The Use and Improvement of the National Spatial Reference System in Ohio

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ABSTRACT

Advances in Geographic Information System (GIS) technology and the use of the Global Positioning System (GPS) for surveying have resulted in greatly increased activity related to the use and improvement of the National Spatial (Geodetic) Reference System (NSRS) during the past ten years. This paper focuses on progress in the State of Ohio during this time. Much of the activity here is at the County level where accurate land records are needed to serve as the basis for property valuation and tax assessment. Private companies work under contract with County government agencies, using GPS to establish accurate geodetic control. Cooperation of County and State government agencies with the Federal Government's National Geodetic Survey (NGS) is important because, working together, they monitor the quality of this geodetic control and ensure it's availability for public use. A High Accuracy Reference Network (HARN) survey is now in progress which will provide accurate connections between local GPS surveys and eventually serve as the basis for a re-adjustment of all NSRS control in the State. In addition, GPS Continuously Operating Reference Stations (CORS) are being established to allow more efficient use of GPS in the future.

INTRODUCTION

This paper describes progress in the use and improvement of the NSRS in the State of Ohio. Much of this activity is related to GIS development at the County level. Activities by State and Federal agencies are underway now that will affect nearly all users of the NSRS, including these Counties. The reason for this activity at the local level is that much "of the required data (for GIS) are being generated at the local level, and in most cases the users are the individual citizens and the local government officials and planning organizations" (NRC 1980, p. 102). Accurate geodetic control, when properly used, serves as the reference framework in a Multipurpose GIS. It helps to ensure compatibility, and permits linkage, of various types of data. Figure 1 (WLRC) shows how geodetic control points can be used to create a Multipurpose GIS. Figure 2 shows the NSRS horizontal control network in Ohio, with denser networks of geodetic control established in a number of counties, mostly in support of GIS'. These local network surveys are the ones submitted to the NGS for review and publication after determining that minimum standards were met. They represent a wise use of tax dollars because they will serve many users and uses...far more than the initial purpose for which they were required. They are an important step toward achieving the vision articulated by Epstein and Brown (FGCC, 1989b, pp 1-3), "of compatible, accurate land information available throughout the United States at all levels of government and supporting a wide range of uses". Local geodetic control surveys shown in Figure 2 were done by about six different private companies under contract to government agenies. These private firms have a range of capabilities. Some own the latest, most sophisticated GPS equipment available. Others lease or rent

equipment as needed. Ownership seems to work best when a company needs the equipment often. Otherwise the rapid obsolescence of GPS technology makes renting a good choice, especially since it allows the possibility of always using the latest technology. Others surveys, not shown on Figure 2, have been done to varying standards, with the data kept by the contracting agency and therefore not generally available to the public.

IMPORTANT ELEMENTS FOR PROGRESS

The NATIONAL GEODETIC SURVEY, NOAA, is the United States Government agency responsible for developing and maintaining the National Spatial Reference System.

The NATIONAL SPATIAL REFERENCE SYSTEM (NSRS) is a network of precisely located points, each typically consisting of a brass disk set in a concrete post in the ground. These points serve as the common base of reference for latitude, longitude, height, scale, orientation and gravity measurements throughout the United States. NSRS supplies the framework for many surveying, mapping, and construction projects conducted every day. Objects located with respect to these monuments can be relied upon for positions of known accuracy. Maps, aerial photographs, and other information can be registered to ground locations using a geodetic framework.

FIGURE 1

NSRS - IT'S RELATIONSHIP TO GPS. With all the publicity about GPS, some people ask why the NSRS is still needed when today positions can easily be determined with the aid of satellites. There are two ways to use GPS, point positioning and relative positioning. A point position is derived directly from the satellites. U.S. Department of Defense policy is that this method will be accurate within 100 meters, 95% of the time. This is acceptable for some uses, such as navigation on open water. If we need something better, as in surveying, mapping, and engineering, we must reference our survey to known points using relative positioning. The position of new points is determined relative to points with positions we already know, using multiple receivers. GPS is used to tie to the NSRS, not as a replacement for it.

OHIO'S PHYSICAL MAKEUP: Ohio has 88 counties averaging about 1000 square kilometers in size. It is a densely populated state, ranking number six nationally, with about 11 million people. It is relatively small in land area, ranking number 36 nationally, with about 100 thousand square kilometers. Much of the State is relatively flat with rich farm land and there is some type of development in every county.

COUNTY OFFICIALS: A County Auditor and a County Engineer are among the elected officials in each Ohio county. State law details their responsibilities with regard to surveying, mapping, and GIS. The County Auditor is responsible for determining property values and assessing taxes. The County Engineer is also the County Surveyor, with responsibility for surveying road centerlines, rights-of-way, and original land subdivision boundaries.

