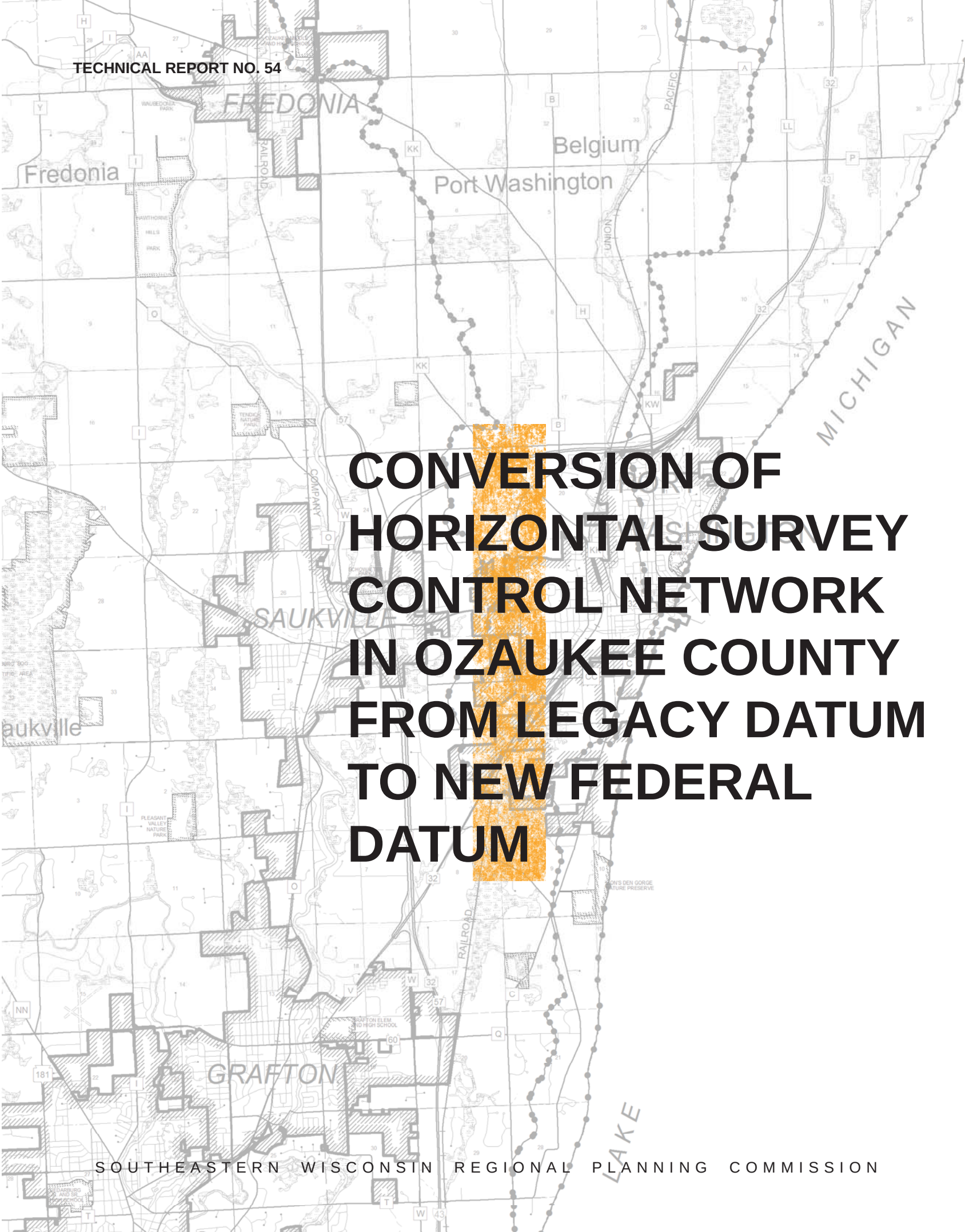


TECHNICAL REPORT NO. 54

CONVERSION OF HORIZONTAL SURVEY CONTROL NETWORK IN OZAUKEE COUNTY FROM LEGACY DATUM TO NEW FEDERAL DATUM

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

KENOSHA COUNTY

Steve Bostrom
Aloysius Nelson
Robert W. Pitts

RACINE COUNTY

Mike Dawson
James A. Ladwig
Peggy L. Shumway

MILWAUKEE COUNTY

Brian R. Dranzik
William R. Drew,
Treasurer
Theodore Lipscomb, Sr.

WALWORTH COUNTY

Charles L. Colman,
Chairman
Nancy Russell
Vacant

OZAUKEE COUNTY

Thomas H. Buestrin
Jennifer Rothstein
Gus W. Wirth, Jr.'
Secretary

WASHINGTON COUNTY

Jeffrey D. Schleif
Daniel S. Schmidt
David L. Stroik

WAUKESHA COUNTY

Michael A. Crowley,
Vice Chairman
José M.Delgado
James T. Dwyer

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION STAFF

Michael G. Hahn, PE, PH ..... Executive Director

Kurt W. Bauer, PE, RLS, AICP ..... Executive Director Emeritus

Kevin J. Muhs, PE, AICP ..... Deputy Director

Nakeisha N. Payne ..... Public Involvement and Outreach Manager

Christopher T. Hiebert, PE. ..... Chief Transportation Engineer

Laura K. Herrick, PE, CFM ..... Chief Environmental Engineer

Elizabeth A. Larsen, SPHR, SHRM-SCP ..... Assistant Director-Administration

Eric D. Lynde ..... Chief Special Projects Planner

Benjamin R. McKay, AICP ..... Chief Community Assistance Planner

Rob W. Merry, PLS ..... Chief Surveyor

David A. Schilling ..... Chief Land Use Planner

Dr. Thomas M. Slawski ..... Chief Biologist

LAND INFORMATION COUNCIL OF OZAUKEE COUNTY

Cristina D. Richards ..... County GIS Coordinator / County Land Information Officer

Ronald Voigt ..... County Register of Deeds

Joshua Morrison ..... County Treasurer

Jason G. Dwzinel ..... County Administrator

Vacant ..... Supervisor, Ozaukee County Board of Supersivors

Andrew Struck ..... Director, County Planning & Parks Department

Andy Holschbach ..... Director, County Land and Water Management Department

James Johnson ..... County Sheriff

Robert W. Merry ..... County Surveyor

Jon Edgren ..... Public Works Director/Highway Commissioner, County Highway Department

Scott Ziegler ..... Emergency Management Director, County Sheriffi's Department

Kirsten Johnson ..... Director and Health Officer, County Health Department

Adam Ward ..... IT Specialist, County Technology Resources

Michael Plotkin ..... Ambulance Director, City of Mequon

Joe Nemith ..... Title Researcher, Knightberry

Cathy Timm ..... City of Cedarburg Assessor

Randy Tetzlaff ..... Former Director of Planning and Development, City of Port Washington

Thomas Sykora ..... Realtor, Coldwell Banker

TASK FORCE

Kurt W. Bauer, PE, RLS, AICP ..... SEWRPC Executive Director Emeritus

Earl F. Burkholder, PS, PE ..... Consulting Geodetic Survey Engineer

Robert W. Merry, RLS ..... SEWRPC Chief Surveyor

TECHNICAL REPORT NUMBER 54

CONVERSION OF HORIZONTAL SURVEY CONTROL NETWORK IN OZAUKEE COUNTY FROM LEGACY DATUM TO NEW FEDERAL DATUM

Prepared by the

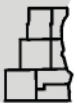
Southeastern Wisconsin Regional Planning Commission
W239 N1812 Rockwood Drive
P.O. Box 1607
Waukesha, WI 53187-1607
www.sewrpc.org

July 2018

$10.00

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
W239 N1812 ROCKWOOD DRIVE • PO BOX 1607 • WAUKESHA, WI 53187-1607• TELEPHONE (262) 547-6721
FAX (262) 547-1103

Serving the Counties of:
KENOSHA
MILWAUKEE
OZAUKEE
RACINE
WALWORTH
WASHINGTON
WAUKESHA



July 2, 2018

STATEMENT OF THE EXECUTIVE DIRECTOR

The Regional Planning Commission has, since 1964, recommended to the governmental agencies operating within the Region the creation and use of a unique system of survey control as a basis for the compilation of large scale topographic and cadastral maps; as a basis for the conduct of land and engineering surveys; and, as a basis for the development of automated, parcel based, land information and public works management systems within the Region. With the assistance of the constituent counties and municipalities, the recommended survey control system has been extended over the entire seven-county Region. All of the 11,753 U.S. Public Land Survey System corners within the Region have been monumented and the coordinate positions and elevations of the corners determined to a high level of survey accuracy. The survey control network has been widely used in the Region for over 50 years.

All of the horizontal survey control work within the Region has been referenced to the North American Datum of 1927. The Federal Government in 1983 created a new horizontal datum known as the North American Datum of 1983. To facilitate the use of the new datum within the Region by such agencies as may determine to do so, the Commission developed procedures for the conversion of the horizontal survey control network within the Region from the legacy datum to the new Federal datum. These procedures, and the issues concerned with datum conversion were addressed in a number of Commission publications, the latest being SEWRPC Memorandum Report No. 206, Estimate of the Costs of Converting the Foundational Elements of the Land Information and Public Works Management Systems in Southeastern Wisconsin from Legacy to New Datums, October 2012 and its August 2015 Addendum, respectively.

In 2016, the county land information council managers within the Region collegially determined to proceed with datum conversion, and to request Commission assistance in carrying out the conversion using the Commission-developed procedures to provide survey grade coordinates for all of the U.S. Public Land Survey System corners within the Region. On April 21, 2017, the Commission entered into an agreement with Ozaukee County governing the conversion of the survey control network within the County from the legacy horizontal datum to the new Federal datum. This report describes the datum conversion completed under the agreement. Importantly, the results demonstrated that the procedure developed by the Commission provided the desired level of accuracy in the converted coordinate positions of the U.S. Public Land Survey System corners, a level of accuracy meeting national Third Order Class I Standards.

As of this date, Ozaukee is the fourth county within the seven county Southeastern Wisconsin Region for which the Commission has completed a datum conversion—the other three counties being Kenosha, Milwaukee, and Racine. It should be noted that the conversion effort for Ozaukee County differed somewhat from that of the other three counties. In those three counties the creation of the legacy control survey network was administered by the Commission. In Ozaukee County, however, the legacy control survey network was created under Commission direction for only about 20 percent of the area of the County. The work in the rest of the area of the County was completed by a consultant employed by the County. The division of effort in the remonumentation and control efforts that produced the legacy date resulted in an increase in the complexity of the conversion work and the amount of additional survey measurements that had to be made. The field verification conducted as part of the conversion effort however, indicates that the converted coordinates of the U.S. Public Land Survey System corners, and the lengths and bearings of quarter-section lines meet the standards for survey-grade control survey network.

It is also important to note that the completed datum conversion provides two of the four foundational elements of the county and municipal land information and public works management systems within the Region, a datum and an attendant map projection. The other two foundational elements—large scale topographic maps and real property boundary—cadastral—maps will also require conversion, as will the attribute data contained in the land information and public works management systems within the Region.

Respectfully submitted,

Michael G. Hahn

Michael G. Hahn
Executive Director

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

CONVERSION OF HORIZONTAL SURVEY CONTROL NETWORK IN OZAUKEE COUNTY FROM LEGACY DATUM TO NEW FEDERAL DATUM

INTRODUCTION AND BACKGROUND

Since early 1964, the Regional Planning Commission has recommended to the governmental agencies operating within the Southeastern Wisconsin Region the use of a unique system of survey control as a basis for the compilation of large-scale topographic and cadastral maps; as a basis for the conduct of land and engineering surveys; and, since 1985, as a basis for the development of automated, parcel-based, land information and public works management systems within the Region. The recommended survey control system requires the remonumentation of the U.S. Public Land Survey System corners within the Region and the establishment of State Plane Coordinates for those corners. The system also includes the establishment of elevations for the monumented corners and for related auxiliary bench marks to provide a reliable vertical survey control network fully integrated with the horizontal network.

Through the cooperative efforts of the Commission and its constituent counties and municipalities, the recommended survey control system has been extended over the entire seven-county Region. All of the 11,985 U.S. Public Land Survey System corners within the Region have been remonumented, and the coordinate positions, and elevations of the remonumented corners have been determined to a high level of accuracy. The resulting survey control network has been widely used for over 50 years in the preparation of large-scale topographic and cadastral maps, in the conduct of land and engineering surveys, and in the creation of parcel-based land information and public works management systems within the Region.

All of the coordinate positions of the remonumented stations of the survey control network within the Region have been referenced to the North American Datum of 1927 (NAD 27), a datum established and promulgated by the Federal government. The datum is based upon the Clarke Spheroid of 1866, a spheroid which fits the North American Continent and the Southeastern Wisconsin Region well. The elevations of the remonumented stations and of certain ancillary benchmarks have been referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929), a datum formerly known as the Sea Level Data of 1929.

The Federal government in 1973 determined to undertake a readjustment of the national horizontal survey control network, and to adopt a new horizontal datum known as the North American Datum of 1983 (NAD 83), utilizing a new reference spheroid known as Geodetic Reference System of 1980 (GRS 80). The new horizontal datum was subsequently readjusted to create NAD 83 (2011). The Federal government in 1977 similarly determined to undertake a readjustment of the national vertical survey control network, and to adopt a new vertical datum known as the North American Vertical Datum of 1988 (NAVD 88).

