REVISED MINUTES OF THE SECOND MEETING

TECHNICAL ADVISORY COMMITTEE
FOR THE REVIEW AND REEVALUATION OF THE
REGIONAL CONTROL SURVEY PROGRAM

DATE: November 16, 2007

TIME: 9:00 a.m.

PLACE: Commissioners' Conference Room
Regional Planning Commission Offices
W239 N1812 Rockwood Drive
Waukesha, Wisconsin

Members Present

Kurt W. Bauer Chairman	Executive Director Emeritus, SEWRPC, County Surveyor for Kenosha, Milwaukee, Walworth, and Waukesha Counties
John M. Bennett	City Engineer-Director of Public Works, City of Franklin
John P. Casucci	Survey Land Development Manager, National Survey and Engineering
Harold S. Charlier	Executive Director, Wisconsin Society of Land Surveyors
Michael R. Duckett	President, Duckett Group; Executive Director, Southeastern Wisconsin Professional Baseball District
John T. Ellingson	Wisconsin State Geodetic Advisor, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geodetic Survey
Thomas M. Grisa	Director of Public Works, City of Brookfield
Gregory G. High	Director; Architectural, Engineering and Environmental Services; Milwaukee County Department of Transportation and Public Works
Marcia G. Lindholm	Civil Engineer Senior, City of Milwaukee Department of Public Works
Cecil F. Mehring	Former Manager of Planning and Engineering Services, Racine County Department of Public Works
George E. Melcher	Director of Planning and Development, Kenosha County
Robert W. Merry	Chief Technical Officer, Aero-Metric, Inc.
Glen R. Schaefer	Geodetic Engineer, Wisconsin Department of Transportation
Thomas J. Tym	Head, Technology Services Department, Ruekert-Mielke, Inc.
William T. Wambach	Former District Director, District 1, Wisconsin Department of Transportation

Members Absent

Kent B. Pena	State GIS Coordinator, U.S. Department of Agriculture Natural Resources Conservation Service
Daniel R. Talarczyk	Survey Services Supervisor, Milwaukee Metropolitan Sewerage District

Guest Present	
Donald G. Dittmar	Manager, Land Information Systems Division, Waukesha County Department of Parks and Land Use
Staff Present	
Earl F. Burkholder	Consulting Geodetic Engineer
Donald P. Simon	Chief Planning Illustrator, SEWRPC; Deputy County Surveyor for Kenosha, Milwaukee, Walworth, and Waukesha Counties
Lynn G. Heis	Staff Secretary, SEWRPC

CALL TO ORDER AND ROLL CALL

Chairman Bauer called the meeting to order at 9:00 a.m. Roll call was taken by circulating an attendance signature sheet, and a quorum was declared present.

CONSIDERATION OF MINUTES OF THE MEETING OF JULY 25, 2007.

Chairman Bauer noted that copies of the minutes of the first meeting of the Technical Advisory Committee for the Review and Reevaluation of the Regional Control Survey Program had been distributed to all members of the Committee for review prior to the meeting. He asked the Committee to consider approval.

In the discussion that followed, it was noted by Mr. Schaefer that the Wisconsin Department of Transportation (WisDOT) had originally introduced The Wisconsin County Coordinate System (WCCS) to avoid the need to apply the combination factor (scale and sea-level reduction factors) used with the State Plane Coordinate system in moving measured or recorded distances between the map projection and ground level – the so called grid to ground conversion. He also noted that the word "System" was singular in the Wisconsin County Coordinate System and the word "Systems" was plural in the Wisconsin Coordinate Reference Systems.

Messrs. Schaefer and Grisa called attention to the second full paragraph on page 5, indicating that the last sentence contained the word "had" twice. Mr. Schaefer suggested that the phrase "data on" be inserted after the word readjusted in the penultimate line of that paragraph. Mr. Schaefer further suggested, and the Committee agreed, that the Commission adopt the National Geodetic Survey standard for datum acronyms so that, for example, in the last line of the paragraph concerned, the acronyms would be noted as NAD 83, NAD 83 (1991), NAD 83 (1997), and NAD 83 (2007). Mr. Schaefer noted that the last line of the paragraph concerned also contained a superfluous conjunction "and." With respect to proper usage, Mr. Schaefer also noted that when referring to a survey monument, the term "bench mark" should be two words, not one. The term "benchmark" would be used when referring to a reference condition in an analysis or study. The Committee agreed that this convention should also be adopted throughout the Commission's work.

Mr. Schaefer called attention to the seventh line of the first paragraph on page 6, noting that the correct acronym for the North American Vertical Datum of 1988 should be NAVD 88 and suggested that same error was made throughout the minutes and should be corrected.

Chairman Bauer noted that Mr. Wambach, based upon his review of the minutes, had indicated by telephone that the word "illicit" in the third line of the first partial paragraph on page 7, should be "elicit." He also indicated his general agreement with and support of the conclusions reached during the Committee's deliberations at the July 25, 2007 meeting.

Mr. Burkholder called attention the fourth line of the last paragraph on page 7, noting that the technology referred to should be correctly identified as "Global Positioning System" not "Geographic Positioning System."

Mr. Schaefer called attention to the last full paragraph on page 11 carrying over to page 12, and suggested that the paragraph be revised to read as follows: Mr. Schaefer indicated perhaps some additional background information on WisDOT's work would be helpful to the Committee in its deliberations. He noted WisDOT was establishing a virtual reference system utilizing initially 25 CORS stations based upon NAD 83 (2007). The NGS has promised they would provide the parameters identifying the differences between, and the means for converting between, the NAD 83 (2007) adjustment and previously used NAD 83 datum adjustments. The NGS has not as yet provided those parameters, he said. In addition to the use of RTK technology in horizontal survey work, the WisDOT desired to utilize this technology to obtain orthometric elevations on points, and to transfer orthometric elevations between points, but realized in the mid-1990s that the ellipsoid heights required to accomplish this were not available at the accuracy required. Therefore, WisDOT conducted observations in 1997 at 78 of the original 80 HARN stations established in 1991. However, the parameters needed to convert between NAD 83 (1991) and NAD 83 (1997) have to date not been provided by NGS. As a result, a number of WisDOT projects are currently using the NAD 83 (1991) adjustment coordinates and some projects are using the NAD 83 (1997), or NAD 83 (2007) adjustment coordinates. He indicated WisDOT addresses this issue by reoccupying common stations and creating its own conversion parameters. Mr. Schaefer noted further that parameters would have to be provided to move between the newer datums and NAD 27 at desired accuracy levels. Depending upon the accuracy levels desired, this may require, he said, reobservation at some points in the older system, so coordinate values are available at the selected points in both the old and new systems.

Mr. Schaefer cautioned that it may be misleading to identify NAD 83 as a horizontal adjustment because technically it is a three-dimensional adjustment, however, the vertical component in that adjustment deals with ellipsoid heights whereas NAVD 88 deals with orthometric heights.

Mr. Schaefer called attention to the last paragraph on page 13 and suggested that this paragraph be revised to read as follows: In answer to a question from Chairman Bauer, Mr. Schaefer indicated with respect to vertical control, WisDOT was utilizing the NAVD 88 datum. Mr. Schaefer noted that the Height Modernization Program was conducted by WisDOT in five phases, to date, covering different geographic areas of the State. Upon completion of the first five phases, it was determined to adjust all differential level data acquired and the adjustment to be constrained by only two points in Southwestern Wisconsin. As a result, the elevations as determined by the adjustment made in 2007 are different from the elevations for bench marks in southeastern Wisconsin which were previously published in 2004. No means for developing and presenting the metadata in a readily useable form has as yet been developed by the NGS. Consequently, WisDOT is using the syntax of NAVD 88 (1991) for the first adjustment and NAVD 88 (2007) for the most recent adjustment. Data adjusted in 2004 are based on the NAVD 88 (1991) adjustment.

Mr. Schaefer called attention to the last full paragraph on page 16 and suggested that that paragraph be revised to read as follows: In this respect, four horizontal adjustments on the NAD 83 datum have been made all of which are in use within the seven county Region since the abandonment of the NAD 27 datum by NGS: NAD 83 (1986), NAD 83 (1991), NAD 83 (1997), and NAD 83 (2007). To date, two vertical adjustments on the NAVD 88 datum have been made by NGS upon its abandonment of the NGVD 29 datum; namely NAVD 88 (1991) and NAVD 88

(2007). All of these adjustments result in shifts in the absolute position of the points involved, but do not significantly change the relative positions of the points to other points within the Region; an exception being when a new value is assigned to a monument, which has been subjected to local movement.

There being no further corrections or additions, the minutes of the meeting of July 25, 2007, were approved as amended on a motion by Mr. Melcher, seconded by Mr. Bennett, and carried unanimously.

[Secretary's Note: Because the minutes of the meetings of the Committee are proposed to be appended to Mr. Burkholder's final report to the Commission, contrary to long established Commission policy, the minutes of the July 25, 2007, meeting have been revised in their entirety to reflect all of the changes directed to be made by the Committee at the meeting held on November 16, 2007. A copy of the revised minutes will be provided to the Committee for reconsideration and re-approval at the meeting scheduled to be held on February 15, 2008.]

REVIEW OF DRAFT REPORT

Chairman Bauer noted that copies of the preliminary draft of Mr. Burkholder's report dated October 2007, had been distributed to all members of the Committee for review prior to the meeting (copy attached.) He then asked Mr. Burkholder to undertake a page by page review of the report. The following comments were made, questions raised, and actions taken in the course of the review.

Mr. Mehring noted that the list of acronyms and abbreviations included two for SEWRPC-Nos. 2 and 34 in the list. It was agreed that No. 2 should be deleted and No. 34 retained. Mr. Grisa called attention to No. 23 on the list and suggested that the acronym be changed to NAD 83 (xxxx) and that the last term in the definition be changed to "the year xxxx." The Committee concurred. Mr. Schaefer suggested that the term NSRS be deleted from acronym No. 22. The Committee concurred.

Mr. Tym called attention to the third line of the second full paragraph on page 4 and suggested that the term "cognizant public officials and users" be inserted after the word Commission. The Committee concurred.
Mr. Grisa suggested that the term "proposed composition" be struck from the second title included in Appendix A, said Appendix being referred to on page 4. The Committee concurred.

Mr. High suggested that the first sentence in the second paragraph on page 4 be divided into two sentences which would read as follows: "Given that Commission established networks of horizontal and vertical survey control are in place and provide a reliable foundation for many spatial data activities throughout the seven-county Region, it is important for the Commission, cognizant public officials and users to recognize the value of these networks, and act to preserve the investment which these networks represent. It is also important for the Commission to review recent technological developments in terms of compatibility with the existing databases and current policies and procedures. The Committee concurred.

Chairman Bauer noted that in accordance with Mr. Schaefer's suggestion, the phrase "the NSRS (2007)" should be struck from the last sentence of the first paragraph on page 5.

