also added to the US Topo feature set. Both the NED and the NHD are databases within *The National Map* that were derived in large part from the original published topographic maps. An example of a US Topo product with the orthoimage layer visible (top) and not visible (bottom), thus allowing surface-water and contour features to be easily viewed is shown in figure 4. Another notable change to the product in 2010 was the switch to a commercial roads data source in the latter part of the production year. In addition, the USGS began adding USFS roads to the product within National Forest boundaries (Moore, et al., 2009).

States that were planned for production in 2010 are shown in figure 3 in red. The products that remained in the 2009 production plan at the end of the year were added to the 2010 production goal for a total goal of 20,380, 7.5-minute US Topo products needed to complete the second year of the 3-year cycle. As of the writing of this paper (August 26, 2010), 15,800 US Topo products had been completed and made available at no cost for download through the USGS Map Store. The rate of increase in this total was approximately 150 per day.

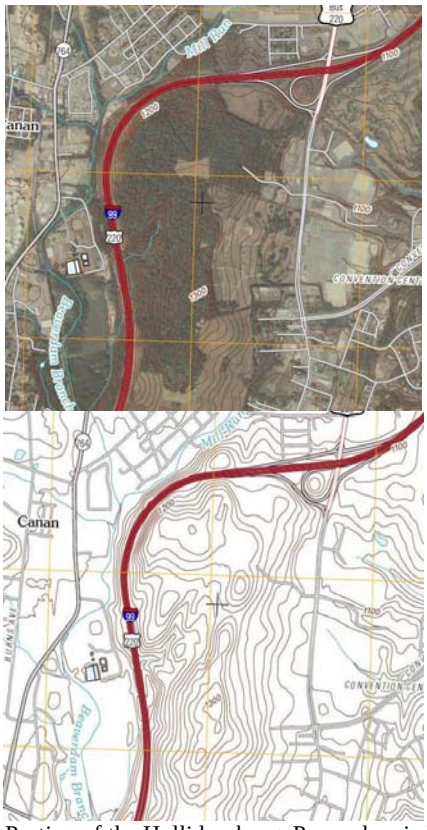

Figure 4. Portion of the Hollidaysburg, Pennsylvania US Topo product with the image layer on (top) and off (bottom).

2.3 Progress and Challenges

Technological challenges plagued the USGS in the initial phases of the "Digital Map-Beta" and US Topo start-up period. Bringing

together a large volume of data from multiple databases to produce a consistent product pushed the hardware, software, and human resources to their limits in many cases. By the end of 2010, however, the USGS had resolved many of these issues and had implemented a relatively stable workflow that was mostly automated. Future work will include automating additional steps in the workflow, adding more feature content, and eventually offering more opportunities for users to customize their own topographic map products by interactively selecting feature content and geographic area of interest.

Although the technological challenges of putting the pieces together were significant in the initial phases of product development and deployment, the foremost challenge for the US Topo product in the long term is the availability of current, consistent, complete feature data in *The National Map* databases. The difference in feature content between the map in figure 2 versus the map in figure 4 is evident. The issue of data availability can be divided into two primary cases. In the first case, the data are available, but are not yet in a form that can be easily added to the US Topo product. This is the simplest case to resolve and the USGS is actively working with partners to add available features in 2011 and 2012. For example, state and county boundaries as well as National Forest and National Grassland boundaries are planned to be added to the US Topo product in 2011. Vegetation information and urban tints will be added as derivative layers from the National Land Cover Database (U.S. Geological Survey, 2010). Fire stations will be the first in a series of point features depicting man-made structures to be added to the US Topo product as the national source of information is completed within the National Structures Dataset.

The second case is more difficult to address and is a long-term, systemic issue. It involves features that were traditionally shown on USGS topographic maps that are currently (2010) unavailable as public domain data in a form that is complete, current, and nationally consistent for the United States. Many of these features are cultural or man-made entities, including transportation features. These types of features tend to be expensive to collect, verify, and maintain because of the frequency of needed updates. Some are maintained at the local level; however, they are typically not collected to national standards and varying data sharing policies make accessing this information challenging. In other cases, these data are collected and maintained by commercial providers who resell the information on a subscription or license-based business model. Although the USGS has made use of commercial roads data on its US Topo product, this is a departure from the previous USGS practice to use data that are freely available in the public domain. During the next several years, the USGS and its Federal and state partners will need to determine the long-term strategy for either creating public domain datasets for these feature types, or purchasing commercial data.

3. SUMMARY

The USGS is continuing its tradition of creating a high quality, consistent, current national topographic map series for the United States by implementing the recommendations made in the 2001 report initially defining *The National Map.* This will be accomplished by relying on partnerships with other Federal, state, and local governments, as well as the private sector, to acquire and maintain the source data that underlies the topographic map series. The most significant risk to this approach is the lack of publicly available source data for significant features included on the original USGS topographic maps. If public sector leaders in the U.S. geospatial community are successful in mitigating this risk, the USGS has shown that *The National Map* strategy can be used successfully to create a set of base geospatial data for the nation and a derived national topographic map series.

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