REEVALUATION OF REGIONAL SURVEY CONTROL NETWORK

The Commission has long maintained that adoption and use of the new Federal datums within the Region do not provide any significant technical advantages over the continued use of the legacy datums. Nevertheless, in response to concerns raised by some practicing land surveyors and some county land information system managers about the continued use of the legacy datums within the Region, the Commission in 2012 prepared SEWRPC Memorandum Report No. 206 entitled, “Estimate of the Costs of Converting the Foundational Elements of the Land Information and Public Works Management Systems in Southeastern Wisconsin from Legacy to New Datums.” In response to the specific requests of some county land information system managers, the report presented a procedure for converting the legacy datums within the Region to the newer datums and presented an estimate of the cost of such conversion meeting land and engineering survey accuracy standards. Given the high estimated cost of the envisioned conversion, and the lack of offsetting monetary benefits, the report recommended the continued use of the

legacy datums within the Region. Despite this recommendation, some practicing land surveyors and some county land information system managers continued to express a desire to pursue datum conversion within the Region and to request Commission assistance in making the desired conversion. Given this continuing concern, and given the significant changes in surveying technology that had taken place since publication of Memorandum Report 206, the Commission in 2015 undertook a reevaluation of the findings and recommendations presented in that report. The findings of that reevaluation are set forth in an Addendum to Memorandum Report No. 206 entitled, "Revised Estimate of the Costs of Converting the Foundational Elements of the Land Information and Public Works Management Systems in Southeastern Wisconsin from Legacy to New Datums."

PROCEDURES FOR DATUM CONVERSION

The procedure for the conversion of the horizontal control survey network within the Region from the legacy to the new datums as originally proposed in Memorandum Report No. 206, was based upon the technology available in 2012 to provide high orders of accuracy in control survey work. The originally proposed conversion procedure utilized a series of static Global Positioning System (GPS) observations[1] to provide new primary and secondary survey control networks within the Region. Based upon these networks, new state plane coordinate positions on the North American Datum of 1983 (NAD 83) would then be obtained by occupying all of the stations comprising the network for further GPS observations. The procedure, while providing a high level of accuracy in the new position data, was costly – probably prohibitively so considering the lack of known offsetting benefits.

As noted previously, significant changes in surveying technology occurred after publication of SEWRPC Memorandum Report No. 206. These changes warranted reconsideration of the procedure originally proposed for datum conversion in that report. The changes in surveying technology included the completion by the Wisconsin Department of Transportation of a Continuously Operating Reference Stations (CORS) network within the State of Wisconsin, coupled with the development and acceptance of Virtual Reference Station (VRS) Technology.[2] This technology eliminates: l) the need to rely upon static GPS observations for the datum conversion work and 2) the need for measurements to be made simultaneously by a roving GPS receiver and an attendant base station or stations. These two changes—while continuing to require occupation of all stations in the control survey network with a roving receiver—presented significant increases in the efficiency of the necessary field survey work, with attendant significant reductions in cost.

Importantly, the Commission staff developed a unique procedure for horizontal datum conversion which minimized the number of control survey stations that had to be occupied by a roving GPS receiver to accomplish the desired conversion work. This procedure combines GPS field observations on a carefully selected minimum number of control survey

---

[1] *In 2012, Global Positioning System observations intended to provide high orders of accuracy, known as static positioning surveys, utilized two or more receivers simultaneously receiving data from the system satellites. These data included dual-frequency carrier phase measurements that in effect represented distances. Post processing of the simultaneous observations provided precise vectors from which coordinate positions could be computed. The static survey procedure required stations in a network to be occupied and attendant data observed for significant periods of time—ranging from approximately 15 minutes to one hour.*

[2] *Virtual Reference Station technology consists of a system of hardware and software designed to facilitate real-time global positioning system measurements based on a network of reference stations known as continuously operating reference stations—performing in the role of the base stations in static global positioning surveys. The network of receivers is linked to a computation center, and each station contributes its raw data to help create network-wide models necessary to provide accurate positioning of the roving receiver. The primary benefit of the technology is that it permits real-time kinematic positioning using a single receiver in the field while achieving centimeter-level accuracy.*

stations in a subarea of the Region—such as a U.S. Public Land Survey System township—with measurement data collected under the original control surveys conducted within the Region to create the legacy survey control network. The procedure uses these legacy measurement data to compute the coordinate positions of the remaining unoccupied stations in the subarea. This procedure is more fully described in Appendix C of the Addendum to Memorandum Report No. 206.

REVISED COMMISSION RECOMMENDATION

The results of the work accomplished in preparing the Addendum to MR No. 206 resulted in a change in the long-standing recommendation of the Commission to continue the use of the legacy survey datums within the Region. The Commission continued to recognize that the benefits of the conversion of the legacy datums to the new Federal datums remained largely intangible. However, the conversion using the procedure developed by the Commission staff would have one very important, although still intangible, benefit namely, the conversion procedure would retain the relative positions of all of the control survey stations within the Region as given by the legacy lengths and bearings of the one-quarter section lines, thus preserving the integrity of the legacy horizontal control survey network within the Region. This benefit, together with the now relatively modest cost of a horizontal data conversion, was considered sufficient to warrant a change in the historical recommendation of the Commission concerning datum conversion. The Addendum accordingly recommended that each of the individual county land information system managers within the Region determine whether or not their agency desired to proceed with the conversion of the horizontal datum in use within the Region from NAD 27 to NAD 83 (2011). If it was determined to proceed, it was indicated that the work could be accomplished by the Commission under contract with the counties concerned, the work being done on a county-by-county basis.

Similarly, the land information system managers would have to determine whether or not their agency desired to proceed with the conversion of the vertical datum in use within the Region from NGVD 29 to NGVD 88 (2012). However, in this case, the conversion would have to be carried out for the Region as a whole. Therefore, all seven county land information system agencies within the Region would have to agree to proceed, and would have to agree upon a distribution of the cost between the counties concerned. If it was determined to proceed, it was indicated that the work could be accomplished by the Commission under contract jointly with all seven county land information systems.

In considering the conversion of the horizontal datum within the Region, it was apparently understood by all concerned that such conversion would entail only two of the four foundational elements of a parcel-based land information or public works management system—the datum and related map projection and the control survey network. Each of the other two foundational elements—the topographic maps for ground truth, and the parcel based cadastral maps, together with the assembled attribute data, will require recompilation, or in the alternative, some form of adjustment if those elements are to be useable with coordinate positions on the new datum. Coordinate positions referred to the new horizontal datum cannot be plotted on the legacy topographic and cadastral maps of the existing land information and public works management systems within the Region. The conversion of the other two foundational elements and the attribute data of the existing systems will constitute by far, the major portion of the costs of the conversion as set forth in SEWRPC Memorandum Report No. 206.

COUNTY ACTION

In a series of informal meetings held during the course of calendar year 2016, the seven county land information managers, acting on behalf of their agencies, unanimously agreed to proceed on a county-by-county basis with the conversion of the legacy horizontal datum in use within the Region to the new Federal datum. The managers similarly agreed unanimously to proceed cooperatively with the conversion of the vertical datum.

Accordingly, on April 21, 2017, Ozaukee County entered into an agreement with the Commission under which the Commission would convert the State Plane Coordinate positions of all 1,064 U.S. Public Land Survey Sys-

tem corners within the County from the legacy datum—NAD 27—to the new Federal datum—NAD 83 (2011). The conversion was to be accomplished by the procedure set forth in Appendix C of the Addendum to SEWRPC Memorandum Report No. 206. A copy of Appendix C of the Addendum to Memorandum Report No. 206 is provided in an appendix to this report. The work was to be accomplished in a period of two years from the date of the agreement. The "deliverables" under the agreement were to include, in addition to the new coordinate positions of the U.S. Public Land Survey system corners, revised control survey station record sheets—commonly known as dossier sheets—for each corner, and new control survey summary diagrams, each diagram covering six U.S. Public Land Survey System sections. This report documents the work accomplished and the products created and delivered under the agreement.

PERTINENT HISTORY

Knowledge of the manner in which the legacy survey control network within Ozaukee County was created is necessary for full appreciation of the work entailed in, and the results of, the datum conversion effort. The legacy survey control networks in the other six counties of the Southeastern Wisconsin Region were created under the direction of the Commission acting on behalf of the counties and municipalities concerned. The work entailed was, therefore, uniformly done to Commission standards as confirmed by quality control measures included in the administration of the work. As shown on Figure 1 appended, in Ozaukee County the survey control network was completed under Commission direction only within the Cities of Mequon and Port Washington, or within about 21 percent of the total area of the County. This area, however, contains about 23 percent of the USPLSS corners within the County. In the remaining area of the County, the survey control network was completed by a consultant employed by the County. Because the procedure used to effect the datum conversion utilizes measurements made in the creation of the legacy survey control network, this division of responsibility for the creation of that network presented potential problems for the datum conversion effort within Ozaukee County which did not exist in the other six counties of the Region. The problems actually encountered included an inordinate number of discrepancies between monumented USPLSS corner locations and attendant coordinate positions; in the relative coordinate positions of corners; and in inadequate monumentation of corners, and of attendant documentation. The resolution of these discrepancies required the recovery and occupation for GPS observations of a significantly greater number of corners than would otherwise have been necessary, and increased the time and cost required to complete the datum transformation project. The discrepancies, while significant, were amenable to sound resolution and did not preclude the use of the legacy measurements in the datum transformation process.

The problems that were encountered related in part to the use of what would, under Commission practice, be considered substandard monumentation of the corners, and by a lack over time of maintenance of the corner monumentation. The problem of substandard monumentation and neglect of maintenance extended to the content of the related documentation, that is, to the content of the Record of U.S. Public Land Survey Control Station sheets—the so called "station dossier sheets." Consequently, an inordinate number of corner positions could not be found, or properly occupied, for GPS positioning—the monumentation required to determine the corner position being either disturbed or entirely missing. The lack of maintenance of the system was recognized by Robert R. Dreblow, PE, RLS, the then Ozaukee County Surveyor when in 2012 he requested the aid of Commission staff in needed maintenance work, and by the County in 2017 when it requested the Commission to provide county surveyor services.

The use of substandard monumentation, the lack over time of maintenance of the monumentation, and the inadequacy of the related documentation, resulted in many corner locations being found to be marked by monuments that were disturbed, broken, paved over during street and highway reconstruction, or that were entirely missing. The inadequacy of the related documentation frequently made it difficult, or sometimes impossible, to find monuments that had been disturbed or paved over during street and highway reconstruction. The lack of recorded tie distances to witness marks made the position and use of some corners questionable. As a consequence, a great many more corner locations had to be visited—the monuments searched for—and if found, verified by the tie distances, and then occupied for GPS observation than was necessary in the datum translation projects completed to date for Kenosha, Milwaukee, and Racine Counties. Specifically, a total of 845 of the 1,064 corner locations within the County had to be visited to obtain 583 corner locations that were properly monumented and could be occupied for GPS observa-

tion. Of the 845 corner locations visited, the monumentation for 11 corners was found to be entirely missing, for 83 corners was found to be broken or disturbed, and for 168 corners was found to be paved over and unavailable for use because of inadequacies in the documentation.

FIELD PROCEDURES

Following the procedure set forth in Appendix C of the Addendum to Memorandum Report No. 206, 278 monumented U.S. Public Land Survey System corners were recovered and occupied for GPS measurement. The locations of these corners are shown on Figure 2 appended, and the observed State Plane Coordinates of these stations referred to the new Federal Horizontal datum are given in Table 1 appended. The observed NAD-83 (2011) coordinates of these corners provided the basis for computing the NAD-83 (2011) coordinates of all of the other corners comprising the County control survey network using the distances and angles measured in the creation of the legacy network.

The remonumented corners were recovered using the Record of U.S. Public Land Survey Control Station sheets – so called dossier sheets – on file with the County and the Commission. To insure that the recovered monuments truly marked the corner locations concerned, a minimum of three tie distances to extant witness corners were measured, and the distances checked against those shown on the dossier sheets.

The equipment used in the field work included a Trimble R-2 Global Positioning System Receiver (GPS receiver) coupled with a Trimble TSC3 Data Collector.[3] During the ob-servations, the GPS receiver was connected to the CORS network created and operated by the Wisconsin Department of Transportation within and adjacent to the County by ordinary mobile telephones. This combination of equipment is known to be capable of obtaining National Geodetic Survey (NGS) Third Order, Class I network accuracy or better, equivalent to an accuracy of one part in 10,000 for the lengths of the one-quarter section lines. The GPS equipment was supported by a TopCon Model GPT-3002LW total station instrument capable of obtaining NGS Third Order Survey accuracy, and by 200 feet steel tapes required to measure tie distances to witness corners, and to make attendant miscellaneous angular and distance measurements.

OFFICE COMPUTATIONS

The procedure for the datum conversion envisions utilizing the legacy lengths of the quarter-section lines and the interior angles of the quarter-sections in combination with the measured NAD 83 (2011) coordinates of the corners occupied for GPS measurement. The initial step in the computation process involved a least squares adjustment of the recorded legacy data to identify any errors or blunders that may exist in the legacy data. This initial step was

---

[3] *The first artificial satellite geodetic positioning and navigation system was developed by the U.S. Department of Defense (DOD) for military purposes and became operational in 1983. Initially the DOD deliberately degraded the satellite transmissions to limit the positional accuracy for civilian use. In 1996 the DOD ended the degradation policy and made the system available for civilian use in a fully accurate mode – thus promoting the use of the system in surveying applications. The DOD system is the satellite positioning system that has become known by the acronym GPS for the term Global Positioning System. The GPS instrumentation used by the Commission in the creation of portions of the legacy regional survey control network exclusively used the DOD system. Since the completion of the legacy survey control network in the Region, other satellite based positioning and navigation systems have been created, such as systems by the European Union, Russia, and China. State-of-the-art receiving instruments can utilize signals from all of these satellite systems. The systems in combination are identified as the Global Navigation Satellite System (GNSS). The receiving instrumentation used in the conduct of the field work for the Ozaukee County datum conversion project utilized the GNSS system and did so in order that the observations would be made in a manner consistent with the instrumentation used by the Wisconsin Department of Transportation in conjunction with its system of Continuously Operating Reference Stations (CORS) within the Region.*

intended to provide an absolutely "clean" data set for use in subsequent computations. A small number of relatively minor errors in the existing network were found together with a very small number of blunders involving such issues as transposition of integers. Those errors and blunders were corrected.

The second step in the computation process involved combining the measured NAD 83 (2011) coordinate positions with the legacy lengths of the one-quarter section lines and the interior angles of the quarter-sections in a least squares adjustment to compute the NAD 83 (2011) coordinate positions of the 786 non-occupied corners within the County. The resulting NAD 83 (2011) State Plane Coordinates, and the lengths and bearings of the one-quarter section lines were recorded on the six section survey control summary diagrams covering the County.