Chairman Bauer suggested, and the Committee concurred, that the first numbered paragraph on page 5 be revised in the next draft of Mr. Burkholder's report so as to address only monumentation of the U.S. Public Land Survey corners, and not the issue of maintenance of bench marks. These, he said, were separate issues. He indicated that the Committee's strong consensus on the need to continue to perpetuate the U.S. Public Land Survey System within the Region through maintenance of the survey monuments concerned should be clearly stated, and that the issue of the maintenance of the bench marks within the Region should be separately addressed in the report after Mr. Burkholder has further investigated WisDOT's height modernization work, as well as the potential for utilizing the GPS system technology, rather than spirit leveling, for obtaining orthometric heights. Mr. Burkholder's conclusions with respect to the issue of bench mark maintenance should be expressed in a separate numbered paragraph he said. The Committee concurred.

Mr. Tym noted that the word "disturbed" was misspelled in the first numbered paragraph on page 5, and indeed throughout much of the remainder of the report and should be corrected.

Chairman Bauer reported that Mr. Casucci had, based upon his review of the draft report, requested in an e-mail message to the Committee Secretary dated November 14, 2007, that the word "inadvertently" be struck from the last sentence of the first numbered paragraph on page 5. He indicated that, in his opinion, the Commission should continue to replace monuments marking the U.S. Public Land Survey corners regardless of how monuments are disturbed or destroyed.

Mr. Tym called attention to the statement made in the second numbered paragraph on page 5 that the costs of migrating to the newer datums far outweighs the benefits associated with such migration, and indicated that the statement should be supported by quantative data.

A lengthy discussion ensued in which Mr. Grisa questioned the feasibility of quantifying the benefits of such migration.

Chairman Bauer indicated that in his opinion there was a practically unquantifiable, but huge cost entailed in not only transforming the very large number of geographic positions comprising the control survey networks within the Region, but also in transforming the huge volume of information in the form of digital and hard copy topographic and cadastral maps; land subdivision plats and certified survey maps; plats of surveys; flood plain delineations and associated hydraulic grade lines along hundreds of miles of streams and water courses, and entire land information and public works management systems that have been created within the Region at great expense. He indicated further, that in his opinion there were no offsetting benefits. Mr. Bennett indicated that there would be a least one offsetting benefit, namely that all of the agencies and interests concerned would be using the same datums. Chairman Bauer responded that that benefit could be more readily obtained by the means to transform values between datums and in any case, would disappear with the next adjustment of, or change in, datums.

Mr. Dittmar indicated that, in his experience, individuals who hold the opinion that migration to a new geodetic datum is not a major issue are usually individuals employed by agencies that do not have to manage and maintain large databases, or are agencies that have ample budgets. Mr. Dittmar indicated that, every year during budget preparation administrative officials and county board supervisors raise two issues with him concerning costs; one, the need to continue to maintain the monuments marking the U.S. Public Land Survey corners within the County and the attendant bench marks; and two, the desirability of moving from the existing to newer geodetic datums. He indicated that the recommendations of Mr. Burkholder and the Committee with respect to these issues were very important and the text of the report should support those

recommendations. Chairman Bauer noted that Mr. Dittmar has raised an important associated issue, namely how would the clearly huge costs of changing geodetic datums be funded.

Upon the conclusion of the discussion, Mr. Tym suggested, and the Committee concurred, that the text concerned be revised to, in effect, indicate that there were minimal benefits associated with the cost of migrating to newer geodetic datums that did not justify the costs involved.

Mr. Schaefer suggested that in his redraft of paragraph No. 2 on page 5, Mr. Burkholder should carefully distinguish between migrations between datums and between adjustments to datums.

Mr. Tym indicated that the phrase "and publication" be inserted after the word development in the third line of paragraph No. 3 on page 5. A brief discussion ensued in which it was indicated that the Commission's policy had been to make the transformation methodologies developed in the past for the Commission by Mr. Burkholder, available to anyone on request as well as to actually perform specific transformations upon request.

Chairman Bauer indicated that the recommendations set forth in paragraph No. 4 on page 5 and 6 and in paragraph No. 5 on page 6 were problematic. He indicated that the Commission had not in the past carried on professional training programs – a function that, in his opinion, should rest with the professions concerned working as may be required with professional societies and educational institutions such as the University of Wisconsin-Extension Service. A lengthy discussion ensued in which Mr. Mehring observed that at a minimum the Commission should make its staff resources available for participation in the needed professional training programs as presenters and instructors. Mr. Grisa agreed that the Commission should continued to be a resource in this respect. Mr. Mehring indicated further that the Commission had at least a more narrow responsibility in educating user communities about the reasons why the Commission is determined to remain on NAD 27 and NGVD 29, and to provide transformation procedures to newer datums. Mr. High suggested substituting the phrase "endorse, promote and support" in place of the word "develop" in the first sentence of the paragraph numbered 4.

Mr. Mehring observed that the Commission had, in the past, published technical reports concerning various issues, and indicated that perhaps a technical report concerning the use of geodetic datums and datum transformations would be in order. Chairman Bauer noted that the Commission had in the past published such reports – known as Technical Records – which did indeed sometimes set forth recommended technical procedures such as for storm sewer design. These reports were funded under the Commission's transportation and water quality management planning program; that the last such report had been prepared in December, 1993; and that funding of the costs entailed in preparing such a report would have to be found.

Mr. Schaefer noted that there were important benefits to be derived from the cooperative efforts of all of the interested and concerned parties including particularly WisDOT and SEWRPC. He indicated further, that within the State the greatest need to develop bidirectional transformation procedures exists within southeastern Wisconsin, and that parties utilizing the extant SEWRPC control survey data, WisDOT control survey data and the new technologies centered in GPS instrumentation would benefit from a bidirectional transformation method with related software programs. Therefore, he suggested there may be some financial support available from State sources to assist in developing those procedures and making them widely available.

Upon the conclusion of the discussion, it was agreed that Mr. Burkholder would reconsider the recommendations in paragraphs No. 4 and 5 on pages 5 and 6 and include in his revised draft of the report a new single paragraph, or paragraphs, setting forth his recommendations with respect

to this issue. In his revised draft Mr. Burkholder should distinguish the need to educate professionals in, for example the use of new technologies such as GPS, CORS and RTN; and the need to correlate the work of SEWRPC and WisDOT in this area.

In answer to a question by Mr. Bennett, Mr. Burkholder indicated that in his opinion it would certainly be possible to develop bidirectional transformation methods that would produce results adequate for public works engineering and land surveying applications, but not necessarily for geodetic surveying applications. In any case, he said, the procedures would have to be accompanied by information about the probable range of accuracy and precision involved.

Mr. Charlier called attention to the section of the draft report on monumentation, indicating that although the section constituted a very nice dissertation on the subject, its purpose within the context of the document was not clear to him. Another lengthy discussion ensued in which Mr. Melcher indicated that while the information presented may be elementary to practicing engineers and surveyors, its educational value with respect to public officials would be significant.

Messrs. Merry and Burkholder commented on the fact that the newer technologies are making it possible to locate specific points on the surface of the earth very quickly and very accurately. A lengthy discussion then ensued concerning the potential to, in the future, dispense with the use of monuments, substituting coordinate positions determined by satellite observations for the monuments. Chairman Bauer observed that this would require, with respect to the U.S. Public Land Survey corners, the prior determination of the coordinates of those corners. Because this has been done within the Region, he said, is precisely why some officials, including at least one County Director of Public Works, have questioned the need to continue to maintain the monuments marking the corners of the U.S. Public Land Survey System.

Mr. High observed that total reliance on coordinate positions may, in the long term, place society at risk since -- for various reasons -- the satellite based system may fail. Chairman Bauer agreed with Mr. High, noting that, although the possibility was remote, the navigation satellites may become targets during a war, or if an economic collapse occurs, society may not be able, or willing, to bear the very high costs of maintaining the satellites. He observed that viewed in this context, monuments were actually a very cheap and cost effective means of maintaining a survey control system. More importantly, however, he said, the need for monuments marking not only the corners of the U.S. Public Land Survey System, but all real property line boundaries was required by the American legal system which had its roots in the English legal system dating back almost one thousand years. Based upon a number of long standing decisions, courts of law may be expected to assign a priority of importance with respect to the location of real property boundaries, corners, and lines in the following order: natural monuments -- consisting of features in the landscape, artificial monuments of record, metes and bounds -- including within the latter in order of precedence measured distances and measured bearings. The courts, he said, may eventually include coordinates on this list, probably assigning them the lowest order of precedence; but even that is highly unlikely given the esoteric nature of coordinate values to laymen; that they are derived by measurements and computations; and the perceived ephemeral nature of coordinates given their relationship to different datums and datum adjustments in coordinate values given the measurements entailed in determining them and their relationship to different datums and datum adjustments. In his experience, real property owners place great reliance, and often great confidence, in visible survey monuments marking the boundaries of their holdings.

In answer to a question by Mr. Grisa, Chairman Bauer observed that there were locations – areas with high rise building, heavily wooded areas and areas in tunnels and under bridges where the GPS systems do not operate and where resort must be made to conventional survey techniques.

Mr. Burkholder observed that GPS technology provides absolute positions, and can be used to derive relative positions from those absolute provisions. There were times, however, he said, when relative measurements will take precedence over absolute measurements in survey work. Nevertheless, he said that technology is moving to the time when perhaps the satellite orbits may provide the best evidence of where a survey point was located.

Mr. Bennett disagreed with Mr. Burkholder indicating that coordinate values were simply, by themselves, an inadequate and uncertain basis for land and engineering surveys. The control system must be stable and usable by everyone concerned, he said, and not all agencies or practitioners can justify the costs involved in the use of the most advanced technologies.

Mr. Grisa observed that the report should be reorganized in that it was not clear to him where in the text the "Executive Summary" concluded and the body of the text began; and suggested that the paragraph entitled "Introduction" on page 4 be moved to wherever the "Executive Summary" concludes, thus making it clear as to where the body of the text begins.

Mr. Schaefer suggested that the last sentence of the first paragraph on page 9 be broken into two sentences and revised to read as follows: "Scientific definitions are more exacting, and indicate that the Earth's center of mass defines recent – although not historic – ellipsoids, and that horizontal datums are defined on the ellipsoids. Vertical datums are referenced to a equipotential surface known as the geoid, approximated by mean sea level.

Mr. Grisa indicated that it would be helpful in obtaining funding for the development of the necessary datum transformation methods to be able to indicate in the report some sense of the order of magnitude of the differences between positions on NAD 27 and NAD 83 (2007). He indicated that if the magnitude of the differences was in the order of one hundredth of a foot then it may not be necessary to be concerned about differences between the two datums. Chairman Bauer indicated that it may be difficult to respond to this suggestion given the complexities involved. He noted that between NAD 27 to NAD 83 (1991) the shifts in latitude ranged from about 6 to 11 feet within the Region, and that the shifts in longitude ranged from about 36 to 39 feet; these shifts being in absolute positions, and should not significantly affect the relative positions of survey points within the Region. He noted further that it would appear that distances derived from inverse computations utilizing control survey stations with coordinates referred to NAD 83 (1991) are generally closer to comparable distances derived from GPS observations, than comparable distances derived by inverse computations using coordinates referred to on NAD 27. The differences, however, are not significant, he said, and are all within the one part in 10,000 standard to be met by the Commission horizontal control survey system.

