REBUILDING CANADA´S NATIONAL CANADA´S TOPOGRAPHIC MAP PUBLISHING PROGRAM

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Executive Summary

This paper provides a short history of topographic mapping in Canada, and concentrates on the efforts of the federal government during the past two decades. The development of a national digital topographic database from the early 1990s to 2007 was followed by the implementation a new semi-automated map production system, which uses this national database as the main source. The term Map Generator was adopted to emphasize that the new map publication system would maximize automation and limit human intervention to the strict minimum. The federal government needed a very efficient system to publish maps from the best available topographic data, in the form of print-ready digital files. While symbolization and the creation of the map surround or template could be fully automated, text placement requires some data preparation and a minimal amount of editing to maintain the high cartographic standards of previous "conventional" maps. The initial plan in spring 2008 included the development and implementation of the Map Generator for an output of 900 new maps in three years. These map tiles were selected in areas of the Canadian landmass where map demand is high.

To a large extent, the future of the Map Generator is linked to the future of paper maps. Having implemented a process whereby we can generate a print-ready map file from a vector topographic database, two areas of improvement remain: the data preparation and integration, and the map delivery formats. It is expected that the results of the data preparation and integration to support the Map Generator will also be profitable to other web or thematic mapping processes and delivery portals. Most importantly the building of relationships between data producers, data managers, map publishers and map users has created a new environment of collaboration and innovation that will position us well to take the next leap into the future of mapping services.

Historical Perspective

Topographic mapping in Canada began in 1843 when the Geological Survey of Canada commenced preparing maps for geological reports; these maps were produced in a variety of scales and depicted mainly landforms and travel routes such as water courses and lake shores. The first organized system of mapping in Canada started in 1871, and was based on a land survey system carried out in the Prairie Provinces at a scale of 1 inch equals 3 miles. The current

National Topographic System (NTS), which provides the numbering scheme for Canadian map tiles at scales of 1:50 000 and 1:250 000 originated from a 1948 agreement between the military mapping agencies of Canada, United States and Great Britain to standardize map scales for defence purposes.[1]

Since 1950, the Department of Natural Resources and the Department of National Defence have collaborated to in various surveys and mapping projects to complete the topographic map coverage of Canada. The landmass of 10 million square kilometres requires approximately 1,000 tiles at 1:250 000, and 13,000 tiles at 1:50 000 scale. While the National Defence Department contributed mostly to the mapping of remote areas, Natural Resources Canada (NRCan) retains to this day the mandate to complete and maintain Canada's topographic map coverage at those scales for the federal government. Provinces each have their own mapping programs to generate larger scale maps for their own governance and land use planning.

A survey of Canadian map distributors conducted during the fall 2006 - winter 2007 revealed that the Canadian public is very fond of the NTS series of maps produced by NRCan. On the other hand, since Canada has the world's lowest population density, it is not surprising that the large majority of topographic map consumption is concentrated over only 10% of the geographic area, generally in Southern Canada along the Canada-US border. The federal government simply cannot rely on map sales alone to fund the mapping program. On the other hand, the level of government funding and the funding mechanisms themselves have fluctuated over the years. Once the 1:250 000 scale mapping was completed, the government had to carefully manage the level of effort between three lines of production: new 1:50 000 scale maps where none exist, updating the existing maps, and modernizing the map production systems. Regarding the production of new maps, as of summer 2009, there remain 1,600 tiles that have never been published. Figure 1 shows the current map coverage of Canada. The map revision cycles took different forms throughout the years depending on the regions, the growth of populated areas and the availability of imagery. The first digital cartographic editing system was established in the early 1990s based on the Canadian Caris software platform. Given the exponential growth in technology and data availability, the challenge of finding the right balance of effort between topographic data collection, mapping and technological platform improvements continues to this day. To ease the burden on both federal and provincial governments, a federal –provincial 'Geomatics Accord" has emerged in the late 1990's promoting shared responsibilities for collecting large scale (1:50 000 and larger) topographic data map under the GeoBase program.[2]

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[1] A.M. Floyd, Historical Development of the National Topographic System of Map Numbering for Canada, Natural Resources Canada, Surveys and Mapping Branch, November 1969.