Analysis of the coordinate positions of the corners as determined from the legacy network and by GPS measurements indicated the existence of problems with respect to the relative positions of some of the corners as indicated by the distances and bearings to other corners in the surrounding network. These problems were found within three areas: an approximately four square mile area located in the Town of Saukville, an approximately two square mile area located in and around the City of Port Washington, and an approximately four square mile area located in the southeastern corner of the City of Mequon. These three areas and the corners concerned are shown on Figure 3 appended. While the relative positions of the corners within these areas met the applicable survey control network standards, the group of corners, as a block, did not meet the standards relative to the distances and bearings to corners in the surrounding network. As indicated in Table 2 appended, the largest discrepancy found was 0.84 feet. The discrepancies were corrected by selective GPS observations of the positions of the blocks of errant corners. The errant and correct coordinate positions of the corners concerned are given in Table 2 appended. The errors in the positions of the corners concerned may be attributed to a lack of sufficient ties between corners in the creation of the legacy network.

The analysis also indicated the existence of some troublesome errors in the legacy survey control network that present an extent problem for the use of some of the corners in the conduct of land and engineering surveys. This type of problem was found to exist with respect to 15 individual corners randomly located throughout the survey control network. The locations of the corners concerned are shown on Figure 3 appended.[4] For these errant corners, the legacy coordinate values were found to differ significantly from the actual corner locations as monumented. As indicated in Table 3 appended, the largest difference between the coordinate and monumented positions was 2.96 feet. These errors, when found, were corrected by occupying the monumented location of the corners for GPS observation to determine the correct coordinate values of the monumented locations. The errant and correct coordinate position values for these corners are given in Table 3 appended. The errors concerned may be attributed to errors in the measurements and adjustments made in the creation of the legacy survey control network, or, in some cases, to subsequent remonumentation of the corners.

It is important to note that this type of error could be found in the datum conversion process only as monumented corners were occupied for GPS measurement. Unfortunately, more corners may exist in the network with this type of discrepancy, and therefore with errors in the assigned NAD 83 (2011) coordinate values. The existence of more corners with this type of discrepancy can only be discovered and corrected through a systematic survey control network maintenance program.

In addition to the previously described problems, the field survey found that four of the U.S. PLSS corners of the survey control network were incorrectly located. That is, the extent monumentation did not mark the true location of the corners. These corners are identified on Figure 3 and listed in Table 4 appended. The County Surveyor will have to remonument these corners in the correct locations with locations that have both legacy and new Federal datum coordinate values.

[4] *Those corners are indicated on Figure 3 as green dots located outside of the cross-hatched problem areas.*

FIELD VERIFICATION OF COMPUTED CORNER POSITIONS

To check the accuracy of the computed survey control station coordinates, an approximately 29 percent random sample of the stations comprising the survey control network—U.S. Public Land Survey System corners—for which the coordinates were computed was selected. The location of the 305 sample stations are shown on Figure 4 appended. The monuments marking the U.S. Public Land Survey System corners comprising the sample were recovered and occupied with GPS instrumentation to obtain independently measured coordinate values for the corners. The measured coordinate positions were then compared with the computed positions. The results are set forth in Table 5 appended. Review of the data presented in Table 5 indicates that the largest difference between a measured and a computed northing was 0.20 feet, while the largest difference found between a measured and a computed easting was 0.19 feet. The root mean square error between the measured and computed northings was 0.08 feet, and of the eastings was 0.07 feet. The test may be considered as confirming the validity of the NAD 83 (2011) coordinates as determined by the conversion procedure. It is interesting to note that the shift in the geographic positions of the legacy and new Federal horizontal datums within the Region, as measured by the spherical coordinate differences of a centrally located station within the County is about 0.021 seconds of latitude, and 0.316 seconds of longitude, equivalent to about 2.1 feet and 31.1 feet, respectively.

LIMITATIONS AND CONCLUSIONS

It may be concluded that the horizontal datum conversion procedure developed by the Commission staff provides an accurate and cost-effective means for the conversion of the legacy horizontal datum in use within the Region to the presently promulgated Federal datum. As described in this report, using that procedure, the existing horizontal survey control network within Ozaukee County was successfully converted from the legacy datum—NAD 27—to the presently promulgated Federal datum—NAD 83 (2011). Independent field observations demonstrated that the converted State Plane Coordinate positions of the monumented County survey control network met Third Order Class 1 Standards—providing linear distance closures of 1 part in 10,000 or better. Importantly, the procedure preserves the validity of the survey control network referred to the legacy datum, the lengths of one-quarter section lines being essentially identical under the two datums.

As described in the section of this report entitled, “Pertinent History,” the legacy County survey control network was created in part under Commission administration and met Commission standards with respect to monumentation and survey accuracy. The remainder of the network was completed by a consultant employed by the County. Because the procedure used to effect the datum conversion utilizes measurements made in the creation of the legacy survey control network, this division of responsibility for the creation of that network presented potential problems for the datum conversion effort. The problems actually encountered included discrepancies between monumented USPLSS corner locations and attendant coordinate positions; in the relative coordinate positions of corners; and in inadequate monumentation of corners and in attendant documentation. When discovered by fieldwork involving recovery and occupation for GPS observations conducted under the datum conversion project, these discrepancies were corrected. A total of 583 of the 1,064 number of corners comprising the County survey control network were so recovered, occupied, and GPS observations made to accurately determine the position of the corners involved. For these corners—constituting approximately—55 percent of the total number of corners in the survey control network—the coordinate positions provided under the project meet the desired accuracy standards in an unqualified manner. For the remaining 45 percent of the corners of the network, the coordinate values of the corner positions as provided must be considered as tentative and subject to limitations for use in the conduct of land and engineering surveys. Based upon the experience gained under the conduct of the project, and particularly upon the results of the field verification process, a relatively small percentage of these corners may be expected to exhibit discrepancies that preclude meeting the corner location and network desired accuracy standards. This uncertainty in the survey control network can only be eliminated by the conduct of a systematic maintenance program for the network in which all of the corners are recovered, remonumented as may be found necessary, and occupied for GPS observation.

In accordance with the agreement entered into between the County and the Commission governing the horizontal datum conversion, the following survey control data and materials were delivered in digital format to the County together with copies of this report:

A revised copy of the "Record of U.S. Public Land Survey Control Station"—so called dossier sheet—for each of the 1,064 survey control stations—monumented U.S. Public Land Survey System corners—within the county. The revised dossier sheets provide the State Plane Coordinates of the corner concerned referred to both the—NAD 27 and NAD 83 (2011) datums. An example of a revised dossier sheet is provided in Figure 5 appended.

New six section survey control summary diagrams covering the County. These 44 diagrams show the monumented U.S. Public Land Survey Station corners, the State Plane Coordinates of those corners referred to NAD 83 (2011), the grid and ground level lengths of the one-quarter section lines, the interior angles of the one-quarter sections and the bearings of the one-quarter lines, and the ground level area of the one-quarter sections. An example of a survey control summary diagram is provided in Figure 6 appended.

TABLES AND FIGURES

Table 1

MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS TO CONTROL DATUM CONVERSION COMPUTATIONS – COORDINATES GIVEN ARE REFERRED TO NAD 83 (2011)

Corner Number	Northing	Easting
1	562892.87	2490728.60
2	562899.28	2493391.13
3	563102.59	2498668.03
4	563583.06	2509212.50
5	564190.34	2525168.24
6	564350.27	2533110.43
7	564524.16	2541085.16
8	564676.40	2546349.20
9	560654.95	2503999.78
10	560240.47	2493462.80
11	557540.81	2490896.01
12	557592.50	2493534.95
13	558767.40	2519968.13
14	559052.07	2533261.57
15	559463.51	2551751.46
16	555857.63	2514723.65
17	555493.28	2506757.41
18	554933.66	2493588.08
19	554882.67	2490925.66
20	552289.79	2493620.53
21	552487.47	2498915.38
22	553203.63	2514809.02
23	553552.16	2525447.59
24	553863.63	2538701.70
25	554010.10	2543992.61
26	554090.03	2546635.66
27	554196.55	2553782.93
28	551438.26	2546711.85
29	550310.76	2509584.54
30	549644.57	2493728.30
31	546924.66	2491181.38
32	547282.26	2501744.88
33	548140.27	2520269.21
34	548424.03	2533583.62
35	548820.95	2549402.79

Corner Number	Northing	Easting
36	548900.59	2553296.21
37	545970.08	2541580.59
38	542342.94	2509784.24
39	542939.76	2525726.45
40	543191.18	2536386.23
41	543624.26	2551460.89
42	540152.31	2520503.66
43	539185.80	2499346.69
44	539629.58	2549734.37
45	538197.90	2547164.13
46	537961.41	2539171.66
47	537628.15	2525893.36
48	537494.34	2520571.36
49	536796.71	2504624.40
50	533952.46	2499396.85
51	531536.98	2507400.17
52	531819.89	2515363.06
53	532979.33	2541828.56
54	533165.99	2546768.38
55	529511.38	2520719.29
56	529175.36	2515402.73
57	529077.75	2512732.91
58	528970.69	2510082.95
59	528887.22	2507444.60
60	525824.88	2494203.48
61	525915.76	2496849.83
62	525988.66	2498853.79
63	526152.82	2504851.01
64	526332.17	2510135.38
65	526525.07	2515442.46
66	526693.51	2518110.27
67	526850.40	2520776.66
68	526959.95	2523434.52
69	527085.22	2526090.85
70	527172.42	2528733.10

Table 1 (continued)

Corner Number	Northing	Easting
71	527251.64	2531362.30
72	527381.36	2533997.79
73	524862.83	2536680.25
74	524513.47	2528770.22
75	520621.46	2497021.27
76	520857.62	2504982.82
77	519426.80	2534176.48
78	518210.82	2505075.66
79	517894.23	2494454.39
80	515127.06	2491899.78
81	515242.31	2494544.36
82	515643.48	2507800.14
83	516215.83	2521054.55
84	513999.13	2531723.99
85	513904.98	2529085.26
86	513806.21	2526435.31
87	509848.30	2492133.42
88	510044.21	2497430.97
89	510436.85	2510650.24
90	511157.10	2526534.83
91	511265.98	2529174.50
92	511365.09	2531827.53
93	508748.44	2532641.84
94	508719.97	2531951.07
95	508608.89	2529292.71
96	508495.45	2526652.97
97	504902.54	2502923.38
98	505237.50	2513488.05
99	505588.67	2521458.34
100	505954.01	2529401.34
101	506073.83	2532084.44
102	506096.02	2532570.59
103	503110.54	2531894.92
104	503060.88	2530645.75
105	501390.02	2493608.44
106	501282.35	2490974.76
107	499323.11	2506928.33
108	499694.95	2512169.09
109	497284.80	2517559.22
110	496829.49	2509657.71

Corner Number	Northing	Easting
111	496539.41	2504400.85
112	493777.12	2501839.74
113	491004.85	2499278.72
114	491697.71	2512489.91
115	489596.79	2525839.23
116	489315.46	2517862.90
117	488635.74	2504665.72
118	488172.19	2494094.93
119	485387.28	2488932.61
120	486256.52	2510064.80
121	484390.93	2528709.82
122	483952.16	2515417.00
123	482755.73	2489020.33
124	482699.60	2486388.19
125	480066.08	2486506.61
126	480110.82	2489147.51
127	480448.02	2499671.55
128	480699.76	2504958.27
129	481355.96	2518178.19
130	478478.42	2512980.43
131	477462.74	2489258.27
132	474968.30	2494621.63
133	475426.39	2505152.87
134	473642.88	2526414.47
135	473371.11	2518480.69
136	472529.87	2499990.13
137	472174.10	2489425.09
138	472137.53	2486770.33
139	470009.01	2494749.35
140	470487.98	2513294.59
141	467964.69	2521328.69
142	467723.00	2510743.50
143	467624.33	2505413.34
144	464485.85	2489663.26
145	465272.96	2518765.39
146	462513.27	2513544.86
147	462242.02	2500309.45
148	459949.71	2516268.81
149	460034.46	2524602.63
150	457125.26	2511040.66

Table 1 (continued)

Corner Number	Northing	Easting
151	456741.90	2495147.80
152	453918.37	2489898.02
153	454391.33	2505773.58
154	454471.31	2511111.94
155	454548.96	2513760.02
156	452067.51	2527426.46
157	452062.75	2527095.26
158	452023.25	2524425.86
159	451998.28	2521761.73
160	451983.52	2519110.35
161	451961.37	2516463.50
162	451629.88	2500569.12
163	448616.92	2490019.55
164	449300.13	2516514.53
165	449321.13	2519158.62
166	449343.88	2521813.31
167	449378.58	2524467.91
168	449413.05	2527116.25
169	449457.34	2528853.05
170	446808.82	2528873.56
171	446775.54	2527144.26
172	446734.68	2524508.02
173	446689.44	2521861.59
174	446663.52	2519207.68
175	446640.07	2516555.58
176	446579.74	2513951.08
177	446449.77	2505963.51
178	446172.64	2495354.38
179	443969.22	2516602.87
180	444008.98	2519245.69
181	444040.36	2521891.01
182	444080.96	2524538.56
183	444125.18	2527161.11
184	444164.18	2528882.72
201	440570.82	2487549.07
202	440674.90	2490194.07
203	440776.06	2492843.12
204	440867.40	2495462.13
205	440948.77	2498112.67
206	441022.02	2500769.46

Corner Number	Northing	Easting
207	441083.47	2503415.24
208	441144.04	2506064.24
209	441188.99	2508711.48
210	441232.19	2511346.02
211	441277.51	2514001.58
212	441300.84	2516639.03
213	441343.80	2519283.32
214	441388.77	2521932.34
215	441433.68	2524562.51
216	441472.18	2527186.59
217	441539.57	2529782.33
218	441552.50	2530182.41
301	440490.24	2484902.01
302	443128.05	2484817.79
303	445785.43	2484726.93
304	448425.84	2484632.93
305	451060.18	2484538.60
306	453709.55	2484454.22
307	456342.20	2484382.76
308	458985.20	2484322.43
309	461629.54	2484272.66
310	464267.50	2484230.16
311	466907.23	2484206.22
312	469549.21	2484190.30
313	472103.81	2484176.66
314	474739.16	2484139.33
315	477379.44	2484106.44
316	480024.83	2484068.27
317	482663.34	2484030.66
318	485298.22	2483987.37
319	487935.18	2483920.31
320	490572.70	2483866.72
321	493214.01	2483819.19
322	495850.10	2483774.17
323	498493.66	2483738.24
324	501135.51	2483705.02
325	504321.95	2484316.52
326	504374.93	2486971.53
327	504465.87	2489625.48
328	507102.12	2489519.58