[Secretary's Note: The comparisons referenced by Chairman Bauer are provided in the following table taken from SEWRPC Technical Report No. 7, *Horizontal and Vertical Survey Control in Southeastern Wisconsin, 3rd Edition, August 1996.*]

DATA COMPARING DISTANCES DERIVED FROM GLOBAL POSITIONING TECHNOLOGY, NORTH AMERICAN DATUM OF 1927 STATION POSITIONS, AND NORTH AMERICAN DATUM OF 1983 STATION POSITIONS WITHIN THE SOUTHEASTERN WISCONSIN REGION

Station to Station (NGS)	Distance (feet)			Discrepancy Ratio	
	GPS	NAD-27	NAD-83(91)	GPS/NAD-27	GPS/NAD-83
New Lisbon-New Berlin	60,652.78	60,654.62	60,653.20	1:33,000	1:144,400
New Lisbon-Richfield	40,063.97	40,064.95	40,064.28	1:40,900	1:129,200
New Lisbon-Virmond	84,598.96	84,600.46	84,599.19	1:56,400	1:367,800
New Lisbon-Carrolville North Base	107,261.75	107,263.17	107,262.05	1:75,500	1:357,500
Richfield-Virmond	79,397.16	79,399.16	79,397.60	1:39,700	1:180,400
New Berlin-Carrolville North Base	72,800.76	72,800.81	72,800.96	1:1,500,000	1:364,000
Virmond-Carrolville North Base	102,953.42	102,955.43	102,953.42	1:51,200	1:51,476,700
New Lisbon-Oak	111,833.38	111,834.95	111,833.84	1:71,200	1:243,100
New Lisbon-Wauke	35,903.62	35,904.35	35,903.77	1:49,200	1:239,400
New Lisbon-Racine	184,255.59	184,257.59	184,256.85	1:92,100	1:146,200
New Lisbon-Somers	207,906.23	207,907.93	207,907.17	1:122,300	1:221,200
Carrolville North Base-Oak	16,439.12	16,439.60	16,439.51	1:34,200	1:42,200
Oak-Racine	72,692.16	72,692.55	72,692.95	1:186,400	1:92,000
Racine-Somers	39,591.04	39,590.79	39,591.06	1:158,400	1:1,978,600

Source: Wisconsin Department of Transportation and SEWRPC

Chairman Bauer noted further that with respect to vertical position, the Clarke Spheroid of 1866 - used as a basis for NAD 27 - fits the geoid within the Region better than does the Geodetic Reference System of 1980 ellipsoid used as the basis for NAD 83. Mr. Burkholder's work has indicated, he said, that the differences between orthometric elevations referred to NGVD 29 and such elevations referred to NAVD 88 range from approximately 0.08 to 0.32 foot within the Region.

Mr. Schaefer noted that NGVD 29 elevations are based on the geoid which approximates mean sea level. Geodetic distances used in NAD 27 are at the NGVD 29 elevation of zero. The surface of the Clarke Spheroid of 1866 and the geoid elevation of zero are not the same surface although they may match at random places. NAVD 88 elevations tend to approximate mean sea level but are not defined as such. Geodetic distances used in NAD 83 are on the surface of the GRS 80 ellipsoid which in Wisconsin differs by approximately 110 feet vertically from the geoid.

Mr. Burkholder observed that although it would be desirable to develop a single bidirectional transformation procedure for the entire Region, there were distortions in the datums concerned that become apparent in comparing data expressed on the two datums concerned. These differences may make it necessary to develop the transformation procedures for subareas of the Region.

Mr. Schaefer observed that in comparing newer survey work with older work, the older work may exhibit anomalies for a number of reasons, one of which may be that the monuments concerned may have moved; therefore, using the original positions of the old monuments will not fit the positions of the existing monuments as determined by the new work. He indicated that WisDOT had elected not to attempt to determine if all of the control survey monuments concerned are still in their original position, but instead to simply determine a new position.

Mr. Grisa referred to the 4th bulleted item on page 10 and indicated it would be desirable to include an estimate of a rate at which the rebound of the earth's crust is occurring within the Region. Chairman Bauer indicated that there were data available in the Commission files on this rate and that he would provide that information with the minutes of this meeting.

[Secretary's Note: The issue of crustal movement, and the need for the use of a dynamic – or equipotential – datum in dealing with the hydraulics of the Great Lakes was addressed in a December 1989 issue of the Commission's "Technical Record." The map on page 15 has been taken from that publication. It should be noted that the map indicates that in the vicinity of Milwaukee the apparent vertical movement rate was as determined by the U.S. Army Corps of Engineers in 1977 to be -0.5 feet per century, indicating that the earth's crust was actually subsiding in this area of the Great Lakes. In the approximately thirty years since the publication of the map that subsidence should have approximated 0.15 foot. The publication also included descriptions of the differences between spirit level elevations, orthometric heights, and dynamic heights.]

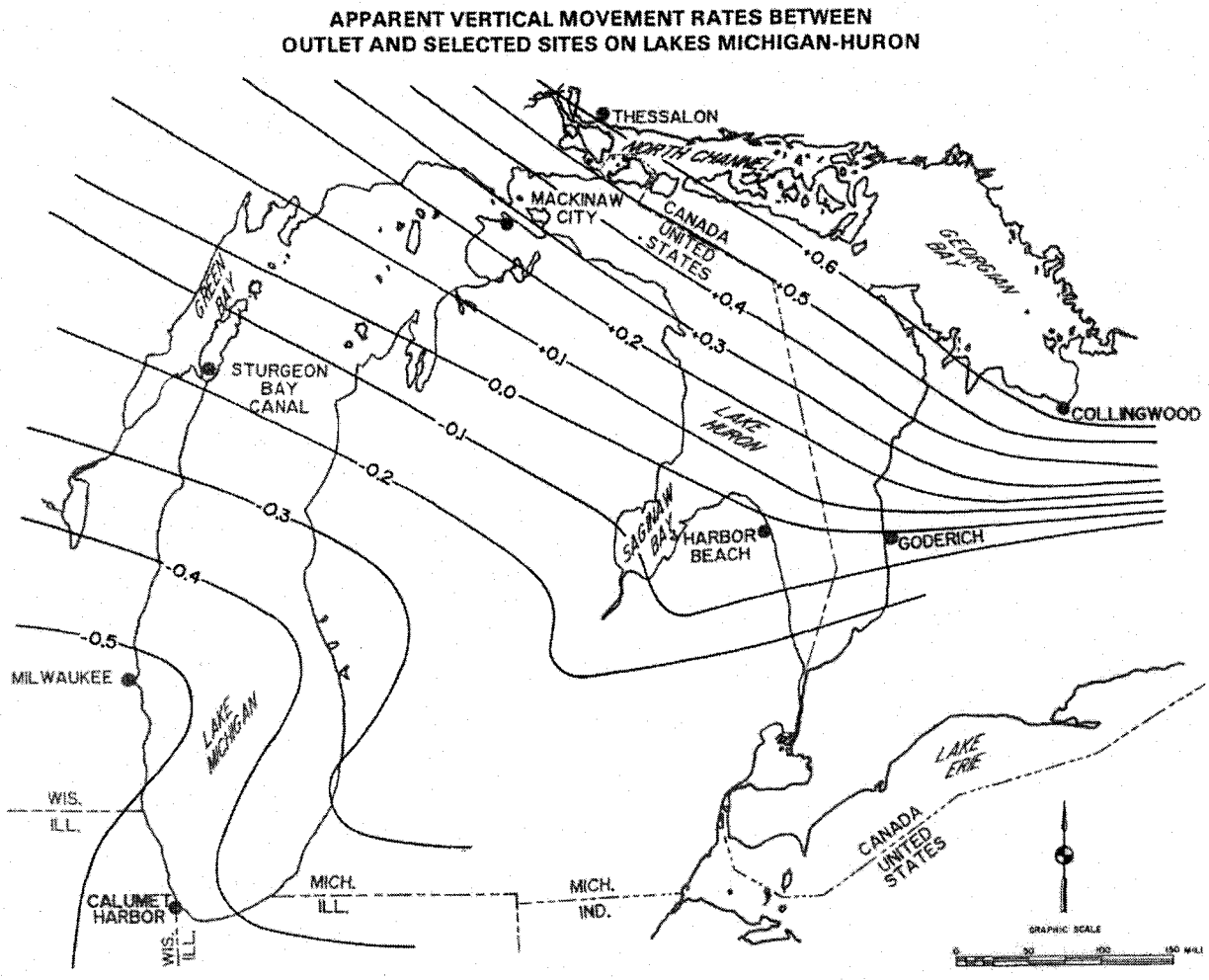
Mr. Schaefer noted that the sixth bulleted item beginning on the bottom of page 10 addressed both horizontal and vertical components of the control networks. He suggested that this item be divided into two bulleted items, one dealing with the horizontal component of the networks and the other the vertical. In the revision it would be helpful, he said, to explain that the NAD 83 (2007) adjustment was a three-dimensional adjustment, but that often only the horizontal component is utilized. He noted that there were really four components that defined the position of a point: latitude and longitude; ellipsoid height; and orthometric height.

Mr. Schaefer called attention to the second full paragraph on page 11 indicating that he felt there were some misleading statements in the paragraph and rather than take the time to describe these in the meeting, he suggested, and it was agreed, that he would provide a revised paragraph to the Committee Secretary for inclusion in the minutes of the report. Mr. Schaefer provided the following paragraph:

> Recommend deleting the last sentence of the paragraph which reads "The NGS incorporates both ITRF and NAD 83 in the positions published for the CORS stations and provides horizontal time dependent positioning (HTDP) software that can be used to translate positions from one epoch to another and between positions on the ITRF and NAD 83." The reason for this recommendation is that since Wisconsin is east of longitude W 111 degrees and the HTDP software only works between longitude W 111 and W 125 degrees, the software does not work in Wisconsin.

Mr. Grisa called attention to the description of the proposed bidirectional transformations and indicated it would indeed be important to be able to convert between NAD 27 and the selected newer datum – apparently NAD 83 (2007) – and that to be able to do so for use in both the field and office. Mr. Burkholder observed achieving this would be a challenge since there would be a need to keep distinct and separate not only the datum issues, but also the direction issues. Chairman Bauer indicated that he did not see a problem as long as a stated specified level of accuracy accompanied the bidirectional transformation method; indicated that if a surveyor or engineer desires to use the Commission's control survey data, but work in NAD 83 (2007), it will be possible using the bidirectional transformation procedure to provide the control survey coordinates in NAD 83 (2007) to the specified level of accuracy; or if a surveyor or engineer has completed field work and provides the municipality, County, or Commission with NAD 83 (2007) coordinates, and the data concerned are to be placed in the municipal, County or Commission database, the NAD 83 (2007) coordinates can be converted to NAD 27 values using the transformation procedure.

Map



Source: "Apparent Vertical Movement Over the Great Lakes," The Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data; Detroit District, U. S. Army Corps of Engineers, July 1977.

Mr. Merry suggested that there could be problems with users confusing the two sets of coordinate values and this could lead to costly errors. Chairman Bauer agreed, and indicated precisely such an error had occurred during the design and construction of the MMSD deep tunnel conveyance system in which a design engineer had apparently used NAD 83 (1991) coordinate values for the location of a drop shaft when he should have used NAD 27 values. However, the Chairman said, no system can be made foolproof, and the selection of the correct coordinate values to use in a given application is a responsibility of the professional practitioner involved. He noted that confusing State Plane Coordinate values based upon NAD 83 (1991) with distances based upon NAD 27 should not in any case occur if the values based upon NAD 83 (1991) are expressed in meters – as they should be – and the values on NAD 27 are expressed in U.S. survey feet, as they should be.

