PLSS as a Spatial Framework: A History of GCDB

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Abstract

The Bureau of Land Management (BLM) initiated the Geographic Coordinate Data Base (GCDB) project to digitally portray the Public Land Survey System (PLSS). The GCDB solution utilized the cadastral record as the spatial framework for a multi-purpose cadastre. The survey measurement based strategy anticipates future surveys with the construction of templates, which catalogue the rules of survey that apply to the data set. The template construct provides an elegant method to update the spatial framework. The project has evolved through multiple generations of collection technologies starting with Ain house@ software development, and culminating with the current NILS partnership.

Background

The Public Land Survey System (PLSS) is a framework for cadastral data. Geographic Coordinate Data Base (GCDB) is the digital portrayal of the PLSS. The origins of GCDB spring from a number of sources; legislative acts, administrative guidance, and academic consultation. The Bureau of Land Management (BLM) authority to survey and to perpetuate the survey record, is legislatively derived (43U.S.C. § 751). The Office of Management and Budget (OMB) originally issued Circular No. A-16 in 1953, and subsequently revised in 1967, directed that "all surveying activities financed in whole or in part by Federal funds contribute to the National Networks of Geodetic Control when it is practicable and economical to do so". The aforementioned directive lead to the Department of the Interior (DOI), Departmental Manual policy guideline, "Geographic positions of PLSS corners will be established by direct ties or by calculation to aid in computer and graphic use of PLSS data"(DOI, 1988). BLM Instructional Memorandum No. 80-459 required all BLM cadastral surveys to, "…provide for a survey tie to the national geodetic network", the ensuing result of the Circular A-16 directive, at the field level. The National Research Council (NRC) provided consultation at the request of the numerous federal agencies. The NRC conducted a study to provide recommendations for a national multipurpose cadastre (Committee on Geodesy, 1980). The federal response to the study was a request for another study (Committee on Integrated Land Mapping, 1982). The resulting <u>Modernization of the Public Land Survey System</u> provides recommendations for bringing the physical features and analogue records of the cadastral infrastructure into a digital environment. The BLM cadastral staff as custodians of the PLSS recognized the need to connect the PLSS to the national geodetic network, in order achieve connectivity within a national cadastral infrastructure, which was the basis for the Circular A-16 directives. Following the recommendations of the 1980 study by the NRC, the federal lead agencies, including the BLM faced challenges and opportunities with attempting to implement the multipurpose cadastre. The

NRC recommendations were so broad in nature that there was a perceived overlap of mission responsibilities between agencies, especially regarding the coordination of the PLSS. The 1982 study proposed a number of strategies, and provided an analysis regarding the technical feasibility and cost benefit projections of each option. The scope of strategies examined ranged from approximating coordinates through a digitizing effort of maps and plats to a collection of Global Positioning System (GPS) observations according to the highest accuracy standards. Between the extremes was a strategy to compute PLSS corner positions utilizing the survey record and adjusted for geodetic referenced best fit.

GCDB Conceived

In 1982, Technical Committee Report for the Development of a Geographic Coordinate Data Base for the Public Land Survey System was released by the BLM assuming responsibility for coordinating the PLSS. Collection methods were proposed which focused primarily upon digitizing techniques for coordinate acquisition, an economical argument. Cadastral staff involved in this process, with significant academic support, pressed for altering collection methodology to a measurement based computation and adjustment procedure. While more expensive, the methodology demonstrates worth when collecting coordinates for corner positions of PLSS that are not identified as found on the USGS and USFS 7.5-minute topographic maps. The survey record will consistently provide the best indication of a corner's position until it is located on the ground; and this concept is standard field survey procedure when searching for corners. The justification for measurement based collection methodology was underpinned by a firm stand that bringing the PLSS into the digital environment means inclusion of the complete survey record. The complete survey record includes, measurements, name of surveyor, survey completion date, survey document date, agency name, and survey method type. It was during this period (1982-1989) that GCDB implementation strategies for data collection were being formulated, which included data modeling. A requirement of the data model was to produce files that could be converted to a GIS spatial framework layer. The GCDB Cadastral Data Collection Data Base Model evolved into the Federal Geographic Data Committee (FGDC) Cadastral Data Content Standard (McKay, 2003). The data model and ensuing data content standard identified minimum data entity requirements for digital cadastral data. Collection of the minimal requirements was most effective in a measurement-based methodology.