Table 1 (continued)

Corner Number	Northing	Easting
329	509733.12	2489409.25
330	512370.52	2489301.23
331	515009.74	2489203.48
332	517641.37	2489096.81
333	520279.88	2489011.02
334	522912.49	2488922.72
335	525546.52	2488871.48
336	528130.68	2488806.91
337	530827.22	2488776.72
338	533467.07	2488734.28
339	536231.94	2488678.27
340	538889.24	2488610.99
341	541541.59	2488540.76
342	544196.86	2488476.28
343	546854.80	2488416.77
344	549511.12	2488366.04
345	552168.44	2488328.61
346	554818.58	2488291.05
347	557476.64	2488257.62
348	560176.55	2488194.85
349	562866.38	2488121.10
350	565520.34	2488058.19
351	568250.20	2487986.08
401	568337.78	2490606.59

Corner Number	Northing	Easting
402	568428.61	2493234.01
403	568530.94	2495875.99
404	568600.89	2498519.11
405	568679.88	2501158.14
406	568750.57	2503797.54
407	568829.97	2506425.56
408	568931.93	2509088.73
409	569040.21	2511725.28
410	569152.13	2514360.82
411	569273.88	2517003.26
412	569386.19	2519645.97
413	569471.99	2522319.70
414	569527.75	2524958.49
415	569578.33	2527615.01
416	569616.48	2530269.80
417	569661.39	2532930.82
418	569709.60	2535591.49
419	569762.86	2538242.46
420	569816.64	2540903.48
421	569876.03	2543551.79
422	569942.15	2546200.84
423	570011.14	2548852.16
424	570079.14	2551512.28
425	570125.24	2553506.89

CORNER IDENTIFICATION NUMBER LOCATION GIVEN ON FIGURE 2.

Source: SEWRPC.

Table 2

MONUMENTED USPLSS CORNERS IN AREAS IN THE TOWN OF SAUKVILLE, CITY OF PORT WASHINGTON, AND CITY OF MEQUON RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS BUT THE COORDINATES OF WHICH WERE FOUND TO DISAGREE WITH LEGACY COORDINATES

COORDINATES ARE REFERRED TO NAD27

Corner Number		Northing	Easting
9	Readjusted	531812.87	2546902.48
	Original	531812.61	2546902.43
	Difference	0.26	0.05
10	Readjusted	531529.92	2538939.50
	Original	531529.87	2538940.14
	Difference	0.05	-0.64
11	Readjusted	528317.55	2523028.38
	Original	528317.57	2523028.26
	Difference	-0.02	0.12
12	Readjusted	528880.14	2538983.93
	Original	528879.66	2538984.50
	Difference	0.48	-0.57
13	Readjusted	528963.62	2541622.32
	Original	528963.49	2541622.99
	Difference	0.13	-0.67
14	Readjusted	529070.68	2544272.33
	Original	529069.85	2544272.82
	Difference	0.83	-0.49
15	Readjusted	529168.30	2546942.20
	Original	529167.75	2546942.54
	Difference	0.55	-0.34
16	Readjusted	529504.31	2552258.76
	Original	529504.00	2552259.00
	Difference	0.31	-0.24
17	Readjusted	527244.64	2562901.89
	Original	527244.32	2562902.31
	Difference	0.32	-0.42
18	Readjusted	527165.38	2560272.66
	Original	527165.02	2560273.00
	Difference	0.36	-0.34
19	Readjusted	527078.15	2557630.38
	Original	527077.71	2557630.86
	Difference	0.44	-0.48

Corner Number		Northing	Easting
20	Readjusted	526952.81	2554974.01
	Original	526952.37	2554974.54
	Difference	0.44	-0.53
21	Readjusted	526843.29	2552316.11
	Original	526842.32	2552316.94
	Difference	0.97	-0.83
22	Readjusted	526686.36	2549649.70
	Original	526685.52	2549650.28
	Difference	0.84	-0.58
23	Readjusted	526517.97	2546981.86
	Original	526517.34	2546982.44
	Difference	0.63	-0.58
24	Readjusted	526325.08	2541674.71
	Original	526324.69	2541674.73
	Difference	0.39	-0.02
25	Readjusted	526145.70	2536390.30
	Original	526145.44	2536390.42
	Difference	0.26	-0.12
26	Readjusted	525981.42	2530392.80
	Original	525981.49	2530393.09
	Difference	-0.07	-0.29
27	Readjusted	525908.42	2528388.83
	Original	525908.65	2528389.24
	Difference	-0.23	-0.41
28	Readjusted	525817.44	2525742.38
	Original	525817.38	2525742.09
	Difference	0.06	0.29
29	Readjusted	523170.64	2525825.53
	Original	523170.57	2525825.39
	Difference	0.07	0.14
30	Readjusted	524506.38	2560309.76
	Original	524506.15	2560310.00
	Difference	0.23	-0.24

Table 2 (continued)

Corner Number		Northing	Easting
31	Readjusted	520850.45	2536522.06
	Original	520850.27	2536522.30
	Difference	0.18	-0.24
32	Readjusted	520614.07	2528560.28
	Original	520614.32	2528560.44
	Difference	-0.25	-0.16
33	Readjusted	517886.76	2525993.33
	Original	517886.47	2525993.25
	Difference	0.29	0.08
34	Readjusted	518203.63	2536614.89
	Original	518202.82	2536615.23
	Difference	0.81	-0.34
35	Readjusted	515234.84	2526083.29
	Original	515234.98	2526083.52
	Difference	-0.14	-0.23
36	Readjusted	515119.56	2523438.63
	Original	515119.90	2523438.92
	Difference	-0.34	-0.29
37	Readjusted	513798.90	2557974.85
	Original	513799.12	2557974.65
	Difference	-0.22	0.20
38	Readjusted	513897.65	2560624.84
	Original	513897.62	2560625.06
	Difference	0.03	-0.22
39	Readjusted	513991.84	2563263.61
	Original	513991.77	2563263.89
	Difference	0.07	-0.28
40	Readjusted	511357.74	2563367.30
	Original	511357.81	2563367.50
	Difference	-0.07	-0.20
41	Readjusted	511258.58	2560714.17
	Original	511258.83	2560714.34
	Difference	-0.25	-0.17
42	Readjusted	511149.73	2558074.40
	Original	511149.96	2558074.39
	Difference	-0.23	0.01

Corner Number		Northing	Easting
43	Readjusted	508488.00	2558192.58
	Original	508488.30	2558192.73
	Difference	-0.30	-0.15
44	Readjusted	508601.42	2560832.42
	Original	508601.63	2560832.81
	Difference	-0.21	-0.39
45	Readjusted	508712.55	2563490.88
	Original	508712.53	2563491.70
	Difference	0.02	-0.82
46	Readjusted	508741.03	2564181.71
	Original	508741.17	2564181.40
	Difference	-0.14	0.31
47	Readjusted	506088.48	2564110.17
	Original	506088.45	2564110.76
	Difference	0.03	-0.59
48	Readjusted	506066.33	2563624.04
	Original	506066.15	2563624.56
	Difference	0.18	-0.52
49	Readjusted	505996.36	2562058.17
	Original	505996.42	2562058.46
	Difference	-0.06	-0.29
50	Readjusted	505946.45	2560940.97
	Original	505946.67	2560941.24
	Difference	-0.22	-0.27
51	Readjusted	505880.37	2559373.42
	Original	505880.46	2559373.43
	Difference	-0.09	-0.01
54	Readjusted	503053.21	2562185.21
	Original	503053.43	2562185.48
	Difference	-0.22	-0.27
55	Readjusted	503102.86	2563434.37
	Original	503103.21	2563434.38
	Difference	-0.35	-0.01
61	Readjusted	454540.42	2545298.54
	Original	454540.65	2545298.30
	Difference	-0.23	0.24

Table 2 (continued)

Corner Number		Northing	Easting
62	Readjusted	454462.85	2542650.42
	Original	454462.81	2542650.11
	Difference	0.04	0.31
63	Readjusted	451952.68	2548002.07
	Original	451953.00	2548001.79
	Difference	-0.32	0.28
64	Readjusted	451974.75	2550648.96
	Original	451975.07	2550648.67
	Difference	-0.32	0.29
65	Readjusted	451989.50	2553300.40
	Original	451989.68	2553300.24
	Difference	-0.18	0.16
66	Readjusted	452014.27	2555964.59
	Original	452014.28	2555964.71
	Difference	-0.01	-0.12
67	Readjusted	452053.87	2558634.06
	Original	452053.74	2558634.16
	Difference	0.13	-0.10
68	Readjusted	452058.58	2558965.26
	Original	452058.51	2558965.36
	Difference	0.07	-0.10
69	Readjusted	449448.14	2560391.50
	Original	449448.24	2560391.95
	Difference	-0.10	-0.45
70	Readjusted	449404.01	2558654.73
	Original	449403.97	2558655.16
	Difference	0.04	-0.44
71	Readjusted	449369.55	2556006.41
	Original	449369.61	2556006.62
	Difference	-0.06	-0.21
72	Readjusted	449335.04	2553351.83
	Original	449335.16	2553352.00
	Difference	-0.12	-0.17
73	Readjusted	449312.33	2550697.14
	Original	449312.59	2550697.02
	Difference	-0.26	0.12
74	Readjusted	449291.36	2548053.07
	Original	449291.82	2548052.86
	Difference	-0.46	0.21
75	Readjusted	446571.00	2545489.59
	Original	446571.30	2545489.82
	Difference	-0.30	-0.23
76	Readjusted	446631.11	2548094.17
	Original	446631.31	2548094.11
	Difference	-0.20	0.06
77	Readjusted	446654.68	2550746.16
	Original	446654.89	2550746.34
	Difference	-0.21	-0.18
78	Readjusted	446680.53	2553400.07
	Original	446680.60	2553400.20
	Difference	-0.07	-0.13
79	Readjusted	446725.58	2556046.48
	Original	446725.65	2556046.86
	Difference	-0.07	-0.38
80	Readjusted	446766.34	2558682.71
	Original	446766.48	2558683.13
	Difference	-0.14	-0.42
81	Readjusted	446799.56	2560411.99
	Original	446799.83	2560412.63
	Difference	-0.27	-0.64
82	Readjusted	444154.85	2560421.19
	Original	444155.06	2560421.46
	Difference	-0.21	-0.27
83	Readjusted	444116.05	2558709.58
	Original	444116.45	2558709.96
	Difference	-0.40	-0.38
84	Readjusted	444120.82	2558699.55
	Original	444121.23	2558699.93
	Difference	-0.41	-0.38
85	Readjusted	444115.82	2558699.58
	Original	444116.23	2558699.96
	Difference	-0.41	-0.38

Table 2 (continued)

Corner Number		Northing	Easting
86	Readjusted	444115.74	2558694.58
	Original	444116.15	2558694.96
	Difference	-0.41	-0.38
87	Readjusted	444071.78	2556077.03
	Original	444072.42	2556077.04
	Difference	-0.64	-0.01
88	Readjusted	444031.40	2553429.48
	Original	444031.54	2553429.52
	Difference	-0.14	-0.04

Corner Number		Northing	Easting
89	Readjusted	444000.03	2550784.17
	Original	444000.24	2550784.21
	Difference	-0.21	-0.04
90	Readjusted	443960.26	2548141.36
	Original	443960.46	2548141.42
	Difference	-0.20	-0.06
91	Readjusted	442232.63	2561313.81
	Original	442232.64	2561313.84
	Difference	-0.01	-0.03

CORNER IDENTIFICATION NUMBER LOCATION GIVEN ON FIGURE 3

Source: SEWRPC.

Table 3

RANDOMLY FOUND MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS BUT THE COORDINATES OF WHICH WERE FOUND TO DISAGREE WITH LEGACY COORDINATES

COORDINATES ARE REFERRED TO NAD27

Corner Number		Northing	Easting
1	Readjusted	565538.35	2522174.78
	Original	565538.34	2522174.68
	Difference	0.01	0.10
2	Readjusted	562892.41	2524930.48
	Original	562892.46	2524930.09
	Difference	-0.05	0.39
3	Readjusted	554003.34	2575532.46
	Original	554003.76	2575532.69
	Difference	-0.42	-0.23
4	Readjusted	554083.28	2578175.49
	Original	554083.16	2578176.11
	Difference	0.12	-0.62
5	Readjusted	551431.51	2578251.69
	Original	551431.41	2578252.30
	Difference	0.10	-0.61
6	Readjusted	540145.45	2552043.27
	Original	540145.75	2552043.58
	Difference	-0.30	-0.31
7	Readjusted	537619.84	2557372.99
	Original	537619.96	2557375.95
	Difference	-0.12	-2.96
8	Readjusted	537621.35	2557432.86
	Original	537621.39	2557432.53
	Difference	-0.04	0.33
52	Readjusted	501274.77	2522513.49
	Original	501274.62	2522513.62
	Difference	0.15	-0.13
53	Readjusted	501382.46	2525147.23
	Original	501382.31	2525146.42
	Difference	0.15	0.81
56	Readjusted	499687.22	2543708.23
	Original	499687.51	2543706.12
	Difference	-0.29	2.11
57	Readjusted	496821.74	2541196.78
	Original	496821.68	2541196.54
	Difference	0.06	0.24
58	Readjusted	496531.74	2535939.82
	Original	496531.54	2535939.85
	Difference	0.20	-0.03
59	Readjusted	493769.44	2533378.62
	Original	493769.58	2533379.23
	Difference	-0.14	-0.61
60	Readjusted	467956.25	2552867.18
	Original	467955.94	2552867.21
	Difference	0.31	-0.03

CORNER IDENTIFICATION NUMBER LOCATION GIVEN ON FIGURE 3

Source: SEWRPC.