Mr. Schaefer asked that the minutes show that the coordinate values of the NAD 83 (1991) were intended to be given in meters, the coordinates are nevertheless, sometimes given in U.S. Survey feet. He noted that this was the case within WisDOT and that the State Plane Coordinate values given for projects can't be used as an indication of the datum concerned.

Mr. High referred to the statement in the last full paragraph on page 12 that bidirectional transformations are proposed to be developed. He indicated that in his opinion, this appeared to be a recommendation which should not be made in the report until after all of the alternatives have been presented and evaluated. Chairman Bauer agreed, and indicated that the introductory sentence of the paragraph should be revised to read "If bidirectional transformations are to be developed ...". Chairman Bauer noted that the recommendations made will be, not only Mr. Burkholder's, but the Committee's and will be addressed to the Regional Planning Commission.

Mr. Tym indicated that it would be important for the report to clearly identify the use to which the bidirectional transformation methods can be put. Mr. Burkholder agreed, indicating that it was not intended for the proposed transformation to be used in precise geodetic control applications, but in public works engineering and land surveying applications. Chairman Bauer indicated that it would appear to him that the accuracy level required should then be equivalent to one part in 10,000 or better, identical to the standard which the Commission horizontal control survey network is intended to meet.

In answer to a question by Mr. Merry, Chairman Bauer indicated that the bidirectional transformation method should provide coordinate values that could indeed be used to locate, at stated levels of accuracy, field positions. Mr. Burkholder agreed.

Chairman Bauer called attention to the levels of accuracy listed on page 13 for various survey techniques, indicating that -- as Mr. Burkholder had pointed out -- the values were taken from trade magazines and not peer reviewed journals. He suggested, and the Committee agreed, that some text be added to point this out and to briefly describe the reasons therefore. Mr. Burkholder noted that in the final report, it may be possible to combine in one table, the levels of accuracy for the various techniques set forth on page 13 and the observation scenarios set forth on page 14.

Chairman Bauer called attention to the last sentence in paragraph "E" on page 14, indicating that the statement made should be clarified to indicate the datum or datums involved. Mr. Schaefer agreed, indicating that if the statement intended to apply to the CORS network that WisDOT is in the process of developing, all coordinate positions will be on NAD 83 (2007) and NAVD 88 (2007).

Chairman Bauer called attention to the third sentence in paragraph "G" on page 14 which includes the phrase: "... CORS stations must typically be closer to the new point being established," and asked that the meaning of the term "closer" be defined in this case, that is, closer than what. Mr. Schaefer also indicated that the word "stations" should be removed from the sentence concerned.

The meeting was adjourned at twelve o'clock noon for lunch and reconvened at 12:30PM.

Chairman Bauer called attention to the heading on the top of page 15 suggesting that the title be changed to "Alternative Commission Actions." He noted that this section would have to address, among other issues, the recommended Commission action with respect to the continued

maintenance of the bench mark system within the Region and the potential of utilizing GPS technology to obtain accurate orthometric elevations within the Region.

Mr. Grisa objected to the phrase "do nothing" in the first numbered paragraph on page 15, noting that the Commission was indeed doing a great deal to maintain the control survey networks within the Region. Chairman Bauer suggested substituting the phrase "status quo."

Chairman Bauer called attention to the third numbered paragraph on page 15 concerning the datum transformations, and indicated that in formulating his recommendations as to how to address the problem of multiple datums within the Region, Mr. Burkholder should clearly identify the datums to be addressed by the transformation method to be developed – presumably NAD 27 and NAD 83 (2007). He noted that Mr. Burkholder had already prepared a bidirectional transformation for NAD 27 and NAD 83 (1991). He also observed that within the Region WisDOT apparently plans to continue to use NAD 83 (2007); the MMSD and many of the local municipalities use and apparently expect to continue to use NAD 27; and the seven counties use and apparently expect to continue to use NAD 27; some municipalities, including the City of Milwaukee ignore the use of coordinates and the related datum issues, relying on plane surveying techniques. He noted further that with respect to vertical datums, many municipalities within the Region use and apparently expect to continue to use NGVD 29 as do the seven counties; while some municipalities such as the City of Milwaukee still utilize local vertical datums. The Commission has, however, he said provided equations between such local datums and NGVD 29.

In answer to a question by Mr. Tym, Chairman Bauer indicated that he was not aware of the practices of the Wisconsin Department of Natural Resources (WDNR) in this respect, but noted that the U.S. Fish and Wild Life Service is currently considering adopting a rule with respect to wetland mapping that if adopted would require that wetland maps be based upon NAD 83 and NAVD 88; and that both the WDNR and the Commission had written letters to the U.S. Fish and Wild Life Service asking that the rule permit the utilization of other datums when cognizant Service officials find such use to be desirable. This request, he indicated, was driven by the fact that all of the historic and current wetland mapping within Southeastern Wisconsin is based upon the NAD 27 and NGVD 29 datums.

Mr. Bennett noted that within the City of Franklin, GPS technology is not utilized for determining elevations; the results being, in his opinion, inadequate accuracy. He indicated that the minimum allowable grade of an 8-inch-diameter sanitary sewer was 0.0040 foot per foot, or 0.4 foot per hundred feet, and that the City requires newly constructed sewers to be relaid if that minimum grade is not met. He indicated further that with respect to surface drainage, the City requires a minimum grade of 0.0050 foot per foot on concrete curbs and gutters and that, in his opinion, GPS technology is currently not accurate enough to be used for vertical control in connection with meeting these standards. Therefore, he said, the City continued to use spirit leveling for vertical control and for this reason believed that the Commission bench mark network should continue to be maintained. Chairman Bauer noted that the minimum permissible grade for larger diameter sanitary sewers were even flatter.

Mr. Grisa indicated that a similar situation existed with respect to the establishment of floodplain elevations and the delineation of floodplains; and that the continued maintenance of the Commission bench mark network was, in his opinion, needed for the efficient and effective administration of floodplain zoning ordinances where floodplain elevations often had to be established on a lot-by-lot basis. Chairman Bauer noted that in this respect WDNR regulations specify that the hydraulic grade of the 100-year recurrence interval flood flow not be increased by

more than 0.01 foot by proposed changes in channel cross sections or bridge and culvert waterway openings; a problematic requirement, he said, given the attainable accuracy of vertical control surveys as well as of the hydrologic and hydraulic modeling involved. Mr. Dittmar reiterated that the issue of the need to continue to maintain the network of Commission bench marks within the Region was invariably raised when County budgets were considered annually and that some County officials suggested that if maintenance of the bench mark network was indeed desirable, the cost be borne at the municipal rather than the County level.

Mr. Grisa observed that the need for accurate elevations was an area-wide need which transcended the boundaries of individual municipalities given that arterial streets and highways, sanitary sewerage facilities, and storm water drainage and flood control facilities all had to be developed on an area-wide basis, and that sound engineering practice would include an area-wide network of bench marks. Chairman Bauer observed that in the Milwaukee area, the kinds of facilities referred to by Mr. Grisa transcended county as well as municipal boundary lines and require uniform area-wide horizontal and vertical datums for planning and engineering purposes as well as attendant monument horizontal and vertical survey control stations. Mr. Melcher agreed, noting that the municipalities are an integral part of the counties and the Region and that the counties, therefore, had a responsibility to continue to maintain the bench marks within the Region.

Chairman Bauer observed that accurate area-wide horizontal and vertical datums and related control survey data were not only essential for the determination of line and grade for facility construction, but also for the preparation of accurate facility "as-built" data for use in the development of parcel based land information and public works management systems.

Chairman Bauer noted that it will be important for Mr. Burkholder's report to recommend whether or not GPS technology can be used to provide needed vertical control for public works engineering and land surveying purposes, or whether reliance will have to continue to be placed upon differential spirit leveling and bench marks.

Mr. Merry observed that utilizing static GPS measurement differences in height of between three to five hundredths of a foot per mile were achievable. Chairman Bauer objected indicating that to convert the ellipsoid heights provided by GPS measurements to the orthometric heights required knowledge of the geoid heights, which within this Region were not known with sufficient accuracy to provide the differences indicated. Mr. Merry agreed.

Chairman Bauer observed that a number of years ago the Commission had proposed a research project which would have utilized GPS measurements in conjunction with the Commission's bench mark network to obtain more accurate geoid heights within the Region so that GPS technology could be used in place of differential spirit level surveys. He said that this project had at that time been discussed with Mr. David B. Zilkoski, then in charge of height measurements within the NGS, who had enthusiastically supported the concept of the proposal and agreed to serve on an advisory committee if such a committee were formed. The project, Chairman Bauer said, was never funded.

Mr. Schaefer observed that if the specifications for GPS height and spirit leveling surveys are compared, it may be concluded that the differences in elevations between two points that are less than four and a half miles apart can be more accurately determined by spirit leveling, but if the distance between the two points is more than four and one half miles, GPS technology may be more accurate. He indicated that, in his opinion, differential spirit level surveys will continue to

be a cost effective means for determining elevations for public works and land surveying applications.

In answer to a question by Mr. Grisa, Chairman Bauer indicated that local municipalities should specify in their land subdivision control ordinances, as well as within the practices of their engineering departments, the horizontal and vertical datums/adjustments to be used within their municipality.

In answer to a question from Mr. Bennett, Mr. Charlier indicated that, with respect to elevation, practicing land surveyors within the Region, use whatever datum is specified by the local municipality concerned. Chairman Bauer observed that there were still a substantial number of local surveyors and local consultant municipal engineers that will use assumed elevations in marking out land and public works surveys. Mr. Charlier agreed that that may be a practice in municipalities where there is no established datum.

Mr. Grisa observed that many communities may not realize that WisDOT is now using different horizontal and vertical datums than those to which the Commission control survey networks are related. Chairman Bauer agreed and indicated that the problem was compounded by the use by WisDOT of the County Coordinate Systems which created cross boundary problems in what is actually a single metropolitan Region. Cecil Mehring observed that the problems inherent in the changing datums were further complicated by the fact that the majority of the WisDOT data are not referred to the current datums.

Mr. Mehring called attention the third numbered paragraph on page 15, noting that the wording implied a one-way conversion from NAD 27 to NAD 83 (2007). Mr. Schaefer agreed and indicated that the wording of paragraph 3c on page 15 should indicate that the proposed transformation procedure can be used to convert between NAD 27 and NAD 83 (2007). This same change is necessary, he said, in paragraph 3a.

Mr. Schaefer reiterated that geodetic distances expressed in the NAD 27 system are at sea-level as opposed to being on the ellipsoid; while geodetic distances in the NAD 83 system are on the ellipsoid; so it would appear that as proposed one "end" of a translation will be expressed in latitude and longitude and ellipsoid heights, while at the other "end" it may be expressed in latitude and longitude and elevation on the geoid. This, he said, would require conversion between the geoid and the ellipsoid, and that the geoid height required may not be known with sufficient accuracy within the Region.