[2] GeoBase data is available at www.GeoBase.ca. The governance of GeoBase program is assumed by the Canadian Council on Geomatics with representatives from the federal, provincial and Territorial governments

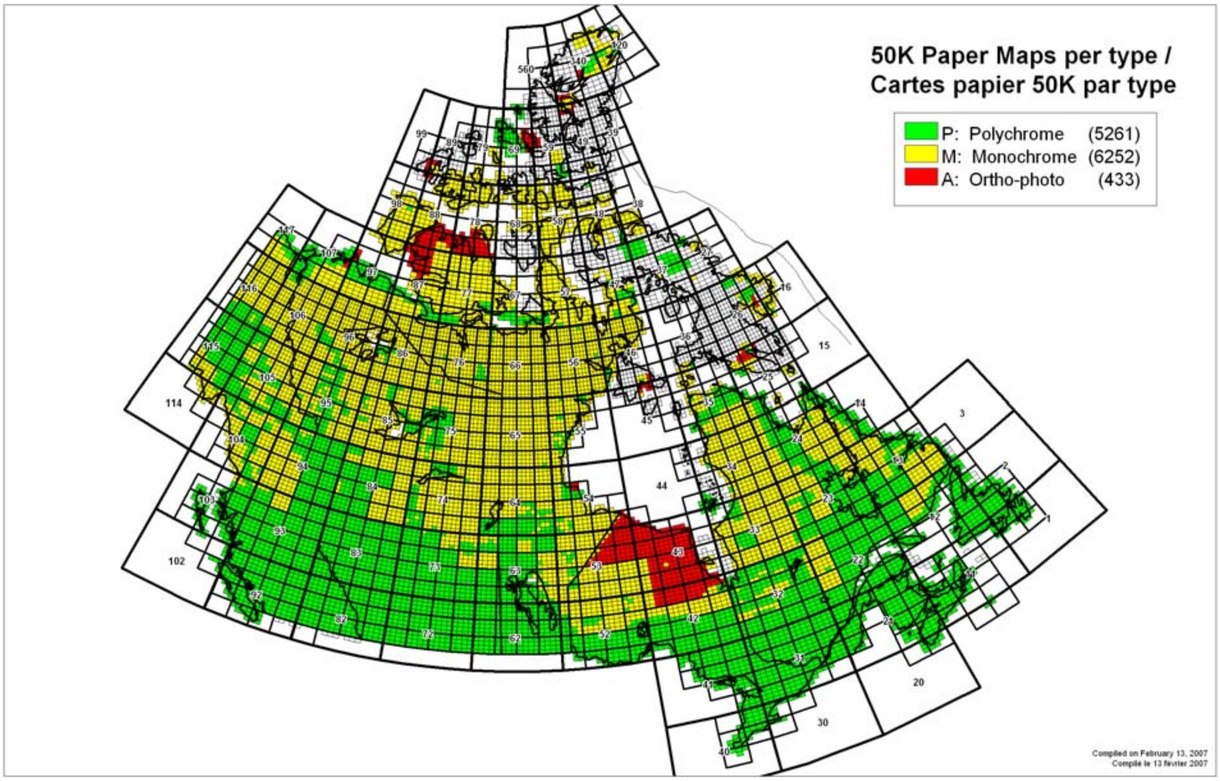

Fig.1. Canadian Map Coverage at 1:50,000. The areas in Northern Canada where no colour is indicated (white) correspond to the missing 1,600 tiles that have yet to be published.

In 1993, NRCan stopped its conventional map production and map revision cycles to concentrate on the creation of a vector topographic database form the existing conventional national map series. Once digitized in vector databases, these maps/datasets could be improved in many ways and a new map revision system could be instituted. The first step was to bring all maps to the same datum (NAD 83). The next step was to improve the planimetric accuracy of the data to +/- 30 meters, matching that of a GeoBase National Imagery Layer (ortho-rectified LandSat7 2000-2003). This imagery was also used to update topographic features for the majority of the Northern Territories: Yukon, Northwest Territories and Nunavut. Through the federal-provincial GeoBase program, it was also agreed that selected national framework layers of topographic data would be collected jointly to build a national database, which would gradually substitute the legacy data. Rather than updating maps by tile, the national data layers are generated in collaboration with the provinces[3], at large scale and closest to source. Under a federal partnership funding mechanism called GeoConnections, standards and data models were developed jointly with the provinces, and partnership funding agreements were coordinated. While provinces