Table 4

INCORRECTLY MONUMENTED USPLSS CORNERS RECOVERED AND THE COORDINATES OF WHICH WERE FOUND TO DISAGREE

COORDINATES GIVEN ARE REFERRED TO NAD 83 (2011)

Corner Number		Northing	Easting
201	Readjusted	569033.59	2543264.80
	Original	569035.48	2543264.42
	Difference	-1.90	0.38
202	Readjusted	569033.77	2543269.11
	Original	569035.66	2543268.65
	Difference	-1.89	0.46
203	Readjusted	472249.17	2492062.22
	Original	472249.50	2492062.70
	Difference	0.33	-0.48
204	Readjusted	472248.44	2492036.55
	Original	472248.40	2492036.66
	Difference	-0.04	-0.11

CORNER IDENTIFICATION NUMBER LOCATION GIVEN OF FIGURE 3.

Source: SEWRPC.

Table 5

MONUMENTED USPLSS CORNERS RECOVERED AND OCCUPIED FOR GPS OBSERVATIONS TO VERIFY COMPUTED COORDINATE POSITION

Corner Number		Northing	Easting
1	Computed	568426.23	2493165.22
	GPS Observed	568426.09	2493165.29
	Difference	-0.14	0.08
2	Computed	568829.76	2506418.64
	GPS Observed	568829.70	2506418.67
	Difference	-0.06	0.03
3	Computed	569152.53	2514369.37
	GPS Observed	569152.44	2514369.43
	Difference	-0.09	0.05
4	Computed	569274.31	2517013.37
	GPS Observed	569274.30	2517013.43
	Difference	-0.01	0.06
5	Computed	569472.25	2522332.27
	GPS Observed	569472.30	2522332.25
	Difference	0.05	-0.02
6	Computed	569528.24	2524983.77
	GPS Observed	569528.15	2524983.72
	Difference	-0.09	-0.05
7	Computed	569578.72	2527641.88
	GPS Observed	569578.70	2527641.83
	Difference	-0.02	-0.06
8	Computed	569617.16	2530310.05
	GPS Observed	569617.10	2530309.96
	Difference	-0.05	-0.09
9	Computed	569662.00	2532964.01
	GPS Observed	569661.95	2532964.01
	Difference	-0.04	0.00
10	Computed	569763.31	2538264.70
	GPS Observed	569763.36	2538264.66
	Difference	0.06	-0.04
11	Computed	569817.38	2540936.49
	GPS Observed	569817.46	2540936.47
	Difference	0.08	-0.01

Corner Number		Northing	Easting
12	Computed	569875.95	2543548.02
	GPS Observed	569875.87	2543548.06
	Difference	-0.07	0.03
13	Computed	570010.76	2548837.57
	GPS Observed	570010.76	2548837.59
	Difference	-0.01	0.02
14	Computed	566718.81	2519729.03
	GPS Observed	566718.82	2519728.90
	Difference	0.01	-0.13
15	Computed	565556.11	2493282.36
	GPS Observed	565556.07	2493282.46
	Difference	-0.04	0.10
16	Computed	563001.92	2496027.99
	GPS Observed	563001.99	2496028.01
	Difference	0.06	0.02
17	Computed	563201.47	2501293.71
	GPS Observed	563201.54	2501293.66
	Difference	0.07	-0.05
18	Computed	563316.69	2503924.07
	GPS Observed	563316.66	2503924.07
	Difference	-0.03	0.01
19	Computed	563443.69	2506575.73
	GPS Observed	563443.72	2506575.77
	Difference	0.03	0.04
20	Computed	563673.56	2511862.70
	GPS Observed	563673.53	2511862.80
	Difference	-0.03	0.10
21	Computed	563822.23	2514518.64
	GPS Observed	563822.30	2514518.60
	Difference	0.07	-0.04
22	Computed	564074.58	2519811.28
	GPS Observed	564074.68	2519811.16
	Difference	0.10	-0.12

Table 5 (continued)

Corner Number		Northing	Easting
23	Computed	564283.86	2530470.04
	GPS Observed	564283.92	2530470.07
	Difference	0.05	0.03
24	Computed	564417.01	2535751.03
	GPS Observed	564416.87	2535750.86
	Difference	-0.14	-0.17
25	Computed	564479.61	2538415.22
	GPS Observed	564479.59	2538415.23
	Difference	-0.02	0.01
26	Computed	564601.76	2543719.91
	GPS Observed	564601.78	2543719.95
	Difference	0.03	0.04
27	Computed	564770.74	2551631.56
	GPS Observed	564770.65	2551631.54
	Difference	-0.09	-0.02
28	Computed	562115.27	2551693.10
	GPS Observed	562115.30	2551693.11
	Difference	0.03	0.01
29	Computed	561686.53	2533186.33
	GPS Observed	561686.38	2533186.46
	Difference	-0.15	0.13
30	Computed	561424.49	2519889.46
	GPS Observed	561424.48	2519889.65
	Difference	-0.01	0.18
31	Computed	561167.55	2514576.36
	GPS Observed	561167.52	2514576.40
	Difference	-0.03	0.04
32	Computed	560341.63	2496100.22
	GPS Observed	560341.68	2496100.33
	Difference	0.05	0.11
33	Computed	557767.23	2498241.97
	GPS Observed	557767.29	2498241.87
	Difference	0.06	-0.10
34	Computed	558271.65	2509361.93
	GPS Observed	558271.70	2509362.01
	Difference	0.05	0.08
35	Computed	558512.35	2514645.07
	GPS Observed	558512.53	2514645.01
	Difference	0.18	-0.05
36	Computed	558988.87	2530622.88
	GPS Observed	558988.85	2530622.91
	Difference	-0.02	0.03
37	Computed	559233.64	2541217.01
	GPS Observed	559233.56	2541217.12
	Difference	-0.08	0.10
38	Computed	559388.31	2546492.10
	GPS Observed	559388.29	2546492.13
	Difference	-0.02	0.03
39	Computed	556741.88	2546559.54
	GPS Observed	556742.03	2546559.37
	Difference	0.15	-0.18
40	Computed	556111.46	2520038.92
	GPS Observed	556111.40	2520038.88
	Difference	-0.06	-0.04
41	Computed	555618.33	2509428.22
	GPS Observed	555618.45	2509428.30
	Difference	0.12	0.08
42	Computed	552365.89	2496268.77
	GPS Observed	552365.73	2496268.72
	Difference	-0.16	-0.05
43	Computed	552594.16	2501566.53
	GPS Observed	552594.22	2501566.54
	Difference	0.06	0.01
44	Computed	552966.75	2509497.29
	GPS Observed	552966.85	2509497.28
	Difference	0.10	-0.01
45	Computed	553690.45	2530777.55
	GPS Observed	553690.41	2530777.54
	Difference	-0.04	-0.01
46	Computed	553800.57	2536062.63
	GPS Observed	553800.38	2536062.72
	Difference	-0.19	0.09

Table 5 (continued)

Corner Number		Northing	Easting
47	Computed	553928.90	2541344.54
	GPS Observed	553928.88	2541344.51
	Difference	-0.02	-0.02
48	Computed	554116.27	2549261.03
	GPS Observed	554116.32	2549260.96
	Difference	0.05	-0.07
49	Computed	554143.79	2551884.34
	GPS Observed	554143.87	2551884.38
	Difference	0.08	0.04
50	Computed	550799.34	2520194.79
	GPS Observed	550799.29	2520194.76
	Difference	-0.05	-0.03
51	Computed	550550.61	2514880.94
	GPS Observed	550550.62	2514881.04
	Difference	0.01	0.10
52	Computed	550184.42	2506941.76
	GPS Observed	550184.38	2506941.69
	Difference	-0.03	-0.07
53	Computed	550057.36	2504301.35
	GPS Observed	550057.41	2504301.23
	Difference	0.05	-0.13
54	Computed	549945.46	2501658.20
	GPS Observed	549945.65	2501658.21
	Difference	0.19	0.01
55	Computed	549833.38	2499004.90
	GPS Observed	549833.35	2499004.82
	Difference	-0.03	-0.08
56	Computed	547396.57	2504389.28
	GPS Observed	547396.63	2504389.09
	Difference	0.06	-0.19
57	Computed	547653.94	2509657.97
	GPS Observed	547654.04	2509658.07
	Difference	0.09	0.10
58	Computed	547772.26	2512305.16
	GPS Observed	547772.24	2512305.10
	Difference	-0.02	-0.07
59	Computed	547889.96	2514953.19
	GPS Observed	547890.11	2514953.33
	Difference	0.14	0.13
60	Computed	548180.14	2522962.25
	GPS Observed	548180.13	2522962.25
	Difference	-0.01	-0.01
61	Computed	548376.61	2530944.03
	GPS Observed	548376.59	2530944.00
	Difference	-0.02	-0.03
62	Computed	548634.22	2541505.23
	GPS Observed	548634.11	2541505.04
	Difference	-0.11	-0.19
63	Computed	548794.37	2546793.45
	GPS Observed	548794.32	2546793.45
	Difference	-0.05	0.00
64	Computed	545478.35	2520347.94
	GPS Observed	545478.34	2520347.86
	Difference	-0.01	-0.08
65	Computed	544630.28	2501829.83
	GPS Observed	544630.26	2501829.84
	Difference	-0.02	0.01
66	Computed	541973.00	2501909.16
	GPS Observed	541972.97	2501909.12
	Difference	-0.04	-0.05
67	Computed	542101.82	2504548.76
	GPS Observed	542101.92	2504548.65
	Difference	0.10	-0.10
68	Computed	542450.16	2512419.92
	GPS Observed	542450.21	2512419.92
	Difference	0.05	0.01
69	Computed	542491.43	2512458.42
	GPS Observed	542491.45	2512458.43
	Difference	0.03	0.01
70	Computed	542576.58	2515082.55
	GPS Observed	542576.66	2515082.54
	Difference	0.08	-0.01

Table 5 (continued)

Corner Number		Northing	Easting
71	Computed	542879.35	2523077.56
	GPS Observed	542879.26	2523077.49
	Difference	-0.09	-0.07
72	Computed	542995.08	2528394.51
	GPS Observed	542995.04	2528394.47
	Difference	-0.04	-0.04
73	Computed	543068.24	2531075.73
	GPS Observed	543068.17	2531075.67
	Difference	-0.07	-0.06
74	Computed	543129.71	2533727.30
	GPS Observed	543129.60	2533727.26
	Difference	-0.10	-0.03
75	Computed	543320.26	2541680.20
	GPS Observed	543320.35	2541680.19
	Difference	0.09	-0.02
76	Computed	543568.77	2549595.48
	GPS Observed	543568.78	2549595.42
	Difference	0.01	-0.06
77	Computed	540672.13	2541765.41
	GPS Observed	540672.03	2541765.43
	Difference	-0.10	0.02
78	Computed	539924.17	2515164.97
	GPS Observed	539924.25	2515164.95
	Difference	0.08	-0.02
79	Computed	539812.09	2512516.72
	GPS Observed	539812.21	2512516.70
	Difference	0.12	-0.02
80	Computed	539448.95	2504632.68
	GPS Observed	539449.09	2504632.65
	Difference	0.13	-0.04
81	Computed	536551.61	2499350.40
	GPS Observed	536551.47	2499350.55
	Difference	-0.14	0.15
82	Computed	536553.22	2499396.86
	GPS Observed	536553.06	2499396.94
	Difference	-0.16	0.09

Corner Number		Northing	Easting
83	Computed	536676.15	2501994.74
	GPS Observed	536676.24	2501994.93
	Difference	0.09	0.19
84	Computed	537050.72	2509948.07
	GPS Observed	537050.83	2509947.99
	Difference	0.11	-0.09
85	Computed	537051.16	2509957.20
	GPS Observed	537051.21	2509957.05
	Difference	0.05	-0.15
86	Computed	537271.94	2515255.34
	GPS Observed	537272.04	2515255.44
	Difference	0.10	0.10
87	Computed	537626.64	2525833.48
	GPS Observed	537626.74	2525833.49
	Difference	0.10	0.01
88	Computed	537703.90	2528550.00
	GPS Observed	537703.86	2528550.04
	Difference	-0.05	0.04
89	Computed	537772.72	2531218.17
	GPS Observed	537772.52	2531218.21
	Difference	-0.20	0.03
90	Computed	537830.76	2533854.83
	GPS Observed	537830.71	2533854.93
	Difference	-0.05	0.10
91	Computed	537959.84	2539115.94
	GPS Observed	537959.83	2539115.97
	Difference	-0.01	0.04
92	Computed	538022.74	2541777.22
	GPS Observed	538022.69	2541777.23
	Difference	-0.05	0.01
93	Computed	538024.41	2541848.38
	GPS Observed	538024.22	2541848.36
	Difference	-0.19	-0.01
94	Computed	538111.55	2544507.72
	GPS Observed	538111.44	2544507.72
	Difference	-0.11	0.00

Table 5 (continued)