Mr. Burkholder indicated that in the modeling process, the equations are not in closed form and the inexactnesses include both differentiations that existed within NAD 27, residual imperfections in the new datum and in small errors attributable to moving from the ellipsoid in one system to the geoid in the other.

Mr. Schaefer observed that the method used to adjust NGVD 29 data was totally different from that used to adjust the NAVD 88 (2007) data, and that, consequently, it would seem that a large number of common points will have to be selected to develop as proposed the needed transformation model. Mr. Burkholder observed that when he developed the vertical transformation procedure for the Commission approximately a decade ago, he abstracted all leveling data done by the Commission and then adjusted the data sequence by level line and simultaneously by area and found that the two approaches yielded the same transformation parameters. He indicated this issue would have to be revisited in the development of a new transformation method.

Mr. Merry suggested that Mr. Burkholder consider recommending the use of nine, instead of seven, parameter Helmert transformation in developing the needed procedure. Mr. Burkholder indicated he would consider the suggestion.

Chairman Bauer noted that Mr. Burkholder had long proposed the adoption of all earth centered x-y-z three-dimensional coordinate system as a basis for the location of points on the surface of the earth, and that he had written a book scheduled to be published soon describing his recommended system. He asked whether the proposed bidirectional transformation methodology might in any way preclude the future adoption and use of a true three-dimensional coordinate system within the Region.

A lengthy discussion ensued concerning the proposed three-dimensional coordinate system which would eliminate the problems associated with the use of multiple datums. In the discussion Mr. Burkholder noted that all of the advantages of the proposed system listed in paragraph number 4 on page 16 and 17 would be attained. Mr. Merry questioned the practicality of the system since it was intended to be earth centered and the realities of physical geodesy would create problems with the application of the system such as uncertainty surrounding the accurate location of the center of mass of the earth, possible instability in that location, and precession of the earth's axis.

In answer to a question by Mr. Schaefer, Mr. Burkholder indicated that in the proposed system, the zero point of the axes involved would be located at the earth's center of mass. The x and y axes would lie in the plane of the equator, while the z axis would lie along the earth's axis of rotation. He indicated that the location of a point in space relative to this system would follow the rules of solid geometry, and height would be a derived quantity; ellipsoids could be superimposed upon the axes which would then introduce the concepts of latitude, longitude, and ellipsoid and orthometric heights; geometrical integrity could be preserved without distortion.

Chairman Bauer called attention to page 17 and noted that estimated costs for carrying out Phase I and Phase II of the proposed bidirectional transformation work would have to be provided in the final draft of the report.

With respect to the "givens" listed on the bottom of page 17, Mr. Merry observed that attempting to combine newer data provided by the application of GPS technology, with older data provided by conventional historic survey techniques might reveal distortions in the systems concerned, and require the modeling involved to be conducted on a relatively small area basis. Mr. Burkholder agreed and indicated that this problem had been successfully addressed in the original effort of a decade ago. He indicated further that his intent would be to begin the analysis with record data and to then identify any additional observations that might be needed.

Mr. Schaefer observed that the heights considered in WisDOT's Height Modernization Program were not determined at the same points used in the 2007 adjustment of NAD 83; and that many bench marks do not have accurate horizontal positions; and that some GPS stations will have GPS derived orthometric heights which are not as good as such heights derived by differential leveling. Consequently, he said, it may be preferable to fall back on the method used by Mr. Burkholder in his original work for the Commission, that considered the horizontal control separately from the vertical, rather than in combination as is apparently being proposed for the new work. Another lengthy discussion ensued concerning this issue, in which Mr. Burkholder indicated that it was intended to accommodate to the extent practical, in the modeling, the HARN, CORS, NAD 83 (2007) and NAVD 88 (2007) data. Mr. Schaefer noted that the NAD 83 (2007) adjustment included CORS, HARN, and some other stations with sufficiently accurate horizontal

positions, and that some of those stations were not included in the vertical adjustment nor vice versa; but that the CORS and HARNS stations would be common stations unless those stations with two dimensions are treated different from those that have three dimensions attached. Mr. Burkholder responded that this was a valid criticism of the proposed approach, and indicated that he would wish to pursue this matter further with Mr. Schaefer before preparing the final draft of his report.

With respect to the first paragraph numbered 2 on the top of page 18, Mr. Schaefer noted that the paragraph should be revised to clarify and support the procedures for horizontal and vertical transformations. The discussion then focused on the detailed procedures proposed to be used in developing the bidirectional transformation method as listed on page 18 and 19, particularly involving issues raised by Mr. Merry concerning the use and treatment of ellipsoid heights derived from GPS measurements, the NGS geoid modeling, and the need for geoid height data at both ends of the transformation. Mr. Burkholder indicated that he was not yet satisfied that the same geoid model should be used at both ends of a transformation, and whether or not the use of a different model at each end of a transformation could be accommodated within the desired accuracy levels of the transformation method.

Mr. Schaefer observed that introducing an intermediate "three dimensional" step in the procedure would require the use of geoid heights to convert between ellipsoid and orthometric heights, a process that involved a number of steps incorporating the use of values that are not very well defined, in particular, geoid height values within the Region, and suggested that a more direct approach would be to use the NGVD 29 and the NAVD 88 (2007) heights, comparing these for known common horizontal positions so that in the modeling the complex intermediate steps could be avoided. Mr. Burkholder indicated that this suggestion had a great deal of merit and should be considered and included in the testing of the methods to be used if the work proceeds.

Chairman Bauer observed that if the recommendation that the Commission develop bidirectional transformation models is accepted by the Commission, and if the recommended work is funded, the creation of a small technical advisory committee to oversee the work would be desirable and could be recommended in the final report.

By consensus, the Committee directed Mr. Burkholder to proceed with the preparation of a revised draft of his report to the Commission, considering in his report the suggestions and directions made and given at this meeting. Chairman Bauer indicated that consideration of the revised draft of Mr. Burkholder's report would be the principal item of business at the third meeting of the Committee.

OTHER BUSINESS AND CONSIDERATION OF DATE AND TIME OF NEXT MEETING

Chairman Bauer then asked the members of the Committee if there were any further business to consider. There being none, Chairman Bauer then asked the Committee to consider a date and time for the next Committee meeting.

After a brief discussion, it was agreed the next meeting of the Committee would be held on February 15, 2008, at the Commission offices beginning at 9:00 a.m.

ADJOURNMENT

There being no further business to come before the Committee, on a motion by Mr. Melcher, seconded by Mr. Charlier, and carried unanimously, the meeting was adjourned at 3:00PM.

Respectfully Submitted,

Lynn G. Heis
Committee Secretary

KWB/lgh
02/20/08
#132710 v2 - C/S - Minutes 2nd Meeting

ATTACHMENT I

PRELIMINARY DRAFT OF BURKHOLDER REPORT AS PRESENTED TO THE COMMITTEE AT THE MEETING HELD ON NOVEMBER 16, 2007

Draft....Draft... Draft....Draft... Draft....Draft... Draft....Draft...

Staff Memorandum for the

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin

Recommendations for Protecting Commission Investment in the System of Horizontal and Vertical Survey Control Networks Throughout the Seven-County Region

by:

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October, 2007

Table of Contents

List of Acronyms and Abbreviations

1.	CBN	Cooperative Base Network - CORS stations operated by others but data sent to NGS.
2.	Commission	Southeastern Wisconsin Regional Planning Commission.
3.	CORPSCON	Program written by U.S CORPS of Engineers for coordinate and datum transformations.
4.	CORS	Continuously Operating Reference System - permanent GPS receiver installation.
5.	DoD	The U.S. Department of Defense
6.	ECEF	Earth-centered Earth-fixed - rectangular geocentric coordinates used by DOD for GPS.
7.	FBN	Federal Base Network - CORS stations maintained by the NGS
8.	FGDC	Federal Geographic Data Committee - interagency organization responsible for the NSDI
9.	Galileo	Satellite positioning system being built by the European community.
10.	Geoidxx	Geoid height interpolation programs published by the NGS in 19XX and 20XX.
11.	GLONASS	Russian satellite navigation system similar to the U.S. GPS system
12.	GNSS	Global Navigation Satellite System - includes GPS, Glonass, and Galileo systems
13.	GPS	Global Positioning System - satellite system built by U.S. DOD and used worldwide.
14.	HTDP	Horizontal Time Dependent Program used by NGS to move data epoch to epoch.
15.	IGLD(55) and (85)	The International Great Lakes Datum developed jointly by U.S. & Canadian scientists.
16.	ITRF	International Terrestrial Reference Frame - international scientific community global datum.
17.	NAD27	North American Datum of 1927 - horizontal datum established by the NGS
18.	NAD83	North American Datum of 1983 - horizontal datum established by the NGS
19.	NAD83(86)	Original NAD83 values as computed and published in 1986.
20.	NAD83(91)	NAD83 values published by the NGS in 1991.
21.	NAD83(97)	NAD83 values published by the NGS in 1997.
22.	NAD83(NSRS2007)	NAD83 values published by the NGS in 2007
23.	NAD83(xx)	Subsequent NAD83 values as published in the year 19XX.
24.	NADCON	Program written by NGS to perform datam conversions NAD27 to NAD83
25.	NAVD88	North American Vertical Datum of 1988 - published and maintained by the NGS
26.	NGS	National Geodetic Survey - responsible for national survey control network.
27.	NGVD29	National Geodetic Vertical Datum of 1929 - vertical datum published by the NGS
28.	NOAA	National Oceanic & Atmospheric Administration - parent agency to the NGS
29.	NSDI	National Spatial Data Infrastructure - the underlying framework of spatial data policies.
30.	NSRS	National Spatial Reference System - combined horizontal/vertical survey control network.
31.	Region	The seven-county area served by the SEWPRC.
32.	RTK	Real-time kinematic - mode of using GPS to establish survey positions in real time.
33.	RTN	Real-time Network of GPS CORS stations providing support for real-time positioning.
34.	SEWRPC	Southeastern Wisconsin Regional Planning Commission
35.	USC&GS	U.S. Coast & Geodetic Survey - predecessor to the NGS
36.	USGS	United States Geological Survey - responsible for national mapping program in the US.
37.	VERTCON	Program written by NGS to perform datum conversion NGVD29 to NAVD88.
38.	WGS84	World Geodetic System of 1984 - datum used by DoD for GPS. Fixed on center of mass.
39.	WHM	Wisconsin Height Modernization program
40.	WISDOT	The Wisconsin Department of Transportation

Introduction

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has, for over 40 years, promulgated establishment of horizontal and vertical survey control networks within the seven-county region. Those networks serve as a framework for the conduct of land and engineering surveys; for the preparation of large-scale topographic and cadastral maps; and as a foundation for the creation of parcel-based land and public works information systems within the region. Dividends on that investment have been significant in terms of orderly infrastructure development, efficient land administration policies, and avoided costs. However, technological developments need to be assessed in terms of compatability with established policies and operational procedures. Such advancements include issues such as computer databases, transition from analog to digital data storage, spatial information management, global positioning system (GPS) measurements, and other tools for generating, analyzing, and using spatial data.