GCDB Software

The GCDB Project initially utilized a set of survey computation software developed "in house" by William (Bill) Ball, Jr. He began writing programs to assist cadastral fieldwork in the late '70s. His software was found to be suitable for converting PLSS survey data into coordinate values after a couple of pilot studies, the New Mexico GCDB Pilot Project and the Western Oregon Digital Data Base (Von Meyer, 1988), demonstrated favorable results. The Bill Ball software was called PLSS Coordinate Computation System (PCCS) and was initially a Honeywell DPS-8 based application, and subsequently was compiled for Prime Systems computers at the start of active GCDB data collection. PCCS software was a suite of independently invoked executables, loosely organized into the following groups; data entry, data organization, subdivision, coordinate manipulation, coordinate transformation, and graphics. The graphics routines constructed the lines file as an end product for input to GIS applications. The label file was produced using the Automated Digitizing System (ADS), an unrelated "in house" application. The label file application was called QLINK and was considered an extension of the PCCS process. The PCCS software collected GCDB in single township units, according to a single measurement based collection methodology. PLSS coordinates were computed with geodetically referenced positions (control) held fixed; and survey data with ties to the control were grouped, computed and adjusted by quality. The townships or portions of townships with the best survey data and control would be collected first, and the resulting coordinates would then be treated as control when collecting coordinates for adjacent surveys of poorer quality, a blocking construction. The PCCS suite, while fulfilling the requirements of the GCDB collection data model, was a challenge to use. There was a significant amount of file manipulation required, as the output files of many executables often needed modification in order to be acceptable as the input file for the next executable in the collection process. While the amount of time required to initially collect GCDB for each township was satisfactory, the time required to update township GCDB as a maintenance process was considered unsatisfactory. The PCCS suite of software was able to successfully launch GCDB initial collection efforts, but a more flexible, user friendly, and efficiently repeatable software was required.

The Eastern States Office of the BLM entered into a cooperative agreement with Dr. Raymond Hintz at the University of Maine, Orono to develop field survey support software for cadastral surveyors. Cadastral Survey Measurement Management (CMM), the result, was initially released in 1991 and is still being used by BLM cadastral surveyors today. While CMM was being developed, Dr. Hintz began a parallel project, the GTHING, as a prototype for GCDB collection software. GTHING computational software utilized Dr. Hintz's least square adjustment algorithm (LSAQ) to create adjusted coordinates of PLSS. The LSAQ executable allowed for the assignment of error estimates to survey measurements and to control data, based upon the surveyor's professional judgment. The software, FORTRAN language programs were compiled for use in MS-DOS stand alone computers. When tested and evaluated the GTHING software produced required GCDB collection data model elements equally as well as PCCS software, but at a measurable cost-savings due to decreased coordinate computation times (NMGPP, 1989). The software demonstrated enhanced flexibility and user-friendliness, when compared to PCCS. The enhanced flexibility focused upon setting a variety of parameters for adjustment, and handling metes and bounds surveys outside of township units, as exists in the non-PLSS states. There were a number of recommendations identified by the evaluation, which guided further development by Dr. Hintz. Geographic Measurement Management (GMM) was released in 1992, a significant improvement to the GTHING prototype. The initial release, GMM v. 1.00.00, was the first working example of constructing township templates as a collection strategy. The software was sequentially organized and utilized a fraction of the executables required by PCCS software. Data entry templates stored survey data and control with associated error estimates to guide the parameters of the least square adjustment. The subdivision template stored the coordinate geometry computations for each township based upon the BLM Manual of Survey Instructions, 1973. The elegance of constructing templates is discerned when re-computing coordinates is required, as the software automatically re-generates coordinates based upon the constructed templates. The templates are easily modified once initially built.