Corner Number		Northing	Easting
95	Computed	535347.35	2533884.42
	GPS Observed	535347.23	2533884.40
	Difference	-0.13	-0.02
96	Computed	535043.58	2525889.53
	GPS Observed	535043.62	2525889.60
	Difference	0.04	0.07
97	Computed	534937.14	2523253.81
	GPS Observed	534937.10	2523253.92
	Difference	-0.03	0.11
98	Computed	534827.87	2520623.86
	GPS Observed	534827.87	2520623.86
	Difference	0.00	0.00
99	Computed	531299.59	2499442.99
	GPS Observed	531299.61	2499443.08
	Difference	0.02	0.08
100	Computed	531364.47	2502083.11
	GPS Observed	531364.45	2502083.10
	Difference	-0.03	-0.01
101	Computed	531453.88	2504748.21
	GPS Observed	531453.82	2504748.14
	Difference	-0.06	-0.07
102	Computed	531621.20	2510052.02
	GPS Observed	531621.23	2510052.02
	Difference	0.04	0.01
103	Computed	531721.06	2512719.15
	GPS Observed	531721.20	2512719.23
	Difference	0.14	0.08
104	Computed	531992.33	2518013.64
	GPS Observed	531992.37	2518013.65
	Difference	0.04	0.01
105	Computed	532170.95	2520663.13
	GPS Observed	532171.03	2520663.09
	Difference	0.08	-0.04
106	Computed	532281.50	2523309.14
	GPS Observed	532281.48	2523309.21
	Difference	-0.03	0.07
107	Computed	532391.93	2525955.37
	GPS Observed	532391.99	2525955.35
	Difference	0.06	-0.01
108	Computed	532485.95	2528615.64
	GPS Observed	532485.90	2528615.48
	Difference	-0.05	-0.16
109	Computed	532692.72	2533911.07
	GPS Observed	532692.71	2533911.09
	Difference	-0.01	0.02
110	Computed	532820.96	2536547.14
	GPS Observed	532820.99	2536547.13
	Difference	0.02	-0.02
111	Computed	530033.66	2533948.15
	GPS Observed	530033.56	2533948.17
	Difference	-0.10	0.02
112	Computed	529822.26	2528669.95
	GPS Observed	529822.31	2528669.94
	Difference	0.05	-0.01
113	Computed	529624.02	2523364.74
	GPS Observed	529624.07	2523364.77
	Difference	0.06	0.03
114	Computed	529338.70	2518058.59
	GPS Observed	529338.74	2518058.56
	Difference	0.04	-0.02
115	Computed	528804.59	2504796.41
	GPS Observed	528804.48	2504796.46
	Difference	-0.11	0.05
116	Computed	528659.25	2499475.48
	GPS Observed	528659.17	2499475.43
	Difference	-0.08	-0.05
117	Computed	526088.76	2502195.17
	GPS Observed	526088.71	2502195.14
	Difference	-0.05	-0.04
118	Computed	524723.76	2534033.55
	GPS Observed	524723.73	2534033.70
	Difference	-0.03	0.14

Table 5 (continued)

Corner Number		Northing	Easting
119	Computed	524308.17	2523487.42
	GPS Observed	524308.00	2523487.44
	Difference	-0.17	0.02
120	Computed	524183.67	2520835.63
	GPS Observed	524183.62	2520835.65
	Difference	-0.05	0.02
121	Computed	523873.35	2515507.62
	GPS Observed	523873.28	2515507.63
	Difference	-0.08	0.01
122	Computed	523178.08	2494286.59
	GPS Observed	523178.08	2494286.60
	Difference	0.00	0.01
123	Computed	520533.98	2494370.16
	GPS Observed	520534.02	2494370.14
	Difference	0.05	-0.02
124	Computed	520793.88	2502330.51
	GPS Observed	520793.81	2502330.44
	Difference	-0.07	-0.07
125	Computed	520946.20	2507630.31
	GPS Observed	520946.26	2507630.30
	Difference	0.06	-0.02
126	Computed	521035.39	2510281.18
	GPS Observed	521035.45	2510281.16
	Difference	0.05	-0.02
127	Computed	521129.16	2512925.09
	GPS Observed	521129.10	2512925.08
	Difference	-0.06	-0.01
128	Computed	521222.77	2515578.27
	GPS Observed	521222.68	2515578.24
	Difference	-0.09	-0.02
129	Computed	521375.58	2518243.86
	GPS Observed	521375.46	2518243.83
	Difference	-0.12	-0.03
130	Computed	521528.03	2520901.71
	GPS Observed	521527.92	2520901.78
	Difference	-0.11	0.07
131	Computed	521779.23	2526180.71
	GPS Observed	521779.23	2526180.68
	Difference	0.00	-0.03
132	Computed	521870.58	2528818.71
	GPS Observed	521870.68	2528818.59
	Difference	0.10	-0.12
133	Computed	521953.33	2531450.77
	GPS Observed	521953.36	2531450.77
	Difference	0.04	-0.01
134	Computed	522069.61	2534096.21
	GPS Observed	522069.55	2534096.23
	Difference	-0.06	0.02
135	Computed	519295.70	2531538.51
	GPS Observed	519295.78	2531538.41
	Difference	0.09	-0.10
136	Computed	518875.72	2520977.06
	GPS Observed	518875.70	2520977.03
	Difference	-0.02	-0.03
137	Computed	518571.63	2515643.53
	GPS Observed	518571.58	2515643.54
	Difference	-0.05	0.01
138	Computed	515342.58	2497204.30
	GPS Observed	515342.50	2497204.19
	Difference	-0.08	-0.11
139	Computed	515736.60	2510443.10
	GPS Observed	515736.57	2510443.13
	Difference	-0.03	0.03
140	Computed	515829.67	2513082.62
	GPS Observed	515829.72	2513082.82
	Difference	0.05	0.20
141	Computed	515919.60	2515721.05
	GPS Observed	515919.53	2515721.05
	Difference	-0.07	0.00
142	Computed	516339.11	2523690.69
	GPS Observed	516339.06	2523690.66
	Difference	-0.06	-0.03

Table 5 (continued)

Corner Number		Northing	Easting
143	Computed	516468.88	2526346.03
	GPS Observed	516468.74	2526345.99
	Difference	-0.15	-0.04
144	Computed	516656.56	2531621.22
	GPS Observed	516656.72	2531621.12
	Difference	0.15	-0.10
145	Computed	516781.12	2534266.76
	GPS Observed	516781.16	2534266.66
	Difference	0.04	-0.10
146	Computed	516741.16	2534268.43
	GPS Observed	516741.17	2534268.38
	Difference	0.01	-0.05
147	Computed	514115.12	2534377.97
	GPS Observed	514115.15	2534377.99
	Difference	0.03	0.01
148	Computed	513552.43	2521147.41
	GPS Observed	513552.31	2521147.28
	Difference	-0.12	-0.13
149	Computed	512921.08	2505270.32
	GPS Observed	512920.96	2505270.23
	Difference	-0.12	-0.08
150	Computed	510192.39	2502714.25
	GPS Observed	510192.50	2502714.18
	Difference	0.10	-0.07
151	Computed	510533.85	2513286.66
	GPS Observed	510533.69	2513286.51
	Difference	-0.16	-0.15
152	Computed	510797.84	2518594.62
	GPS Observed	510797.66	2518594.50
	Difference	-0.18	-0.12
153	Computed	511027.15	2523882.04
	GPS Observed	511027.10	2523882.00
	Difference	-0.04	-0.04
154	Computed	508367.15	2523991.11
	GPS Observed	508366.99	2523991.07
	Difference	-0.16	-0.05
155	Computed	508110.91	2518691.36
	GPS Observed	508110.74	2518691.29
	Difference	-0.17	-0.08
156	Computed	504346.45	2485544.42
	GPS Observed	504346.45	2485544.50
	Difference	0.00	0.08
157	Computed	504417.28	2488207.50
	GPS Observed	504417.13	2488207.55
	Difference	-0.15	0.05
158	Computed	504642.89	2495021.79
	GPS Observed	504642.98	2495021.78
	Difference	0.09	-0.01
159	Computed	504765.60	2498751.68
	GPS Observed	504765.55	2498751.67
	Difference	-0.04	0.00
160	Computed	504815.87	2500290.93
	GPS Observed	504815.89	2500290.90
	Difference	0.03	-0.03
161	Computed	504852.35	2501399.14
	GPS Observed	504852.36	2501399.08
	Difference	0.01	-0.06
162	Computed	505181.11	2511939.43
	GPS Observed	505181.22	2511939.39
	Difference	0.11	-0.04
163	Computed	505503.07	2519855.79
	GPS Observed	505502.98	2519855.77
	Difference	-0.09	-0.01
164	Computed	505761.89	2525149.64
	GPS Observed	505761.95	2525149.59
	Difference	0.06	-0.04
165	Computed	505842.38	2526754.17
	GPS Observed	505842.37	2526754.09
	Difference	-0.01	-0.08
166	Computed	506003.90	2530518.55
	GPS Observed	506003.73	2530518.53
	Difference	-0.17	-0.02

Table 5 (continued)

Corner Number		Northing	Easting
167	Computed	502886.31	2525296.71
	GPS Observed	502886.21	2525296.71
	Difference	-0.09	0.00
168	Computed	502583.42	2517333.57
	GPS Observed	502583.52	2517333.66
	Difference	0.10	0.10
169	Computed	501564.46	2498891.19
	GPS Observed	501564.46	2498891.23
	Difference	0.00	0.04
170	Computed	498505.53	2485810.62
	GPS Observed	498505.67	2485810.70
	Difference	0.14	0.07
171	Computed	498556.86	2488448.77
	GPS Observed	498556.95	2488448.82
	Difference	0.09	0.06
172	Computed	498640.92	2491088.01
	GPS Observed	498640.91	2491088.11
	Difference	-0.01	0.09
173	Computed	498922.24	2499004.48
	GPS Observed	498922.28	2499004.41
	Difference	0.03	-0.07
174	Computed	499053.69	2501654.59
	GPS Observed	499053.64	2501654.43
	Difference	-0.05	-0.16
175	Computed	499947.95	2517452.60
	GPS Observed	499947.97	2517452.67
	Difference	0.02	0.06
176	Computed	499981.86	2520107.85
	GPS Observed	499981.99	2520107.86
	Difference	0.13	0.01
177	Computed	500103.72	2522761.12
	GPS Observed	500103.73	2522761.06
	Difference	0.02	-0.06
178	Computed	497328.84	2520218.75
	GPS Observed	497328.99	2520218.76
	Difference	0.15	0.02

Corner Number		Northing	Easting
179	Computed	497036.74	2512278.65
	GPS Observed	497036.68	2512278.65
	Difference	-0.06	-0.01
180	Computed	496284.32	2499112.93
	GPS Observed	496284.29	2499112.79
	Difference	-0.03	-0.14
181	Computed	495914.79	2488554.27
	GPS Observed	495914.89	2488554.39
	Difference	0.10	0.12
182	Computed	495871.21	2485908.33
	GPS Observed	495871.13	2485908.36
	Difference	-0.07	0.03
183	Computed	493238.69	2486019.65
	GPS Observed	493238.68	2486019.69
	Difference	0.00	0.04
184	Computed	493285.68	2488650.47
	GPS Observed	493285.72	2488650.48
	Difference	0.04	0.01
185	Computed	493561.59	2496562.88
	GPS Observed	493561.58	2496562.95
	Difference	-0.01	0.07
186	Computed	494035.57	2507130.65
	GPS Observed	494035.37	2507130.69
	Difference	-0.19	0.04
187	Computed	494178.75	2509774.81
	GPS Observed	494178.66	2509774.89
	Difference	-0.09	0.07
188	Computed	494388.23	2512387.77
	GPS Observed	494388.09	2512387.82
	Difference	-0.14	0.05
189	Computed	494630.66	2517665.84
	GPS Observed	494630.56	2517665.77
	Difference	-0.10	-0.07
190	Computed	494678.52	2520316.84
	GPS Observed	494678.58	2520316.91
	Difference	0.06	0.07

Table 5 (continued)

Corner Number		Northing	Easting
191	Computed	494903.62	2525637.97
	GPS Observed	494903.67	2525637.92
	Difference	0.05	-0.04
192	Computed	495012.11	2528286.41
	GPS Observed	495012.30	2528286.40
	Difference	0.18	-0.01
193	Computed	492023.75	2520415.42
	GPS Observed	492023.65	2520415.48
	Difference	-0.10	0.05
194	Computed	490644.29	2488745.29
	GPS Observed	490644.39	2488745.24
	Difference	0.10	-0.05
195	Computed	487959.85	2486190.72
	GPS Observed	487959.99	2486190.78
	Difference	0.14	0.06
196	Computed	488013.05	2488836.03
	GPS Observed	488013.06	2488836.11
	Difference	0.01	0.07
197	Computed	488077.28	2491463.80
	GPS Observed	488077.31	2491463.91
	Difference	0.03	0.12
198	Computed	488372.64	2499359.85
	GPS Observed	488372.67	2499359.81
	Difference	0.03	-0.04
199	Computed	488500.42	2502013.24
	GPS Observed	488500.42	2502013.19
	Difference	0.00	-0.05
200	Computed	488765.54	2507319.07
	GPS Observed	488765.42	2507319.11
	Difference	-0.13	0.03
201	Computed	488896.08	2509957.91
	GPS Observed	488896.02	2509958.03
	Difference	-0.06	0.13
202	Computed	489080.58	2512586.95
	GPS Observed	489080.55	2512587.12
	Difference	-0.03	0.17

Corner Number		Northing	Easting
203	Computed	489367.04	2520508.73
	GPS Observed	489367.09	2520508.79
	Difference	0.04	0.06
204	Computed	486940.86	2525942.45
	GPS Observed	486940.83	2525942.45
	Difference	-0.03	-0.01
205	Computed	486668.17	2517962.35
	GPS Observed	486668.30	2517962.37
	Difference	0.13	0.02
206	Computed	486621.36	2515311.80
	GPS Observed	486621.45	2515311.84
	Difference	0.09	0.03
207	Computed	486121.02	2507417.13
	GPS Observed	486120.95	2507417.12
	Difference	-0.06	-0.01
208	Computed	485985.99	2504768.72
	GPS Observed	485986.00	2504768.70
	Difference	0.00	-0.03
209	Computed	485528.19	2494193.14
	GPS Observed	485528.08	2494193.18
	Difference	-0.11	0.05
210	Computed	482886.94	2494294.88
	GPS Observed	482886.86	2494294.90
	Difference	-0.08	0.02
211	Computed	483472.85	2507516.34
	GPS Observed	483472.77	2507516.36
	Difference	-0.07	0.02
212	Computed	483607.23	2510179.38
	GPS Observed	483607.17	2510179.37
	Difference	-0.07	-0.02
213	Computed	484014.54	2518074.08
	GPS Observed	484014.58	2518074.07
	Difference	0.04	-0.01
214	Computed	484182.60	2523391.70
	GPS Observed	484182.57	2523391.67
	Difference	-0.03	-0.04

Table 5 (continued)