[3] NRCan retains full responsibility for collecting topographic data over Northwest Territories and Nunavut, but not Yukon, which has a devolved responsibility.

would take a primary responsibility for providing and maintaining provincial elevation dataset, as well as their roads networks, and watershed data, NRCan took a prominent role in providing the initial technological infrastructure for this national database, and retained full responsibility for the North-West Territories and Nunavut. Figure 2 shows the National GeoBase data layers.

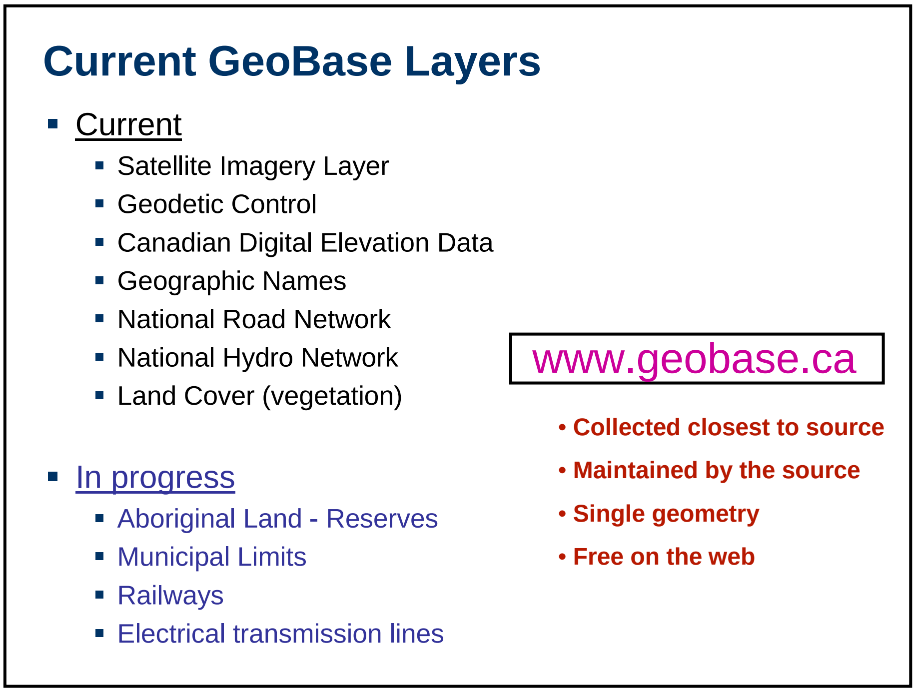

Fig.2. GeoBase Layers

The Geospatial Database that resulted from the combination of both new GeoBase data with the legacy data of the older conventional map series serves as the source for multiple products, which are currently distributed for free to the public via www.geogratis.ca. The first example is the CanVec product, which consist of the vector form of the database, in GML and Shape file formats. The second example is the Toporama web service, which provides a WMS output of the CanVec data. The missing link was the ability to generate a full size topographic map at 1:50 000 scale from the same database.

In 2007, after 15 years of digital topographic database developments, and with the advantage of the latest advancement in GIS technology, the Earth Sciences Sector of NRCan instituted a new Topographic Mapping program to update and publish a new generation of Canadian Topographic Maps. This will be the focus of this paper.

Objectives

The approach of the new mapping program is to utilize the GeoBase data, and complement it where necessary to update or complete its content, and publish the next generation of the 1:50 000 scale national topographic map series. The GeoBase data layers must therefore be integrated (vertically aligned) with legacy vector data from the conventional maps. In addition, through separate processes, place names and administrative limits are delineated and integrated, and imperial contour lines (with intervals in feet) on the older map sheets are converted to metric intervals. The new digital maps resulting from this process are distributed on the web for free in TIFF and PDF formats to be downloaded and printed locally by individuals, or by distributors who can now offer paper-map clients the next edition of the full-size topographic maps.