Executive Summary:

Given that Commission established networks of horizontal and vertical survey control are in place and provide a reliable foundation for many spatial data activities throughout the region, it is important for the Commission to recognize the value of that investment and to review recent technological developments in terms of compatability with the existing databases and current policies/procedures. To that end, the Commission established a "Technical Advisory Committee on the Review and Reevaluation of the Regional Control Survey Program" with a charge to:

- Critically review and reevaluate the status and continued utility of the Commission control survey network.
- Recommend any needed changes in the network and in the means for its perpetuation, maintenance and use; and
- Recommend the Commission's role, if any, in the perpetuation, maintenance and use of the network and identify any attendant funding requirements and sources.

The Technical Advisory Committee (see Appendix A) has met, discussed issues, raised questions, offered suggestions, and provided insight into the issues, concerns, and priorities addressed in this report. The Committee is convinced of the continuing need for the control survey network to support land and engineering surveys within the Region and agrees that the survey control networks should continue to serve as the foundational framework for automated parcel based land and public works information systems within the Region.

Recommendations:

The Commission is to be commended for identifying the need and taking steps to protect the investment in the basic horizontal and vertical survey control networks in the seven-county Region. These recommendations are made in recognition of the value of the existing networks, wide-spread reliance on Commission established survey control by spatial data users in various disciplines, the capability of newer positioning technologies, and requests from external users for the Commission to establish compatibility between existing survey control and the recently updated horizontal and vertical datums, the NSRS(2007) as published by the National Geodetic Survey (NGS).

Specific recommendations include:

1. As opposed to using GPS observations and satellite orbit parameters as published by others, the Commission should continue to place primary reliance on the published positions of stable survey monuments as established throughout the Region. Furthermore, the Commission should continue to replace and to re-survey the positions of those monuments that are inadvertently distrubed or destroyed.

2. The Commission should continue the established policy of basing the horizontal survey control network on the North American Datum of 1927 (NAD27) and the vertical network on the National Geodetic Vertical Datum of 1929 (NGVD29). Given the investment in existing horizontal and vertical control databases, the proven quality of those control values, and continued reliance on those datums by spatial data users within the seven-county region, the cost (in terms of resources, efficiency, convenience, and good will) of migrating to the newer North American Datum of 1983 (NSRS2007), and to the North American Vertical Datum of 1988 (NAVD88) currently far outweighs the benefits associated with making such a change.

3. Recognizing advances in positioning technology and the subsequent impact of those advances on many uses of spatial data (digital data files and hard-copy maps), the Commission should pursue development of transformation procedures by which bi-directional conversions between the NAD27 and NAD83(NSRS2007) horizontal datums and the NGVD29 and NAVD88 vertical datums can be accomplished. The procedures should be well defined, technically defensible, and easy to use. Developing bi-directional transformations is a major portion of this report and cost estimates for developing those transformations are included in a subsequent section of this report.

4. The Commission should develop an on-going training and up-dating program whereby procedures involving new technology (e.g. GPS, CORS, and RTN) can be incorporated into the standard spatial data flow affecting both internal and

external users. Of particular interest, the Wisconsin Department of Transportation (WISDOT) has devoted significant resources to Wisconsin height modernization (WHM) both throughout the state and within the seven-county Region. GPS measurements and improved geoid modeling procedures have been proven to be more cost effective than traditional geodetic leveling for establishing orthometric heights in specific cases. The Commission should be aware of that capability because, if used competently, it can be more effective than tradional leveling for establishing reliable orthometric heights on new benchmarks.

5. The Commission should renew its commitment to the user community by re-emphasizing the value of the survey control networks to the spatial data user community. Education and outreach efforts should be developed that highlight the benefits of having the horizontal and vertical control networks in place and relied upon by various disciplines within the Region. It would be appropriate for the Commission to sponsor a yearly (or bi-yearly) forum to inform the user community (both internal and external) on policies regarding use of Commission established survey control network and on technical issues relating to use of new technology.

6. The Commission should continue to participate in the broader professional community by developing and publishing technical papers related to the value and benefits of using a well-controlled digital spatial database.

Monumentation

A survey monument is an object, either natural or man-made, that has been surveyed and precisely located. In years gone by a natural monument could be called for as the top of a mountain, the course of a stream, a tree, or an identifiable rock outcrop. As survey methods and measurements improved, natural monuments have given way to man-made monuments such as an "x" chisled into a concrete pad to mark a survey point; pipes, rods, or axles driven into the ground to mark a property corner; or railroad spikes driven into power poles to serve as a benchmark. Even better, appropriately enscribed brass tablets are embedded into concrete or grouted into bedrock outcrops; stainless steel rods are driven deep into the ground; or a huge pedestal is erected to mark a particular location. Several criteria for survey monuments are:

- The monument must be stable. If the survey mark is located in unconsolidated fill, on the side of a hill subject to lateral movement, set on a stream bank that erodes away, or set in such a manner that it is subject to frost heave, then the value of any surveyed position for the mark is severely compromised and the usefulness of the mark is destroyed.

- A good survey monument must be permanent. Cases exist in which a cedar post has been retrived from a swamp and positively identified as the mark set over 100

years ago by a surveyor who carefully described its location. Although impressive, such an example is not an argument for wood survey monuments. More typically, a permanent monument is constructed of non-ferrous metal and built such that a very specific point on the object is identified as being the survey mark.

- A good survey monument is also readily accessible. In years gone by, geodetic survey markers were located on hills or mountain tops from which other distant points could be viewed. However the value of a survey monument is enhanced if the monument is also located in proximity to where it is to be used. In recent years, GPS surveying has been used to transfer remote and/or hill-top positions to more convenient locations - often on public property or rights-of-way where they are easily reachable by normal vehicular traffic.

- The value of a good survey monument is also enhanced to the extent the site is free of obstacles (trees, buildings, etc) which prevent line of sight to other objects.

Stated differently, the ideal survey monument is one that is located close to where it is needed, is accessible, is permanent, is stable, and has reliable survey control associated with it. In the big picture, survey monuments provide end users reliable convenient access to the horizontal and vertical datums adopted for use in a given area. Nationally, the adopted datums are the National Spatial Reference System (NSRS). Within the seven-county Region the datums include both the NAD27/NGVD29 and the NSRS.

At this point, a distinction should be made between geodetic control monuments and survey monuments intended to mark property corners. Their purposes, although quite similar, are somewhat different. A geodetic marker is intended to provide the end user ready access to the overall geodetic datums while the property corner is intended to delineate property boundaries. Prior to GPS surveying, geodetic surveys were marked with substantial permanent objects. Each monument location was also carefully chosen for stability to protect the investment required to establish the geodetic monument. On the other hand, markers for property corners are set on the corner, whether convenient or not, and off-sets are only used when it is impossible to set a marker on the actual property corner. Property corners are typically marked with iron rods driven in the earth and are admittedly not as permanent as a typical geodetic marker.

Survey monuments are also called for in legal descriptions of real property and a fundamental tenent of land ownership is that an original undistrubed monument controls the location of associated property lines even if current measurements are inconsistent with the stated surveyed location of the monument. Even though this line of reasoing leads to broader issues of relative positioning (monuments and coordinate differences) and absolute positioning (coordinates), several points of which to be aware include:

- The role of the surveyor is to collect, evaluate, and present evidence. That evidence may include records of prior surveys, knowledge of local history and

practice, measurements and retracements, and any other information having an impact on the correct determination of the intent of the parties.

- Sometimes it is very difficult to prove that a found monument is undistrubed.

- When the surveyed location of section corners and property corners have been defined by state plane coordinates (as is generally the case throughout the seven-county region) then the ambiguity of any subsequently resurveyed location can be enormously reduced. Evaluation of the evidence can be very straightforward because of the excellent agreement between the record and current measurements.

- It is now possible using current GPS equipment and measurements to duplicate the location of any published state plane coordinate within a small tolerance. Access to the NSRS no longer depends upon the location, stability, permanence, or configuration of a survey monument. The state plane coordinate position (and to a lesser degree elevations) can be determined from measurements to the satellites within the framework of the defined datum.

In that latest scenario, the observation is made that the satellite orbits have effectively replaced the monument on the ground as end-user access to the NSRS. In either case a competent surveyor is able to establish and/or re-establish the known position of a corner within practical tolerances – say within 0.05 to 0.10 feet. However, it is often much easier for a lay person (a neighbor or the courts) to understand the location of a property corner related to a visible nearby geodetic survey control monument or other physical feature (such as roads, fences, or streams) than to believe the numbers generated from an electronic gadget collecting signals from orbiting satellites.

There is a long-standing legal history involving priority of coordinates and monuments with regard to definition of property lines. Although GPS technology can be used to show remarkable agreement between record positions and surveyed positions, it is viewed as prematue to question the importance or the legal stature of the called-for monument. In the big picture, the GPS surveyed location of a geodetic control monument or a property corner can be accomplished with similar ease and efficiency. But, just because a property corner can be competently located with GPS independent of a nearby geodetic control monument does not mean that is the way everyone should do it. Prudent policy should continue to honor the well established principle that the undistrubed monument is the prima-facie evidence. As practice continues to evolve, the agreement between a monument-based location and the satellite-derived location should fall within the combined positional tolerance of both sources. Resolving discrepancies between record and measurement should be part of the standard procedures for evaluating and using the best available evidence.

Multiple Datums

A datum is a reference to which other values are related. Historically, in surveying there are horizontal datums and vertical datums. They are separate in that a horizontal datum is referenced to parallels of latitude and meridians of longitude but a vertical datum is understood to be referenced to mean sea level. Scientific definitions are more exacting and it is said that horizontal datums are ultimately referenced to Earth's center of mass while vertical datums are referenced to an equipotential surface known as the geoid (approximated by mean sea level).

The National Geodetic Survey (NGS), formerly known as the U.S.Coast & Geodetic Survey, is a component of the National Oceanic and Atmospheric Administration (NOAA) and is the agency reponsible for establishing and maintaining the surveying datums in the United States. The NGS is a small agency but, since the early 1800's, has enjoyed a proud tradition of conducting high caliber surveys to establish precise geodetic positions on both horizontal and vertical control monuments throughout the United States. A brief summary of horizontal datums was written by Joe Dracup, former Chief Geodesist for the USC&GS, as:

> *In 1879 the first national datum was established and identified as the New England Datum. Station PRINCIPIO in Maryland, about midway between Maine and Georgia, the extent of the contiguous triangulation was selected as the initial point with its position and azimuth to TURKEY POINT determined from all available astronomical data, i.e. 56 determinations of latitude, 7 of longitude, and 72 for azimuth.*
>
> *Later its position was transferred to station MEADES RANCH in Kansas and the azimuth to WALDO by computation through the triangulation. The Clarke Spheroid of 1866 was selected as the computational surface for the datum in 1880, replacing the Bessel spheroid of 1841 used after 1843. Prior to 1843, there is some evidence that the Walbeck 1819 spheroid was employed.*
>
> *The datum was renamed the U.S. Standard Datum in 1901 and in 1913 the North American Datum (NAD) as Canada and Mexico adopted the system. In 1927 an adjustment of the first-order triangulation of the U.S., Canada and Mexico was began and completed about 1931. The end result was the North American Datum of 1927 (NAD27).*

A similar history of the vertical datums was written by Ralph Moore Berry (1976), former Assistant to the Director of NGS, who notes that the National Geodetic Vertical Datum of 1929 is identical to the Mean Sea Level Datum of 1929 except for the name change to avoid the implication that a "zero" elevation provides a reliable distinction between what is land and what is ocean. No benchmark elevations or names of stations were changed – only the name of the datum was changed.