Corner Number		Northing	Easting
215	Computed	484282.57	2526046.32
	GPS Observed	484282.53	2526046.32
	Difference	-0.04	0.00
216	Computed	481751.70	2528778.02
	GPS Observed	481751.78	2528777.98
	Difference	0.08	-0.04
217	Computed	480836.07	2507602.31
	GPS Observed	480836.01	2507602.25
	Difference	-0.06	-0.06
218	Computed	480574.60	2502308.95
	GPS Observed	480574.60	2502308.92
	Difference	0.00	-0.02
219	Computed	480348.76	2497036.43
	GPS Observed	480348.78	2497036.37
	Difference	0.02	-0.06
220	Computed	480249.81	2494407.08
	GPS Observed	480249.69	2494407.04
	Difference	-0.12	-0.05
221	Computed	477807.99	2499766.65
	GPS Observed	477807.86	2499766.58
	Difference	-0.13	-0.07
222	Computed	477941.00	2502412.80
	GPS Observed	477940.99	2502412.76
	Difference	-0.01	-0.04
223	Computed	478181.93	2507689.32
	GPS Observed	478181.78	2507689.23
	Difference	-0.15	-0.09
224	Computed	478325.30	2510327.88
	GPS Observed	478325.34	2510327.87
	Difference	0.04	-0.01
225	Computed	478703.44	2518282.02
	GPS Observed	478703.46	2518282.06
	Difference	0.02	0.04
226	Computed	478870.59	2523566.48
	GPS Observed	478870.64	2523566.49
	Difference	0.05	0.01

Corner Number		Northing	Easting
227	Computed	478964.50	2526221.13
	GPS Observed	478964.49	2526221.13
	Difference	-0.01	0.00
228	Computed	476304.41	2526298.36
	GPS Observed	476304.35	2526298.24
	Difference	-0.06	-0.11
229	Computed	476111.08	2521016.23
	GPS Observed	476111.08	2521016.23
	Difference	0.00	0.00
230	Computed	475297.43	2502519.04
	GPS Observed	475297.40	2502519.00
	Difference	-0.03	-0.04
231	Computed	472137.75	2486786.60
	GPS Observed	472137.76	2486786.62
	Difference	0.00	0.02
232	Computed	472173.70	2489396.50
	GPS Observed	472173.72	2489396.45
	Difference	0.02	-0.05
233	Computed	472248.44	2492036.55
	GPS Observed	472248.40	2492036.66
	Difference	-0.04	0.11
234	Computed	472326.56	2494675.95
	GPS Observed	472326.71	2494675.92
	Difference	0.16	-0.04
235	Computed	472327.54	2494709.30
	GPS Observed	472327.67	2494709.19
	Difference	0.12	-0.10
236	Computed	472527.90	2499940.94
	GPS Observed	472527.89	2499940.94
	Difference	-0.01	0.00
237	Computed	473465.50	2521110.39
	GPS Observed	473465.48	2521110.44
	Difference	-0.03	0.04
238	Computed	473559.80	2523739.01
	GPS Observed	473559.76	2523738.96
	Difference	-0.04	-0.04

Table 5 (continued)

Corner Number		Northing	Easting
239	Computed	473561.43	2523791.52
	GPS Observed	473561.37	2523791.43
	Difference	-0.06	-0.08
240	Computed	473641.29	2526364.23
	GPS Observed	473641.14	2526364.25
	Difference	-0.15	0.02
241	Computed	470625.45	2521244.57
	GPS Observed	470625.32	2521244.55
	Difference	-0.13	-0.02
242	Computed	470607.52	2515952.49
	GPS Observed	470607.44	2515952.35
	Difference	-0.08	-0.14
243	Computed	469775.78	2489458.73
	GPS Observed	469775.73	2489458.55
	Difference	-0.06	-0.19
244	Computed	467675.33	2508075.02
	GPS Observed	467675.17	2508075.08
	Difference	-0.16	0.06
245	Computed	467826.21	2513392.48
	GPS Observed	467826.27	2513392.63
	Difference	0.06	0.15
246	Computed	467942.59	2518681.91
	GPS Observed	467942.73	2518681.97
	Difference	0.14	0.06
247	Computed	468029.71	2523980.84
	GPS Observed	468029.56	2523980.75
	Difference	-0.15	-0.09
248	Computed	465296.76	2521415.61
	GPS Observed	465296.84	2521415.43
	Difference	0.08	-0.18
249	Computed	461732.27	2487105.21
	GPS Observed	461732.21	2487105.19
	Difference	-0.06	-0.02
250	Computed	461845.51	2489728.94
	GPS Observed	461845.49	2489729.04
	Difference	-0.02	0.10

Corner Number		Northing	Easting
251	Computed	461939.33	2492375.54
	GPS Observed	461939.39	2492375.55
	Difference	0.06	0.01
252	Computed	462050.19	2495014.67
	GPS Observed	462050.20	2495014.69
	Difference	0.00	0.02
253	Computed	462148.74	2497664.44
	GPS Observed	462148.79	2497664.56
	Difference	0.05	0.12
254	Computed	462341.83	2505598.15
	GPS Observed	462341.90	2505598.21
	Difference	0.06	0.06
255	Computed	462384.30	2508245.04
	GPS Observed	462384.31	2508245.04
	Difference	0.01	0.00
256	Computed	462424.66	2510893.64
	GPS Observed	462424.74	2510893.65
	Difference	0.08	0.01
257	Computed	462637.51	2521508.72
	GPS Observed	462637.55	2521508.71
	Difference	0.04	0.00
258	Computed	462691.17	2524162.38
	GPS Observed	462691.18	2524162.34
	Difference	0.01	-0.04
259	Computed	460026.85	2524240.75
	GPS Observed	460026.86	2524240.80
	Difference	0.02	0.05
260	Computed	459972.61	2521580.61
	GPS Observed	459972.53	2521580.57
	Difference	-0.08	-0.05
261	Computed	456463.65	2487202.79
	GPS Observed	456463.65	2487202.89
	Difference	0.00	0.10
262	Computed	456654.75	2492500.54
	GPS Observed	456654.74	2492500.48
	Difference	-0.01	-0.06

Table 5 (continued)

Corner Number		Northing	Easting
263	Computed	456836.65	2497801.86
	GPS Observed	456836.64	2497801.98
	Difference	-0.02	0.12
264	Computed	456982.44	2503089.02
	GPS Observed	456982.40	2503089.11
	Difference	-0.04	0.09
265	Computed	457034.72	2505720.89
	GPS Observed	457034.73	2505720.95
	Difference	0.01	0.06
266	Computed	457086.14	2508382.01
	GPS Observed	457086.26	2508381.84
	Difference	0.12	-0.17
267	Computed	457308.51	2518990.93
	GPS Observed	457308.57	2518990.86
	Difference	0.06	-0.07
268	Computed	457303.54	2518996.08
	GPS Observed	457303.58	2518995.98
	Difference	0.04	-0.09
269	Computed	457321.07	2521646.91
	GPS Observed	457321.20	2521646.84
	Difference	0.13	-0.07
270	Computed	454856.70	2505764.30
	GPS Observed	454856.80	2505764.42
	Difference	0.10	0.12
271	Computed	454193.87	2497848.44
	GPS Observed	454193.87	2497848.36
	Difference	0.00	-0.08
272	Computed	454390.13	2505714.46
	GPS Observed	454390.02	2505714.49
	Difference	-0.11	0.03
273	Computed	454445.03	2508447.58
	GPS Observed	454445.02	2508447.55
	Difference	-0.02	-0.03
274	Computed	454552.26	2513756.26
	GPS Observed	454552.26	2513756.26
	Difference	0.00	0.00

Corner Number		Northing	Easting
275	Computed	454545.43	2513756.48
	GPS Observed	454545.43	2513756.48
	Difference	0.01	-0.01
276	Computed	454627.39	2516402.49
	GPS Observed	454627.30	2516402.56
	Difference	-0.10	0.07
277	Computed	454640.15	2519052.65
	GPS Observed	454640.06	2519052.83
	Difference	-0.09	0.18
278	Computed	454659.74	2521702.40
	GPS Observed	454659.68	2521702.41
	Difference	-0.06	0.01
279	Computed	454693.49	2524365.56
	GPS Observed	454693.55	2524365.41
	Difference	0.06	-0.14
280	Computed	451832.78	2511176.19
	GPS Observed	451832.69	2511176.28
	Difference	-0.09	0.08
281	Computed	451748.09	2505851.09
	GPS Observed	451747.98	2505851.02
	Difference	-0.11	-0.06
282	Computed	451685.37	2503209.08
	GPS Observed	451685.32	2503208.94
	Difference	-0.05	-0.14
283	Computed	451543.93	2497898.14
	GPS Observed	451543.95	2497898.15
	Difference	0.02	0.01
284	Computed	451458.63	2495257.90
	GPS Observed	451458.62	2495257.86
	Difference	-0.01	-0.04
285	Computed	451366.12	2492603.72
	GPS Observed	451366.19	2492603.67
	Difference	0.07	-0.05
286	Computed	451267.24	2489949.95
	GPS Observed	451267.29	2489949.89
	Difference	0.05	-0.06

Table 5 (continued)

Corner Number		Northing	Easting
287	Computed	451171.61	2487299.32
	GPS Observed	451171.68	2487299.28
	Difference	0.07	-0.03
288	Computed	448811.02	2495311.09
	GPS Observed	448810.96	2495311.07
	Difference	-0.06	-0.02
289	Computed	448975.36	2500619.47
	GPS Observed	448975.39	2500619.48
	Difference	0.03	0.01
290	Computed	449172.91	2511235.99
	GPS Observed	449172.93	2511236.02
	Difference	0.02	0.03
291	Computed	449324.63	2519155.05
	GPS Observed	449324.64	2519155.03
	Difference	0.01	-0.01
292	Computed	449317.66	2519155.02
	GPS Observed	449317.66	2519155.02
	Difference	-0.01	-0.01
293	Computed	446526.22	2511287.57
	GPS Observed	446526.07	2511287.51
	Difference	-0.15	-0.06
294	Computed	446492.93	2508622.72
	GPS Observed	446492.95	2508622.77
	Difference	0.03	0.06
295	Computed	446386.04	2503317.76
	GPS Observed	446386.05	2503317.74
	Difference	0.01	-0.02
296	Computed	446325.75	2500671.71
	GPS Observed	446325.80	2500671.67
	Difference	0.05	-0.04
297	Computed	445963.56	2490087.71
	GPS Observed	445963.50	2490087.71
	Difference	-0.06	0.00
298	Computed	445878.95	2487450.08
	GPS Observed	445878.96	2487450.07
	Difference	0.01	-0.01
299	Computed	443316.56	2490138.42
	GPS Observed	443316.55	2490138.29
	Difference	-0.01	-0.13
300	Computed	443518.91	2495406.84
	GPS Observed	443519.03	2495406.86
	Difference	0.12	0.01
301	Computed	443675.25	2500720.29
	GPS Observed	443675.25	2500720.28
	Difference	-0.01	-0.01
302	Computed	443798.16	2506013.53
	GPS Observed	443798.27	2506013.50
	Difference	0.11	-0.02
303	Computed	444130.18	2527161.07
	GPS Observed	444130.17	2527161.16
	Difference	-0.01	0.08
304	Computed	444125.10	2527156.11
	GPS Observed	444125.02	2527156.07
	Difference	-0.08	-0.04
305	Computed	444125.41	2527171.10
	GPS Observed	444125.37	2527171.08
	Difference	-0.04	-0.02

CORNER IDENTIFICATION NUMBER LOCATION GIVEN ON FIGURE 4

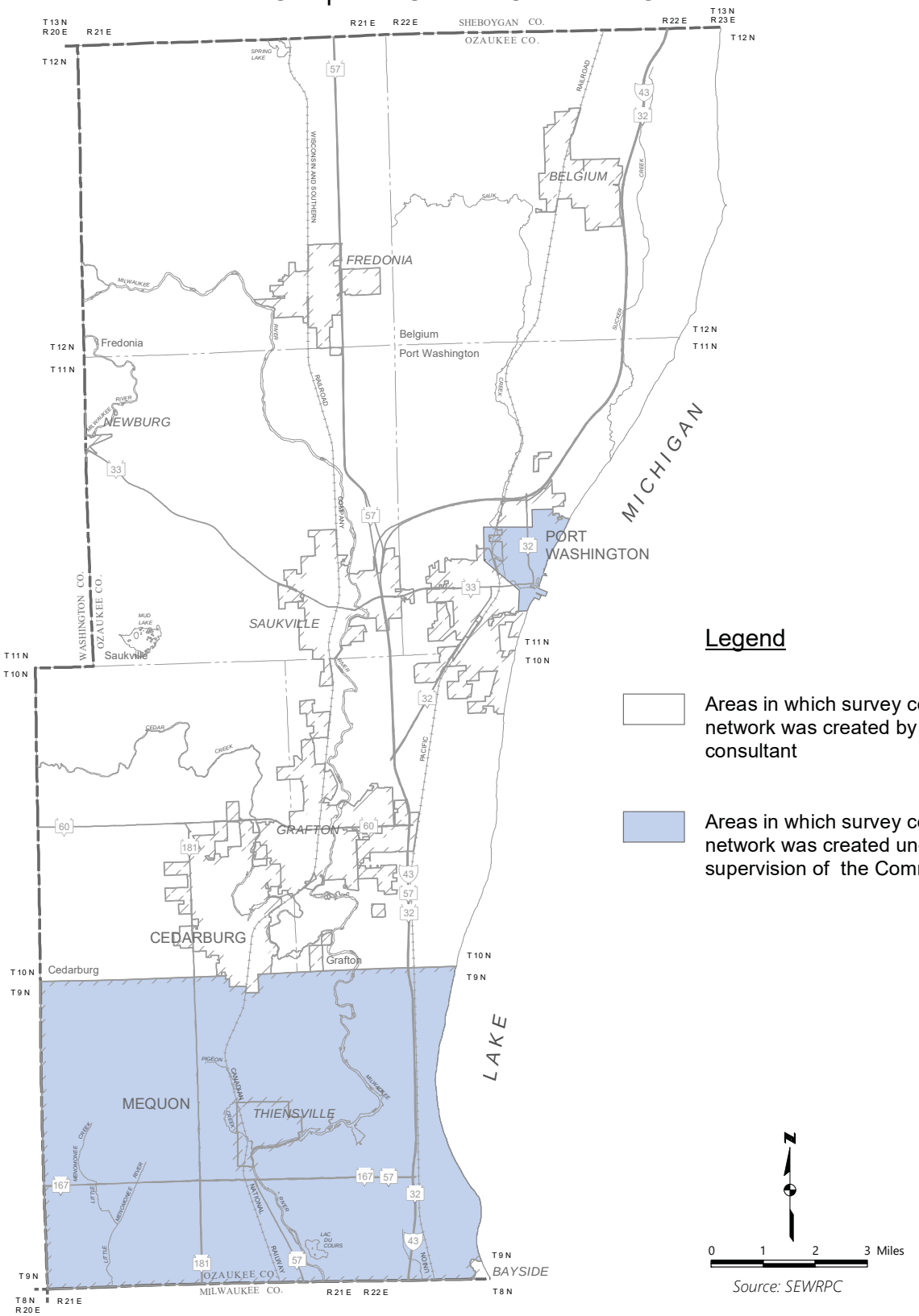
Table 5 (continued)

	Northing	Easting
Sum of Squared Differences	2.036	1.594
Average	-0.008	-0.005
Minimum Difference	-0.199	-0.191
Maximum Difference	0.187	0.204
RMSE	0.082	0.072
$RMSE_{min}$ / $RMSE_{max}$	0.885	
NSSDA 95% RMSE $Accuracy_r$	0.188	
Note: $RMSE_{min}$ / $RMSE_{max}$ is between 0.6 and 1.0, $Accuracy_r$ = 2.4477 * 0.5 * ($RMSE_{Northing}$ + $RMSE_{Easting}$)		

Source: SEWRPC.