The term Map Generator was adopted to emphasize that the map publication system or engine would maximize automation and limit human intervention to the strict minimum. The federal government needed a very efficient system to publish maps from the best available topographic data, in the form of print-ready digital files. In essence, the new program establishes the link between the national digital topographic database that was has evolved over the last 15 years, and updated large format topographic paper maps that continue to be in demand by several segments of the public and private sectors including the military, geologists, explorers, recreational users, etc.

From a cartographic perspective, three automation objectives were set:

- Symbolization. Some map symbols needed to be modified to be red-light-readable (a military requirement) and adapted to the current GIS - map publishing and plotter technology.

- Text Placement. A maximum average of two hours of human intervention per map sheet was set as a target, focusing mostly on finalizing the 10% of text placement that could not be automated.

- Map surround (collar). The neat line templates and grids were prepared in advance, but all text and graphics within the surround was to be created automatically and dynamically from the metadata.

The initial production plan in spring 2008 included the development and implementation of the map generator for an output of 900 new maps in three years.[4] These map tiles were selected in areas of the Canadian landmass where map demand is high. See figure 3 for initial target areas.

Prototyping and consultation

Since the new topographic mapping program had been initiated following a consultation process with the map distributors, the program deemed essential to maintain contact with map users during in the initial stages of development. The selection of software platforms for cartographic editing quickly became a priority so that prototypes could be created and modified to achieve the preferred "look and feel" of the maps.

The cartographic editing software selection followed a request for information from the GIS industry and a formal evaluation process. After 4 months, the final decision was to use ESRI's

[4] The number of 900 map sheets corresponds to approximately 60% of the best selling map tiles. Among the first 900 sheets selected, some special demands of the Geological Survey of Canada and National Defence Department were injected in Northern Canada.

ArcGIS in combination with several other software products. The overall architecture and design of the system would be performed in-house; this would allow better control over map design, and provide the flexibility to adapt to the continual improvements to the source databases. See figure 4 for the list of software used by the Map Generator system. The prototypes were developed using personal geodatabases, recognizing that Map Generator production system would inevitably migrate to an enterprise platform.