The survey control networks currently utilized by the Commission in the seven-county region are based upon the North American Datum of 1927 (NAD27) for horizontal and the National Geodetic Vertical Datum of 1929 (NGVD29) for vertical.

In the normal conduct of their duties, the NGS has readjusted and up-dated both the horizontal and vertical datums in the United States – including the State of Wisconsin. Several realizations of the updates include:

- A horizontal datum update from NAD27 to the North American Datum of 1983. The completion happened in 1986 so the datum is known as the NAD83(86).

- A horizontal datum update in 1991 based upon improved positions as a result of using GPS technology. The update is state specific and known as NAD83(91).

- A horizontal datum update in 1997 based upon an improved 3-D GPS survey. That update is also state specific and known as NAD86(97).

- Scientific agencies within Canada and the United States have long collaborated on elevation issues in Canada and the upper midwest. The International Great Lakes Datum (IGLD) was established in 1955 in recognition of the continuing rebound of the Earth's crust in the greater Hudson Bay region in response to removal of the crustal loading since the most recent ice age. A separate issue is that conventional orthometric heights do not accurately reflect hydraulic gradients for the Great Lakes System. The IGLD was designed to use dynamic heights in place of orthometric heights and the IGLD was intended to be readjusted every 30 years or so to reflect the on-going crustal rebound. Those issues and changes, although small, do affect elevations as used in the SEWRPC Region.

- Following readjustment of the horizontal datum published in 1986, the NGS turned their attention to updating the vertical datum in the United States. The new vertical datum adjustment is known as the North American Vertical Datum of 1988. From a big picture (and scientific) perspective, the NADV88 is superior to the NGVD29 because elevation differences between benchmarks (both locally and coast to coast) are more consistent than those of the NGVD29. And, an added advantage is the consistency established between the new NAVD88 and the IGLD85 due to the underlying geopotential numbers being the same on both datums. The difference is that NAVD88 publishes orthometric heights and while the IGLD publishes and use dynamic heights.

- In 2006 and 2007, NGS readjusted the entire National Spatial Reference System and combined the various state-specific adjustments into a single adjustment constrained to the national network of CORS stations whose positions are precisely known and continuously monitored. The adjustment provides 3-D consistency throughout the United States and avoids the state-specific localized adjustments conducted between 1986 and 2007. The latest readjustment is known as the NAD83(NSRS2007). The adjustment was completed in February 2007 but

the adjusted information has only recently become available on the published data sheets for published control points. With publication of the NAD83(NSRS2007) the datum is effectively a single 3-D datum with separate horizontal and vertical components available for use at the prerogative of the user.

- The Wisconsin Department of Transportation (WISDOT) has also conducted geodetic surveys – both horizontal and vertical – within the seven-county region and has conducted localized adjustments in conjunction with the NGS. Those results are available as part of the NGS database and eligibible to contribute to the realization of the the NSRS in the seven-county region.

Separately, the U.S. DoD is the agency that developed the GPS that has become the standard positioning system used all over the world. The datum used by GPS is the World Geodetic System of 1984 and includes both an ellipsoid and a formal datum definition. The GPS satellites physically orbit the Earth's center of mass and the intent of the DOD is for the datum to match the orbits as closely as practicable. That means the WGS84 datum origin is modified from time to time to reflect better knowledge of that center of mass. The various epochs of the WGS84 are numbered in GPS weeks starting 6 January 1980 and include WGS84(G730), WGS84(G873), and WGS84(G1150) which was implemented on 20 January 2002. Orbits of the GPS satellites are monitored continuously by the DoD and ephemerides are computed for the orbits – both predicted (known as broadcast) and historical (precise). Those orbit parameters are the basis of positions computed from GPS observations. The point is that WGS84 is governed by knowledge of the Earth's center of mass, that GPS signals are native to the WGS84, and that the U.S.DoD maintains the GPS for its declared purposes. It could be said that civilian communities worldwide are at the mercy of the US DoD with regard to continued use of GPS.

The international scientific community also monitors GPS satellite orbits and has defined the International Terrestrial Reference Frame (ITRF) which very closely matches the WGS84 but whose determination and use is separate from the U.S.DoD. The ITRF is designed for a global best fit and continental drift shows up in the positions determined within the ITRF. On the other hand, the NAD83 is fixed to the North American continent and, for practical puposes, the NAD83 moves with the North American plate. The NAD83 as a datum is very stable for areas, including the SEWRPC Region, within the United States. The NGS incorporates both ITRF and NAD83 in the positions published for the CORS stations and provides horizontal time dependent positioning (HTDP) software that can be used to translate positions from one epoch to another and between positions on the ITRF and NAD83.

The following is included for information purposes and judged to have little or no impact on the issues currently being discussed with regard to datums being used within the SEWRPC Region. The Russian GLONASS and the European Galileo systems use neither the WGS84 nor the NAD83 datums. To the extent that becomes an issue in the United States, the vendors deal with those issues and equipment marketed in the United States is designed to be used on either the NAD83 or the WGS84 datums.

All this background is offered for the purpose of better understanding the questions related to continued use of the NAD27 and NAVD88 datums within the SEWRPC Region. Ideally there would be a civilian datum which does not change and a military/scientific datum to serve other purposes. However, the problem is that the "civilian" datum is subject to periodic upgrades and that modern measurements obtained from GPS are inextractably linked to the WGS84 "military" datum. There is no "fixed" or mathematically defined relationship between the WDG84, the NAD83(NSRS2007), and the NAD29/NAVD88 and spatial data users, both internal and external to SEWRPC, find themselves in a position needing to deal with elements of both.

Scenario: For some it is already possible, but spatial data users in the near future will enjoy the luxury of carrying an instrument into the field that is capable of providing real-time positioning within 0.10 feet (3 centimeters). The same portable field equipment will also have storage capacity and processing capability to access the spatial data base. Apples and oranges (datums) do not mix. Without using some sort of transformation, it is not reasonable to expect values from the SEWRPC data base to be compatible with data collected with modern GPS units.

The problem to be avoided is for the end user to contend with datum issues instead of proceeding with productive work. Implemented appropriately, the datum issues will have been addressed behind the scenes and the spatial data user, both internal and external, will be able to engage in productive spatial data activities without needing to worry about datum issues.

Bi-directional transformations are proposed to be developed that will enable data to be transformed between NAD27/NGVD29 and the NAD83(NSRS2007) datums. No transformation will be perfect. But each of the two following alternatives is possible.

A. In the first case, the existing database values will be automatically and instantly converted to NAD83(NSRS2007) values within the field unit so that "record" values are compatible with those being obtained from the satellites orbiting the Earth's physical center of mass.

B. In the second case, the observed GPS values will be automatically (if directed by the user) and instantly converted to NAD27 and NGVD29 values so that the modern "GPS" values will be compatible with those currently residing in the SEWRPC database.

C. In either case, the "relative" differences between common points in both systems should be very similar. But, they will not be perfect due to known distortion existing within the NAD27 datum. For second and third order comparsions and for use in local civil infrastructure development and cadastral parcel definition, those comparisons should (and are expected to) be very acceptable. There will be a point where such procedures are not deemed acceptable for geodetic control

surveys. That level of spatial data integrity will need to be determined in testing the veracity of the transformations.

The same criteria also need to be applied to other field and office operations. A consistent policy needs to be applied so that all users know specifically what datum they are working with and what steps/decisions with regard to datum issues must be accomplished to achieve consistent results.

CORS, RTK and RTN

GPS positioning technology has matured to the point it is possible to determine horizontal and vertical positions within 0.5 feet in real-time. And, depending upon the level of sophistication applied the geodetic position of a point can be determined in 3 dimensions within 2-5 centimeters (about 0.1 to 0.2 feet) very economically. Even more precise geodetic positions are routinely possible using carrier phase GPS baselines to build a network tied to the NGS CORS.

Techniques and levels of accuracy typically attainable include:

	Within about
A. Hand-held code-phase receivers operating in autonomous mode	5 m or 15 ft.
B. WAAS corrected code-phase receivers	2-3 m or 10 ft
C. Differentially corrected code-phase receivers – local	1-2 m or 8 ft
D. Post processed code-phase differentially corrected	0.5 to 2 m or 6 ft
E. RTK carrier phase single baseline over nominal distance	0.05 to 0.5 m or 1.5 ft
F. RTK carrier phase multiple (redundant) baselines	0.01 to 0.2 m or 0.5 ft
G. RTK carrier phase network solution	0.01 to 0.1 m or 0.3 ft
H. OPUS dual frequency 2 hours of data – absolute position	0.02 to 0.05 m or 0.2 ft
I. OPUS-RS single frequency 15 minutes of data	0.02 to 0.05 m or 0.2 ft
J. Static carrier phase, either single baseline or network,	0.005 to 0.020 m or 0.02 ft

Traditional static GPS observations (1-2 hours of data in a network configuration with two independent occupations) can be used to determine the 3-D position of a survey monument within 1-2 cm (less than 0.10 feet). Sites with good sky visibility are required and data processing must be carefully monitored.

Possible equipment/observation scenarios include:

A. Autonomous position single receiver – typically hand-held.

B. Differentially corrected position from base (may be permanent) and remote units.

C. Static carrier phase observations to 2 or more instruments simultaneously. Post processing is required.

D. Real-time kinematic carrier phase positions obtained from base station and remote. Processing occurs in the remote unit and displays position in real time. This mode requires radio or cell phone communication between base and remote units.

E. Real-time network solution is based upon multiple permanent base stations configured in a local network that broadcast corrections to local remote units. High quality positions are available in real-time. Transportation Departments in the states of Ohio (2004) and Michigan (2005) were pioneers in the United States for investing in state-wide Real-Time Networks. In several other states (Texas and Virginia) private networks have been installed and supported on a user subscription basis. In other cities and metropolitan areas (e.g. Albuquerque and Atlanta), a smaller permanent GPS network serves the needs of local users. Getting a RTN set up and operational is no trivial undertaking but once established, seems to work quite well for the mutual benefit of subscribing users. Such networks, whether public or private, provide subscribing users the ability to position points precisely anywhere within the coverage of the network.

F. Dual frequency carrier phase data are collected for several hours and sent via email to NGS for processing. The results are typically sent back within minutes and provide an absolute position within about 0.05 to 0.10 meters. The solution is developed automatically without human intervention and based upon using data from the network of continuously operating reference stations (CORS).

G. Single frequency data sets as short as 15 minutes can be submitted to NGS for processing using a newer algorithm. Results are still be tested but indications are they are as good as regular OPUS solutions. However, the CORS stations must typically be closer to the new point being established. A general comment is that an OPUS solution is more time dependent while the OPUS-RS is more distance dependent to the CORS used in the solution.

Alternatives and Using GPS for Orthometric Heights

Several alternatives that could be selected by the Commission include:

1. "Do nothing" is probably best described as continuing to do what is being done now. That means that values in the database are NAD27 and NGVD29 and on-going development of the civil infrastructure, topographic mapping, cadastral overlays, flood plain studies, and other spatial data uses are based upon those datums. It also means that use of modern GPS positioning methods is hampered because those systems generate answers and solutions based upon the WGS84 and/or the NAD83. The problem is that satellites physically orbit the Earth's center of mass and GPS data/results are compatible with those datums.