A REAL ESTATE ASSESSMENT FUND (REAF) exists for each county. It consists of a percentage of property taxes collected by the County Auditor. Monies in this Fund are for use by the Auditor to pay the cost of assessing real estate, including photogrammetry, mapping, and geodetic surveys necessary to accomplish this task. State law sets maximum limits for the percentage of tax revenue available for this fund. These limits and other details are found in Section 319.54 of the Ohio Revised Code (Anderson Publishing Company). A formula is used which allows a smaller percentage of revenues to be used as the total amount of revenue increases. For example, three and one-half percent of the first one hundred thousand dollars of property tax revenue collected can be kept for the REAF, while revenue above one hundred fifty million dollars can be credited to the REAF at a rate of only six-tenths of one percent, or sixty cents for each one hundred dollars collected. This results in a larger total amount of money available to the the REAF in larger counties, as much as several million dollars per year. The monies provided were once inadequate to pay for new mapping, etc., but this changed in 1986 when a new law effectively doubled these amounts. Rapid advances in surveying and mapping technology were occuring in the 1980's and this trend has continued at an even faster rate, allowing ever more to be done with the funding provided by the REAF.

NEED FOR GEODETIC CONTROL

A 1982 study classified Ohio as severely deficient, nearly statewide, with regard to adequacy of the horizontal and vertical control networks (National Ocean Survey). Criteria used to determine adequacy were population density, rate of population growth, and number of existing control points. By 1986 the need for updated land records and an improved geodetic control network coincided with increased funding and improved technology for providing them.

Franklin County then set an excellent example in Ohio with a very ambitious GIS begun in 1987 by the County Auditor. This County includes Ohio's state capital, Columbus. It has experienced a higher growth rate in recent years than most other areas of the state, and is one of the wealthiest areas in Ohio. Local government

agencies throughout Ohio watched Franklin County's progress with great interest. Similar GIS projects were soon underway in other large metropolitan areas, including Cincinnati and Cleveland.

Some less densely populated counties adjacent to these metropolitan areas have also been experiencing high growth rates. They have a critical need for GIS technology to help manage this growth and thus they pay close attention to the progress of their urban neighbors. At first, there was an attitude that while they might need a GIS like Franklin County's, these smaller counties could hardly afford one. However, the technological revolution continues to result in decreasing costs and increasing capabilities. Many of the smaller suburban counties are implementing their own GIS projects now, with many more in the planning stages. Referencing data to accurate geodetic control is one of the requirements to permit data from various sources to be merged in a computer and multiple purposes. While there is no requirement by any central authority regarding proper use of geodetic control, many counties do it because of the economic incentives. GIS development has been funded with REAF monies in 30 of Ohio’s 88 counties during the past two years alone.

FIGURE 2

STATEWIDE NSRS IMPROVEMENT AND THE FRANKLIN COUNTY EXAMPLE

In 1982, Franklin County ranked as the worst county in Ohio regarding the adequacy of geodetic control. In fact it ranked as the seventh worst county in the United States (Committee on the North American Datum), based on points shown as existing in the NSRS. The situation was actually worse because most of the control points shown to exist had in fact been destroyed over the years. The Franklin County Auditor began development of a GIS in 1987. The County Engineer and many other organizations, including the City of Columbus, Mid-Ohio Regional Planning Commission, and a variety of utility companies, realized the value of the project in their own operations and soon became involved.

Establishing a network of accurate geodetic control points was one of the first steps in the project. This network was needed to control the aerial photography that would be used to create new digital maps. It would also be used in the ongoing process of updating the GIS. Referencing future surveys to these control points will permit inclusion of new information in the GIS. New subdivisions are one example of the kind of information that must be added to a GIS to keep it current. Figure 1 shows some of the wide variety of data that can be used in a GIS. The Auditor employed a contractor who used GPS to establish a network of about 100 first order geodetic control points throughout the County. The new points were positioned relative to the existing, very sparse, geodetic control network. The survey was performed in accordance with standard procedures for geodetic control surveys developed by the Federal Geodetic Control Committee (FGCC 1988). All points were permanently monumented, the survey was submitted to NGS for quality review, ultimately accepted, and then published as part of the NSRS.

The cooperation of various government agencies to develop a GIS makes Franklin County a good example for other counties planning GIS projects. While many counties in Ohio are now developing a GIS, most of the remaining counties are in some stage of planning one and they have some excellent examples upon which to model their projects.