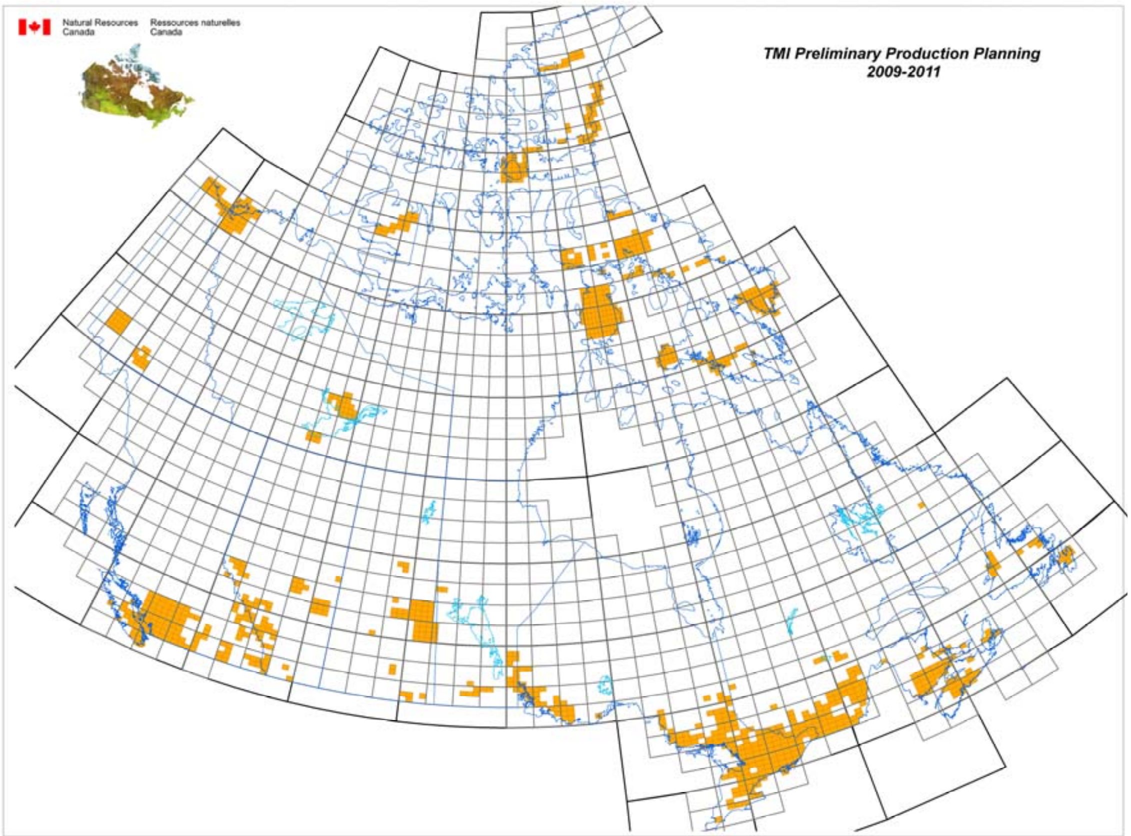

Fig.3. Initial target areas for the new Topographic Mapping Program

Final Software for Topographic Map Production System

- Enterprise Architect for architecture design
- ArcSDE 9.1 on Oracle for Database
- ArcGIS - ArcEditor 9.2 for map publishing
- ArcObject
- ESRI Grid Manager extension for grids
- Safe Software's FME for data manipulation
- MapText's Label-EZ, Label-Edit and Label-Contour for text placement
- Opalis ,VB, .net for scheduling tool
- Python
- TerraGo for GeoPDF output

Fig.4. List of software used for the new topographic map production system

Technical advisory teams were established early in the development process to:

- determine what features were essential to the maps,
- investigate and define reliable sources, and
- identify potential cartographic challenges.

The results of the work of these technical advisory teams were briefed and discussed internally, but also proposed to external stakeholders which included colleagues in other departments of NRCan, users from private industry and academia, the Association of Canadian Map Librarians and Archivists (ACMLA) and the Department of National Defence (DND). This consultation process helped reach decisions on the essential topographic features and the map design for the next generation of topographic maps. Over a period of six months, these consultations provided the feedback necessary to design the map generator system and better anticipate its final implementation cost and productivity rate. See figure 4.