2. An alternative would be to find a way to move the horizontal and vertical databases to the NAD83(NSRS2007) horizontal datum and the NAVD88 vertical datum. The advantage would be that issues of datum difference would disappear. This alternative would be technically possible but it would also be a very expensive undertaking. The benefits of making that transition would need to justify both the dollar cost and the inconvenience of the transition.

3. A more reasonable approach is to develop one or more bi-directional transformations that can be used to convert NAD27 values to NAD83(NSRS200) and NGVD29 values to NAVD88 values. Due to the distortions known to exist in the older datums, it is impossible to develop a closed form mathematical equation to be used for all points. If this alternative is selected, the following issues will need to be considered and addressed.

    a. Transformations can be used to convert NAD27 values to NAD83 values so that users are working with values that are compatible with GPS operations – including real-time positioning.

    b. Transformations can be used to convert NAD83 GPS derived values to NAD27 values so that data to be included in the existing database will be compatible with what is already there.

    c. Users could be permitted to choose and use either approach as dictated by the circumstance. This option provides the most flexibility and convenience but this option has the potential to be confusing because all users will need to be very specific about which datum they are using.

    d. It may be the position of the Commission to continue using NAD27 and NGVD29 for all internal uses and to provide the transformation procedures to external users and expect them to assume responsibility for any and all transformations. That makes it cleaner for internal operations but it will likely drive up the cost to the Commission to secure services of those using the modern positioning technology.

e. Current transformations as described in SEWERPC Technical Reports #34 and #35 were developed separately for horizontal and vertical datums. Given the NAD83(NSRS2007) is a 3-D datum, the transformation modeling for the current effort should be done with the 7-parameter Helmert transformation. The tools used in Technical Report #34 were valid for 2-D transformations but the Helmert transformations are specifically applicable for combining both the horizontal and vertical transformations into a single modeling operation. Once the Helmert transformation is completed (behind the scenes), subsequent steps will be identified so that the end user will be able to employ bi-directional horizontal and vertical transformations separately.

4. The remaining alternative is a huge step and, if done all at once, could be quite costly. But the potential benefits will likely make this alternative attractive at some point in the future. This alternative is not recommended at this time but listed in order to provide context and comparison for the other alternatives. The process is to convert the existing horizontal and vertical databases to an integrated 3-D database in which datum issues largely disappear because:

   a. All subsequent spatial data operations are based upon values stored in the integrated 3-D database.

   b. Each point is stored as absolute X/Y/Z coordinates along with a covariance matrix which provides reliable statistical information on spatial data accuracy.

   c. Any point pulled out of the database will have its positional accuracy immediately available in each of three dimensions. The user will be able to impose a filter of any (selectable) magnitude to decide what points to use or not use.

   d. The relative position of any point-pair is immediately available at the ground level of either end point (user choice) and the direction between points is referenced to the true meridian. Geodetic forward and back azimuths are both available.

   e. Another option is for the user to select any convenient Point-of-Begininng and all relative distances/directions are reported on the basis of a tangent plane through the selected P.O.B. This feature makes the issue of low distortion projection moot.

   f. Plotting topographic maps is facilitated by computing the relative local easting and northing from any selected P.O.B.

g. When working with relative values, datum issues are largely moot because datum issues are applicable to absolute coordinates.

h. The standard deviation of any computed distance, azimuth, or elevation is immediately avaliable if the covariance information has been stored in the 3-D database. Such data are (or can be) standard products of modern positioning technology and processing software.

Another issue deserving careful consideration is using GPS as the primary means by which to establish orthometric heights. The WISDOT has been engaged in the Wisconsin Height Modernization Program (WHM) for several years and has conducted operations within the seven-county Region as well as throughout the state. Information concerning those operations as they affect policies and procedures recommended to the Commission will be included in the final report.

Description and Cost of Developing Bi-Directional Transformations

The scope of developing bi-directional transformations is listed in two phases. It is anticipated that the conceptual framework described herein will first be tested and proven on a representative portion of data within the SEWRPC Region. Upon satisfactory completion of the testing, the proven process will be applied to the remainder of areas included within the SEWPRC Region.

The estimated cost for Phase I lasting from 6 to 12 months is $_____

The estimated cost for Phase II lasting for another 9 months is $_____

Givens:

1. First and Second Order control points within seven-county region on NAD27.
2. First and Second Order elevations within seven-county region on NGVD29 benchmarks

3. Published control values on CORS stations in seven-county region; 3-D. (Identify by name and location).
4. Published NAD83(NSRS2007) positions on same control points.

5. Published NAD83(NSRS2007) values on HARN points in the region.
6. Published NAVD88 first and second order elevations on existing benchmarks.

Tools:

1. Applicable software tools routinely available from the NGS include:

   a. Geoid96, Geoid99, Geoid03
   b. NADCON
   c. VERTCON
   d. HDTP
   e. OPUS
   f. OPUS-RS
   g. Other

2. Existing transformations procedures identified for NAD27 to NAD83(91).

   a. A Mathematical Relationship Between NAD27 and NAD83(91) State Plane Coordinates in Southeastern Wisconsin. SEWRPC Technical Report #34. 1994.

   b. Vertical Datum Differences in Southeastern Wisconsin, SEWRPC Technical Report #35.

Procedures envisioned developing the bi-directional transformations:

1. Inventory existing first (and maybe second) order horizontal control points within the seven county region.

2. Inventory existing first and second order benchmarks within the seven county region.

3. Identify sub-set of points holding both horizontal and vertical control.

4. Convert NGVD29 elevations to ellipsoid heights using Geoidxx.

5. Using NAD27 latitude/longitude and ellispoid heights, compute geocentric X/Y/Z values for such common stations. Estimate standard deviation for each component – easting, northing, and up.

6. Determine (high order) NAD83(NSRS2007) X/Y/Z coordinates for common points either from existing records or new GPS survey. The number of new points needed won't be known until we know what is available to work with. Standard deviations of NAD83(NSRS2007) points should be readily available and used as input.

7. Hold common points (with estimated standard deviations) in both datums and use in Helmert 7-parmeter transformation to solve for Tx, Ty, Tz, $R\omega$, $R\varphi$, $R\kappa$, and scale. This solution will also provide standard deviations of the solved parameters.

8. Evaluate the scope (area coverage) for which those parameters provide acceptable results. This will be done by carefully conducted "blind tests" to verify level of accuracy achieved by the transformation. Note, it is known that distortions exist between the older NAD27 datum and the newer NAD83(NSRS2007) datum. This is analogous to the procedures used for the previous transformations 10 years ago. We were able to determine acceptable transformations for the seven-county region using 14 different sets of parameters.

9. The previous (1994) project determined parameters for horizontal transformations only. By using the Helmert transformation we will be able to model horizontal and vertical distortions simultaneously. It would be possible to develop separate horizontal and vertical models but the Helmert transformation is mathematically rigorous and well defined for the 3-D X/Y/Z environment.

10. Once the Helmert transformation parameters are determined, it will be possible to model separate horizontal and vertical procedures for local provable use. X/Y/Z values will be converted to latitude/longitude/ellipsoid height. Those latitude/longitude values will be converted to NAD83(NSRS2007) state plane coordinates and ellipsoid heights will be converted to NAVD88 orthometric heights. Length units will be users selectable – presumably U.S. Survey feet. An estimate of the accuracy will be available from the statistics of the transformation process.

    A. For horizontal, the local transformations will look very similar to those developed in 1994.

    B. For vertical, the local transformation will be very close to that obtained by using Vertcon. The difference will be that geoid modeling will be used twice – once in converting NGVD29 orthometric heights to (NAD27) ellipsoid heights and again when converting NAD83(NSRS2007) ellipsoid heights to NAVD88 orthometric heights. Note, this item will need careful testing to document the level of acceptability.

References

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Berry, Ralph Moore, 1976; "History of Geodetic Leveling in the United States," Surveying & Mapping, Vol. 32, No. 2, pp 137-153.

A Mathematical Relationship Between NAD27 and NAD83(91) State Plane Coordinates in Southeastern Wisconsin, SEWRPC Technical Report No. 34, December 1994

Vertical Datum Differences in Southeastern Wisconsin, SEWPRC Technical Report No. 35, December, 1995.

Definition of a Three-Dimensional Spatial Data Model for Southeastern Wisconsin, prepared by Earl F. Burkholder, January 1997.

RTN-101 – A series of articles by Gavin Schrock, LS published in American Surveyor magazine.

Part 1 - September 2006	An introduction to Network Corrected Real-Time GPS/GNSS
Part 2 - October 2006	An Introduction to Network Corrected Real-Time GPS/GNSS
Part 3 - November 2006	Communications – Making that First Rover Connection
Part 4 - December 2006	On-Grid – An Initiative in Support of TRN Development
Part 5 - March 2007	Reference Station Communications
Part 6 - April 2007	Network Connected Real-Time GPS/GNSS (Tips and Tricks)
Part 7 - May 2007	Technological Approaches to Network-based Corrections

The On-Grid Initiative by Galvin Schrock, LS; March 2006, Prepared for the American Congress on Surveying & Mapping and the National Society of Professional Surveyors, Washington State Reference Network.

Appendix A – List of Technical Advisory Committee Members

PROPOSED COMPOSITION
TECHNICAL ADVISORY COMMITTEE ON THE REVIEW OF THE REGIONAL CONTROL SURVEY PROGRAM

Kurt W. Bauer, PE, RLS, AICP	Executive Director Emeritus, SEWRPC
John M. Bennett, PE	City Engineer-Director of Public Works, City of Franklin
John P. Casucci, RLS	Survey Land Development Manager, National Survey and Engineering
Harold S. Charlier, RLS	Executive Director, Wisconsin Society of Land Surveyors
Michael R. Duckett, PE, RLS	President, Duckett Group, Executive Director, Southeast Wisconsin Professional Baseball District
John T. Ellingson, RLS	Wisconsin State Geodetic Advisor, Natural Geodetic Survey
Thomas M. Grisa, PE	Director of Public Works, City of Brookfield
Gregory G. High, PE	Director, Architectural, Engineering and Environmental Services Milwaukee County Department of Transportation and Public Works
Ms. Marcia G. Lindholm, PE	Civil Engineer Senior, City of Milwaukee Department of Public Works
Cecil F. Mehring, PE	Manager of Planning and Engineering Services Racine County Department of Public Works
George E. Melcher	Director of Planning and Development, Kenosha County
Robert W. Merry, RLS	Chief Technical Officer, Aero-Metric, Inc.
Kent B. Pena	State GIS Coordinator, USDA Natural Resources Conservation Service
Glen R. Schaefer, PE, RLS	Geodetic Engineer, Wisconsin Department of Transportation
Daniel R. Talarczyk, RLS	Survey Services Supervisor, Milwaukee Metropolitan Sewerage District
Thomas J. Tym	Head, Technology Services Department, Ruekert-Mielke, Inc.
William T. Wambach, PE, RLS	Former District Director, District 1, Wisconsin Department of Transportation

Appendix B – Minutes of Technical Advisory Committee Meetings:

1. July 25, 2007
2. November 16, 2007
3. December xx, 2007