A HIGH ACCURACY REFERENCE NETWORK SURVEY AND HOW IT WILL RELATE TO THE NSRS

A state-wide GPS survey is now under-way in Ohio called the High Accuracy Reference Network (HARN). Similar surveys have already been done in many other states. Wherever possible existing stations in the NSRS, preferably with strong horizontal and vertical connections to the network, are being used as HARN stations. These points will have their coordinates re-determined with extreme accuracy with respect to distant global reference stations. Existing stations in the NSRS are generally not so accurate in the global sense. They were established with methods that maintained relatively high accuracy between nearby stations but allowed the possibility of accumulating small errors that could degrade their global accuracy. This causes some concern today because of the increasing use of the GPS which can detect these global differences. Using existing NSRS stations in the HARN is important because they will provide the basis for an eventual readjustment of the overall network

HARN stations will have their positions determined very accurately in all three dimensions, as opposed to the existing often separate horizontal and vertical networks. Horizontal accuracy of HARN stations will be higher than existing NSRS stations, but they will be more widely spaced. The HARN will offer an increase in accuracy over the existing North American Datum of 1983 (NAD 83) network, from the present first-order (1:100,000) to B-order (1:1,000,000).

All NSRS horizontal control in Ohio will eventually be re-adjusted, with new coordinate information for all stations in the network. This will make the new coordinates of HARN stations consistent with the rest of the NSRS control points in Ohio and with adjoining States' HARN's. This new adjustment will be labelled as NAD 83 (9_), to distinguish it from the existing NAD 83 (86). It could be as long as two or more years after completion of the HARN survey before the re-adjustment is complete. Therefore, labeling of coordinate datum and date will be more important than ever (i.e., NAD 83 (adjustment of 1986), State Plane Coordinates, Ohio North Zone).

NGS has a nationwide commitment to establish HARN stations at 100 km spacing. This commitment alone would result in about 15 stations in Ohio. NGS now has an additional requirement to establish more accurate control on many U.S. airports, including 108 in Ohio. The Ohio Department of Transportation (ODOT) is cooperating with NGS to survey the HARN, plus the airports and many additional points at locations selected by ODOT, all to be surveyed at the same time as the HARN and to the same level of accuracy. The net result of this inter-agency cooperation will be about 225 HARN stations in Ohio at an average spacing of about 20 km (12 miles). Figure 3 shows the points in this project.

FIGURE 3

An important element of the HARN being addressed with ODOT support is the quality of Ohio's vertical network. ODOT and NGS cooperated to run first-order levels from Cincinnati to Toledo, along the Interstate 75 highway corridor, in 1993. This improved one of the oldest sections of Ohio's vertical network and resulted in the establishment of many new benchmarks along the highway, all suitable for use with GPS. NGS re-leveled another line in Northern Ohio in 1992. Altogether these two projects total about 600 km of new leveling in Ohio. Some of the new bench marks will become HARN stations, improving the vertical component of the network state-wide. A concerted effort will be made to establish precise elevations on HARN stations that are not already existing NSRS vertical control points.

With funding from ODOT, NGS will use the HARN and new leveling data to perform an accuracy analysis of the geoid model in and around Ohio. The geoid model is the algorithm used to relate GPS determined ellipsoidal heights to orthometric (sea level) heights. This analysis will therefore help determine a level of accuracy and reliability for orthometric heights derived from GPS. NGS will also make recommendations for improving the accuracy of the geoid model.

GPS CORS are planned by NGS to be a component of the NSRS. NGS is cooperating with other federal agencies to establish a nationwide network of CORS. In addition, ODOT plans to establish a network of five CORS in Ohio by the end of 1997.

HARN BENEFITS

Current control points may have an accurately determined horizontal position or elevation, but usually not both since horizontal and vertical positions were historically developed by different methods and with respect to different reference surfaces. Horizontal and vertical positions often need to be used in combination, however, to satisfy a particular application.

- The HARN will ensure that nationwide there is accurate and reliable control, both horizontal and vertical, suitable for use by GPS, within some minimum distance of a project area.
- Time needed for field reconnaissance will be reduced in most cases.
- Analysis and adjustment of GPS surveys will be simplified.
- Accuracy and reliability of elevations derived from GPS will be improved.

CONCLUSION

There is much to be learned from the efforts of others. Models exist today for Multipurpose GIS development at the local government level. The activities underway in Ohio are representative of what is happening in many other areas. Communication and cooperation are important, both to learn from others and to allow participation by as many potential users as possible. When GIS data are based on accurate geodetic control and minimum standards are met, we move closer to the day when “compatible, accurate land information will be available at all levels of government, and supporting a wide range of uses” (FGCC, 1989b, pp 1-3).

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