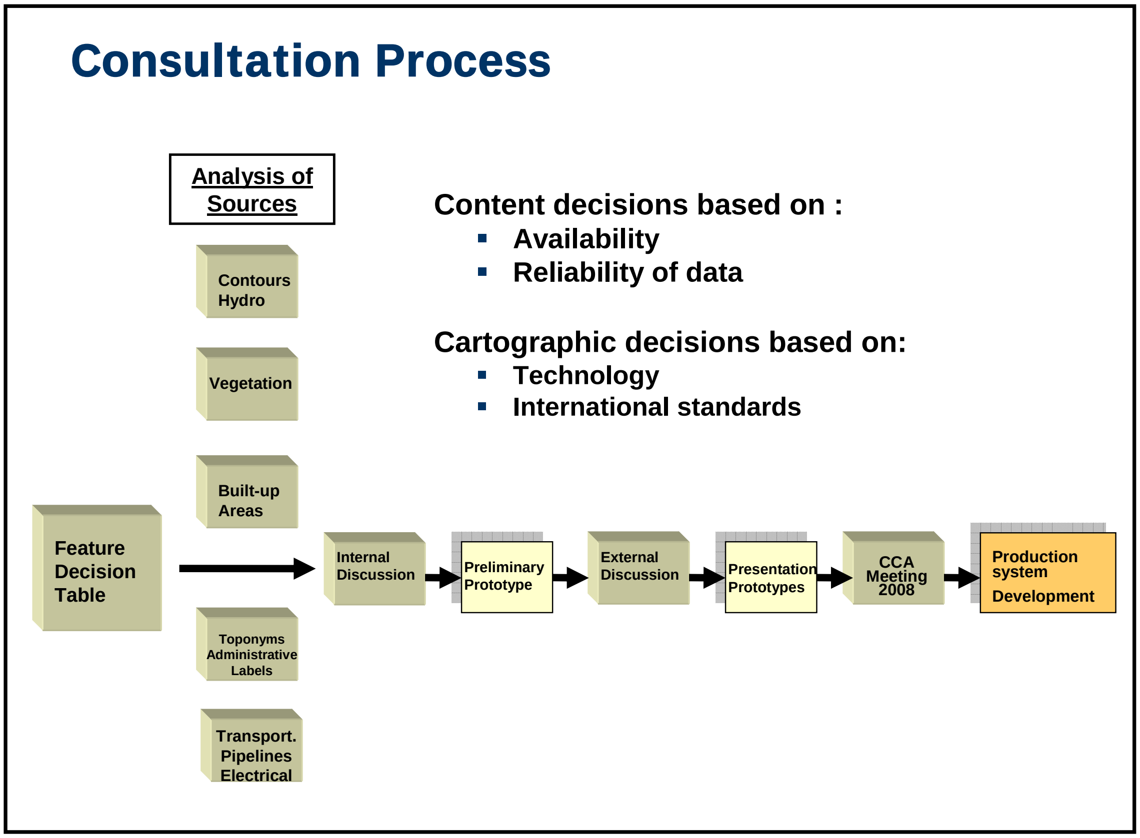

Fig. 4 Consultation process for map design

The implementation of the map production system within NRCan involved two teams in two separate locations, connected by the departmental communications network. The development and design team included eight engineers located in from Ottawa, Ontario, where cartographic expertise was the strongest; this team was in turn exploiting the information technology infrastructure located in Sherbrooke, Quebec, where the data collection and database expertise was concentrated . To ensure that other production workflows using the same geospatial database would not be adversely affected by the Map Generator implementation, the engineers followed a rigorous design process whereby they gradually migrated the data processing from a development environment, isolated from other production, to a testing environment, and finally to the full-fledge production environment. This implementation process was completed in March 2009 after 12 months: this was three months longer than originally anticipated, but proved necessary to provide increased flexibility and reliability of the final system.

Map Generator Development

The following are some of the major phases of development for the Map Generator:

- From a cartographic map design perspective, the first step was to adjust some of the map symbols from the conventional map specifications to the capabilities of the ArcGIS 9.2. The map surround and grid ticks were also re-designed and simplified to improve readability.

- Since the federal geospatial database containing the combination of the GeoBase data and the legacy data had control measures that restricted the integration of non-GeoBase data, a separate "Cartographic" database was created to store the needed complementary data, including toponyms, administrative limits, grids, etc. This database also included the final representation files after the editing process.

- Several data manipulation scripts were programmed using Safe Software's FME to enhance the "vertical" integration between various data layers and to facilitate their cartographic representation.

- For text placement, the sets of rules that had been developed for our previous cartographic editing system were transposed and enhanced using MapText Label-EZ software.

- The automatic map creation steps were programmed using VB, .NET and ArcObjects, and the sequence of production is controlled using Opalis software.

- Starting from the principle that metadata was essential for both the final product as well as each data layer within the map; the production system was linked directly to the production metadata database, which had already been established for other production lines. The map production process could not be initiated without having provided all metadata for that sheet according to FGDC standards.

Data Preparation

The map publishing component of the production process map depends heavily on a series of data preparation activities that must be completed prior to the publishing step. They include:

- The conversion of imperial contours into metric contours if not already done (approximately half of the map sheets need this conversion) ;

- The preparation of UTM and MGRS grids;

- The generation of bar codes, ISSN and ISBN numbers; and

- The updating, delineation and integration of official place names, provincial administrative boundaries such as municipalities and parks, and federal boundaries, e.g. airports, National Defence ranges and training areas, etc.

The automation of text placement is facilitated through the use of placement rules that require all linear and surface features, real or virtual, to have their name "tagged" as attributes to their respective geometry. The most complicated and time consuming step of this preparation process consist in aligning administrative limits and virtual features, such as mountains and bays, with the physical entities that they are related to. This "Digital Compilation of Geographic Names" process is currently performed on a separate production system. The resulting delineated toponyms and boundaries must then be imported into the Cartographic Database. On average, one operator takes a day and a half to compile a sheet that has 175 toponyms. The number of toponyms and administrative boundaries per map sheet has become the key factor for production planning, as it affects both the data preparation time, and the cartographic editing time. The success rate of the automated text placement is estimated at 90%, hence the need for an average of 2 hours of cartographic (text placement) editing per map sheet.