Subsequent versions of GMM were released periodically when enhancements and performance improvements were required. GMM v 2.00.00 was notable for the introduction of regional adjustments. Regional adjustments allowed for coordinate computations of multiple townships units. GMM v 3.00.00 included functionality, called GLINK, to generate polygons of all the PLSS parcels and to create label point files. The GLINK process replaced the QLINK application, a hold over from the PCCS era. The final enhancement to GMM was wrapping the MS-DOS compiled executables in Visual Basic (VB) creating Graphical User Interfaces (GUIs), and was renamed WinGMM v1.00. The GUIs created by Dr. Kurt Wurm provided considerable cost savings to the GCDB collection process. The two interactive GUIs for subdivision significantly reduced time required assembling the subdivision template. Dr.Wurm constructed a GUI for the GLINK process, which not only speeded up the label editing process, but also included a quality assurance routine calling Banding. The regional computations GUI enhanced the region-building template and introduced a template for post regional update of individual township end product files. WinGMM v. 1.00 is presently the official GCDB collection software, but collection strategies are evolving to take advantage of emerging GIS software technologies. All of the GCDB collection softwares to date produce ASCII files as end products, and the GCDB lines and label files are used to create ARC/INFO coverages, to function as a GIS spatial framework layer. During the mid 1990s, the BLM wrote an Arc Macro Language (AML) routine, GCDB2ARC, to create GCDB coverages. Today, GCDB ARC/INFO coverages comprise the preferred PLSS portrayal of the federal government. They meet the FGDC Cadastral Data Content Standard and contain FGDC compliant metadata files.

The future collection software of GCDB will reside within National Integrated Lands System (NILS). NILS a consortium of BLM, U.S. Forest Service, state and county government consultation, and ESRI, is developing customized modules to load and maintain the cadastral data and parcel records for a multipurpose cadastre. The BLM provided functional requirements in the form of use-cases, as the bureau expertise encompasses application of the rules of survey to correctly portray the PLSS; and the experience of implementation of and production using measurement based computation software. Two of the modules, Survey Management(SM) and Measurement Management (MM) are specifically Land Surveyor applications, which execute within the Object-oriented technology of ARCGIS software. After implementation of full functionality of SM and MM, which is expected in the near future, GCDB collection efforts will proceed in a relational database environment, with updates to the PLSS spatial framework occurring “on the fly”.

Conclusions

The NRC study, Need for a Multipurpose Cadastre was well received by the intended audience. The model proposed by the study, while broad in concept, was quite specific about envisioning a digital PLSS as an overlay upon a spatial framework. The BLM under visionary leadership altered the paradigm. The GCDB solution to coordinating the PLSS pulled the geodetic reference framework, as control, inside the PLSS framework. The measurement based methodology allowed for updates to both control and survey data, to generate new data sets of PLSS townships. GCDB cadastral surveyors are able to analyze the fit of survey measurements with control to determine potential problems to be found on the ground. Additionally, the methodology maintains BLM custodianship of cadastral public domain surveys and of the cadastral records of the PLSS as authorized by statute (43U.S.C. § 751). BLM cadastral staff, working on the GCDB project, has collected digital PLSS data to mirror the legal survey record, and the software supporting the effort has evolved in efficacy and expanded functionality. The NILS partnership creates both opportunities and challenges to the BLM cadastral staff. Production software will be Commercial off the Shelf (COTS), and will permit a true “Field to Finish” workflow for cadastral surveys. The NILS Spatial Data Engine (SDE) could become the repository of the survey record, and presents an emerging issue concerning the extent of the BLM Cadastral survey authority.

Acknowledgements

BLM Cadastral Survey, as an organizational unit, has undergone numerous name changes since it’s establishment in 1785, but the mission is still the same, custodianship of the PLSS. This paper draws inspiration from the traditions and responsibilities maintained since Cadastral Survey’s inception, and attempts to envision where the program is heading. Thanks to all the surveyors of cadastral, past and present, who take pride in their mission. Special thanks to Bob Dahl, Frank Hissong, Dennis McKay, Nancy von Meyer, Frank Profazier, Gary Speight, Marc Thomas, and Dr. Kurt Wurm for their contributions to this paper. Finally, thanks to Bernard Hostrop, who was an integral factor in the paradigm shift, making GCDB possible as a Cadastral Survey function.

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