Map Publishing Workflow

Once the data preparation is completed, the sequence for map publishing proceeds with three automatic and two manual steps as follows:

- The operator calls the topographic data map sheet for a map sheet number form the Cartographic Database. The Map Generator automatically provides all the topographic data (inside the neat line) on the screen, already symbolized according to the specifications. Since 90% of the text is positioned correctly by the text placement software, the operator can concentrate on the manual editing required which is already highlighted in red;

- The operator manually edits the text placement and checks for gross data errors;

- The operator then sends the file back into the Map Generator process, which finalizes the symbolization and places the map surround template automatically;

- The operator and supervisor perform the final visual inspection of the complete map sheet; and,

- The Map Generator creates the TIFF, PDF and GeoPDF, and automatically and places them on a server for distribution.

- A final quality assurance check is performed to confirm that the scale of the final paper version of these files is correct.

Results and Achievements

The Map Generator has been in operation since March 2009. The initial map publishing productivity rate during the first three months was one map per operator per day for the priority area of the 2010 Vancouver Olympics and Paralympics games. During the first few weeks, when the database would first appear symbolized on their screen, the operators had to detect and think through numerous unusual cartographic events or circumstances. Several data preparation steps needed adjustments, but after the first 150 map sheets, most of the unusual cases had been encountered and dealt with through programming or adjusting the editing processes. It is anticipated that, as the operators refine their editing procedures, they will achieve the expected rate of two map sheets per day.

These early successes have since generated interest from some provinces that are now considering partnership arrangements for data sharing and map publishing. The production of the remaining 1600 map sheets in Northern Canada (Nunavut and North-West Territories), that have never been published has also been recently added to the production objectives in July 2009.

Lessons

At the start of this process, under pressure from the users, the approach taken by the Map Generator design team was to retain as much of the previous editions' map content as possible, and reduce it only if no reliable source could be found.[5] The resulting map therefore indicates validity dates by layers e.g. roads, hydrology, vegetation structures, etc to indicate that not all feature classes are updated to the same date. Although the new maps will have an overall new look & feel and a recent publication date, the content will be partially revised. Client feedback will provide indications if the content improvement will be sufficient to maintain interest in this product. Given the increasing availability and popularity of commercial web mapping services offering navigation information and imagery, it is likely that the federal government will eventually concentrate on a lesser number of feature classes to improve the completeness and accuracy of each national GeoBase layers. Content improvement for built-up areas, buildings, and resource roads remain to be addressed.

As the engineers progressed in the development of the publishing process, it became obvious that some symbols had to be modified for a variety of reasons. Given the red-light readability criteria, the choice of road network colours has a cascading effect on numerous other symbols. The map design experts had to make adjustments in the context of a preferred colour palette for the map, and other objectives of regrouping associated feature types under colour groupings. Finding the right balance between the need for automation and the maintenance of good cartographic quality proved very challenging at times. For example, several symbols were created in an effort to reduce the use of labels given the aim of reducing text placement conflicts.

Despite management pressures to start production early, the additional time spent in development during the implementation stage has proven its worth since to date there has been no significant work stoppage due to a Map Generator system malfunction. By building the system with a multi-step approach, the developers provided much needed flexibility to be able to modify the symbology and surround at a later date, in reaction to client feedback; by simply re-sending the cartographic database through the final automatic steps of the map generator with new parameters, different versions of the maps can be generated using batch processes.

The majority of the complications in the development and the implementation of this process originated from either the intrinsic quality of the datasets, or the lack of integration between various data layers from various sources. Data preparation activities were essential in order to maintain a reasonable cartographic standard, and limit the manual cartographic editing to text placement only. Among all data preparations, the integration of administrative limits was the most problematic as these boundaries often follow natural features such as rivers and shorelines. Assembling legacy with new data, dealing with varying levels of accuracy and varying scales between datasets required additional data preparation motivated mostly by the desire to maintain the high cartographic quality of the previous generation of maps. It became obvious that: improving the data at the preparation stage had a direct effect in facilitating the cartographic

[5] The conventional maps up to 1993 included 390 items within the map legend.

stage; automated map publishing is much more efficient if all data is retrieved from a single database; and full automation of map publishing would only be possible with fewer layers of "vertically integrated" data, which we did not have.

Future

To a large extent, the future of the Map Generator is linked to the future of paper maps. While the future demand for paper topographic maps looks uncertain in a world where all kinds of digital portable devices connected to the internet have a map display capability, the need for them will never completely disappear. Having implemented a process whereby we can generate a print-ready map file from a vector topographic database, two areas of improvement remain: the data and the map delivery formats.

The advent and popularity of numerous web mapping services that require relatively little GIS expertise will create more opportunities for users to create their own thematic maps on the web. From a data perspective, the emphasis of Natural Resources Canada' mapping program will likely be placed on improving the completeness and integrity of the topographic base maps that will form the structure or frame upon which other thematic maps could be made; map layers will likely be limited to elevation data, transportation, hydrology, land cover, official names and administrative limits. Within each of these layers, the content and level of attribution provided by NRCan will be limited to what can be achieved through federal-provincial collaboration. By limiting the content to emphasizing the integration of these layers at the 1:20 000 to 1:50 000 scale range, we will facilitate both the cartographic and generalization processes of both public and private sector geomatics agencies.

Topographic data integration and map generalization projects require a robust and flexible spatial data infrastructure. The Canadian Geospatial Data Infrastructure was reinforced largely through the GeoBase program, which was indeed a first instance of collaborative mapping between government levels. Although the GeoBase program has been extremely successful, it's now time to take advantage of a broader spectrum of collaborative mapping venues including Volunteered Geographic Information. Modifications to NRCan's geospatial data management approaches are planned to facilitate the intake of a wider variety of data sources, and to work more efficiently with multiple collaborators. Such objective poses the challenge to efficiently validate and integrate external datasets within the federal and national databases. Concentrating on the data preparation and integration both horizontal (between map tiles) and vertical (between layers) will allow the Map Generator will gain much efficiency by drawing all data from a single federal or national database. The first concrete step toward this goal is to ensure that the results of the Digital Compilation of Geographic Names process will be integrated into the main geospatial databases rather than remain separate from it.

From a map delivery perspective, the Map Generator will be optimized in many ways. As the horizontal and vertical data integration work progresses, and automated text placement rules improve, the map publishing processes will become more fully automatic, while maintaining good map readability. More flexibility will be provided to the users so that they will get paper maps centered on a chosen point, in different sizes and templates. The Map Generator output will become one of many geospatial products available through a single NRCan web portal, but will remain primarily aimed at the paper map client. It is also expected that the results of the data preparation and integration to support the Map Generator will be profitable to other web or thematic mapping processes and products within the government.

Conclusions

Mapping 10 million square kilometres at 1:50 000 is an enormous task requiring decisiveness, clear priorities, technological expertise and collaboration. When conventional map production and revision was set aside in 1993 to focus on the vectorization and improvement of our legacy data, it was indeed with the intent to create a better digital topographic database from which GIS experts could analyse data and create value-added products. After 15 years of gradual improvements of this database through the federal-provincial collaboration under the GeoBase program, and taking advantage of the latest GIS technology, NRCan's has indeed resurrected their topographic mapping program, and in doing so, established the critical linkage between the digital world and the paper world of topographic maps. The Map Generator is currently publishing new print-ready full size topographic maps, using the best available national data, with efficiency and flexibility. The project team used a powerful GIS-based map publishing system to better address the expected data quality issues and maintain high cartographic standards. The current web mapping service solutions are not yet up to par at this point in time to generate good quality maps from complex datasets. With improved data management practices and data integration techniques to absorb data from more collaborators and volunteered geographic information, we have to expect that technological advances and highly efficient web mapping techniques will soon be good enough to satisfy the needs of those who use to depend on paper maps.

Many of the technological developments and concepts in map design, data integration, and automation of map publishing that were implemented in a GIS environment for topographic mapping are indeed transferrable to other types of geological, thematic mapping and web mapping services. Most importantly the building of relationships between data producers, data managers, map publishers and map users has created a new environment of collaboration and innovation that will position us well to take the next leap into the future of mapping services.