Figure 1

Areas of Ozaukee County Within Which the Legacy Survey Control Network Was Completed Under Commission Supervision and Areas Within Which the Work Was Completed Under a Consultant Contract



Legend

Areas in which survey control network was created by a consultant

Areas in which survey control network was created under supervision of the Commission

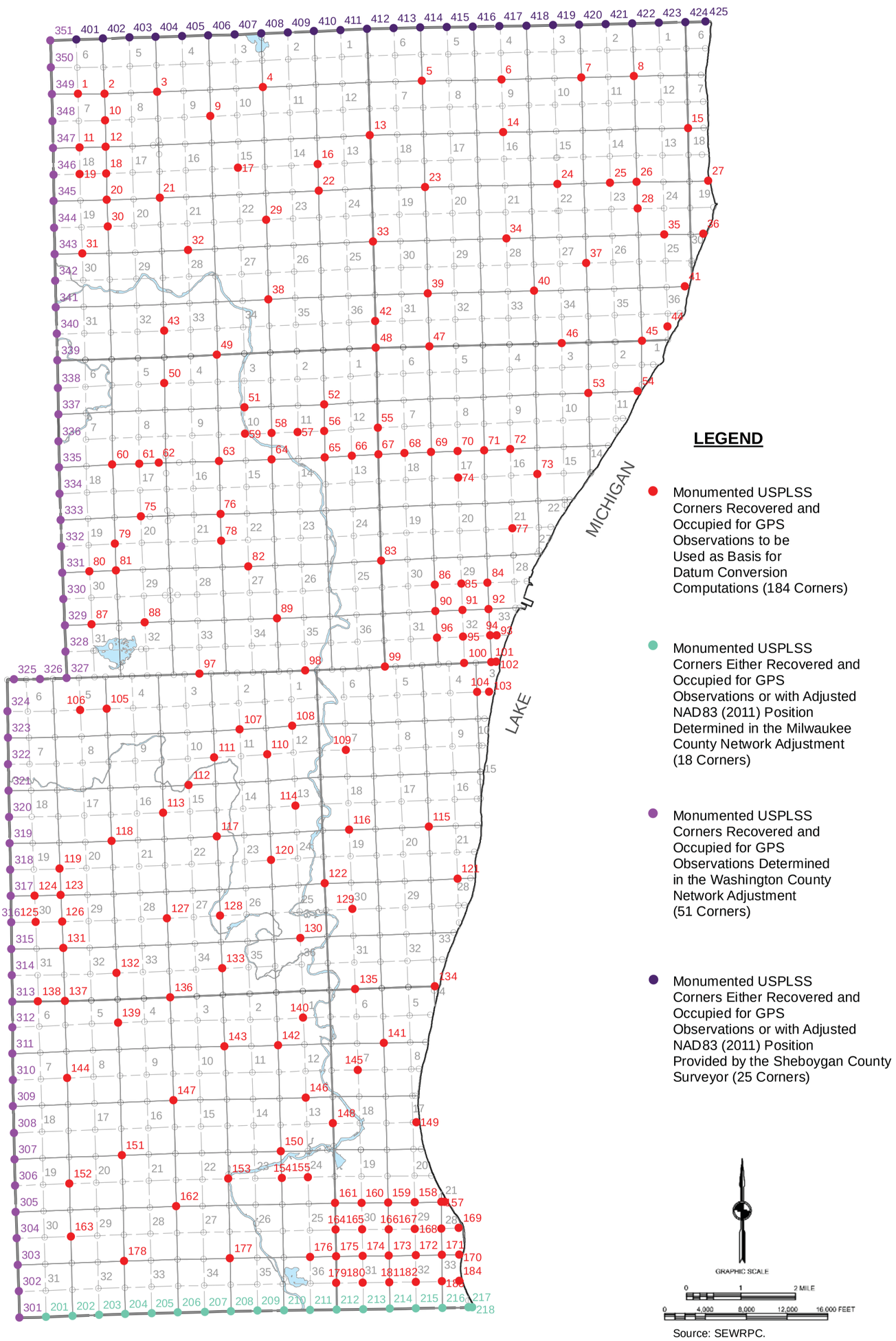
N

0 1 2 3 Miles

Source: SEWRPC

FIGURE 2

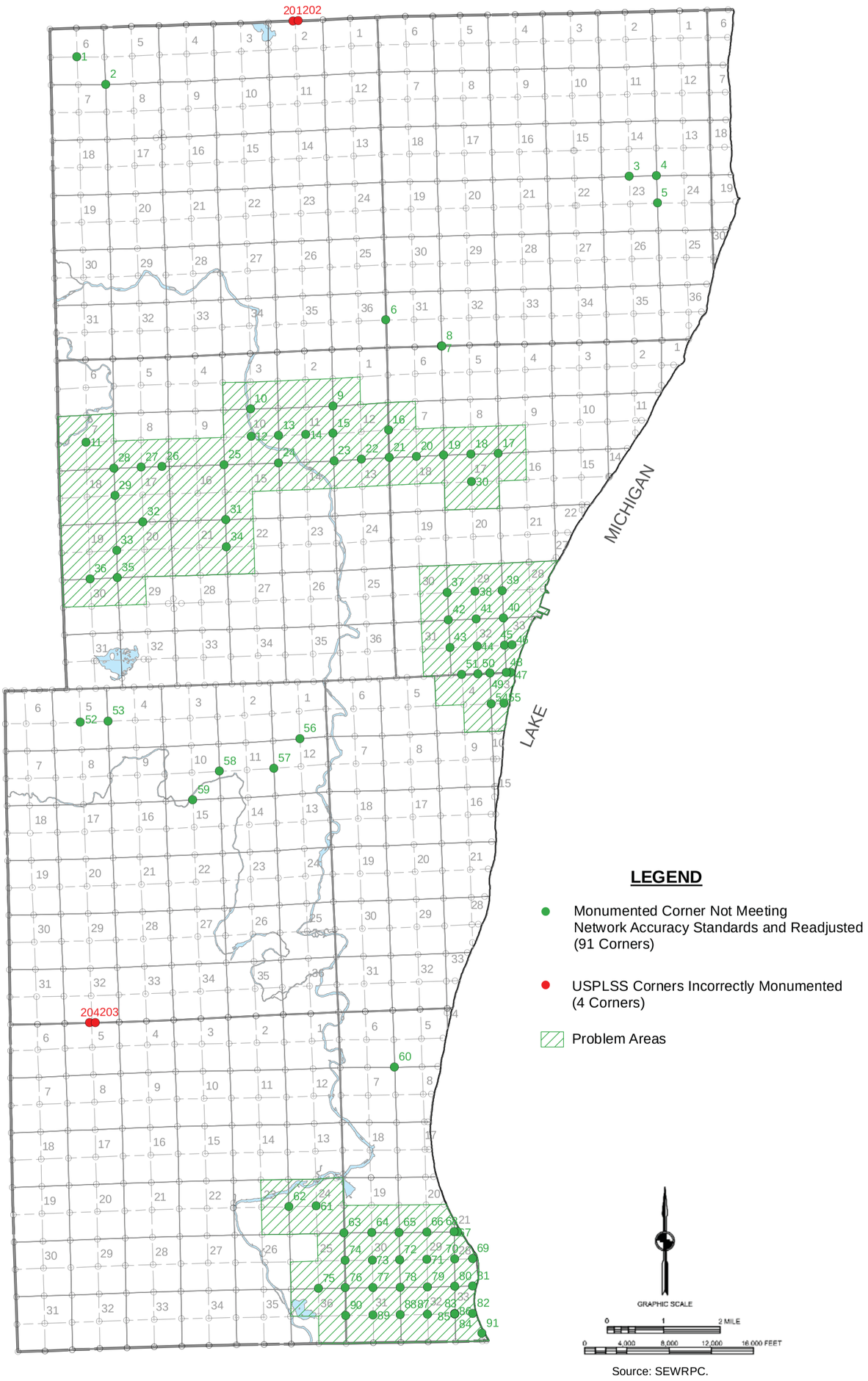
MAP OF OZAUKEE COUNTY SHOWING US PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO DETERMINE NAD83 (2011) COORDINATES AS BASIS FOR DATUM CONVERSION COMPUTATIONS



Source: SEWRPC.

FIGURE 3

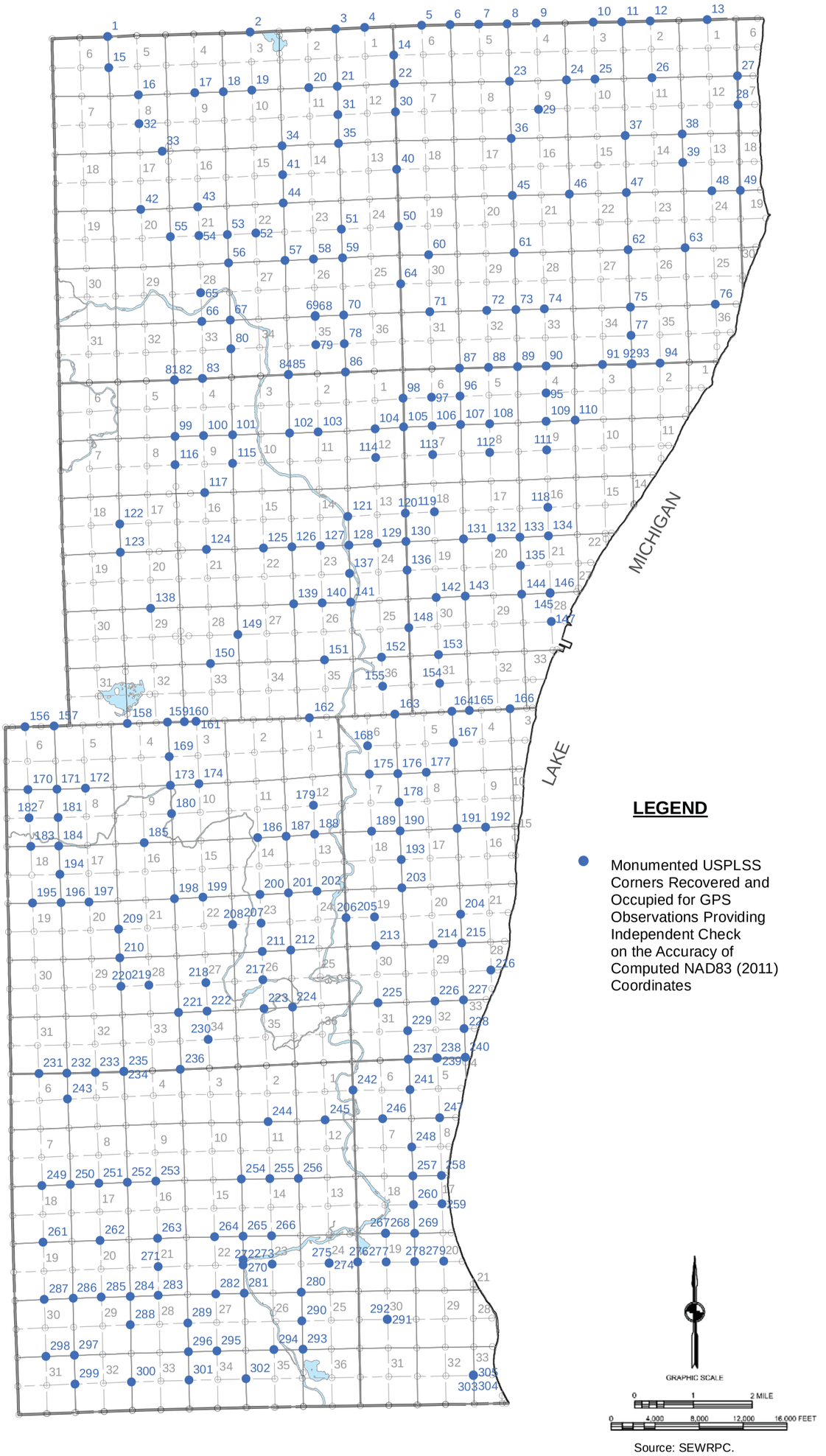
MAP OF OZAUKEE COUNTY SHOWING US PUBLIC LAND SURVEY CORNERS THE INITIALLY COMPUTED COORDINATES OF WHICH DID NOT MEET SURVEY CONTROL NETWORK ACCURACY STANDARDS



Source: SEWRPC.

FIGURE 4

MAP OF OZAUKEE COUNTY SHOWING US PUBLIC LAND SURVEY CORNERS OCCUPIED FOR GPS OBSERVATIONS TO VERIFY COMPUTED COORDINATE POSITIONS



Source: SEWRPC.

Figure 5

SAMPLE DOSSIER

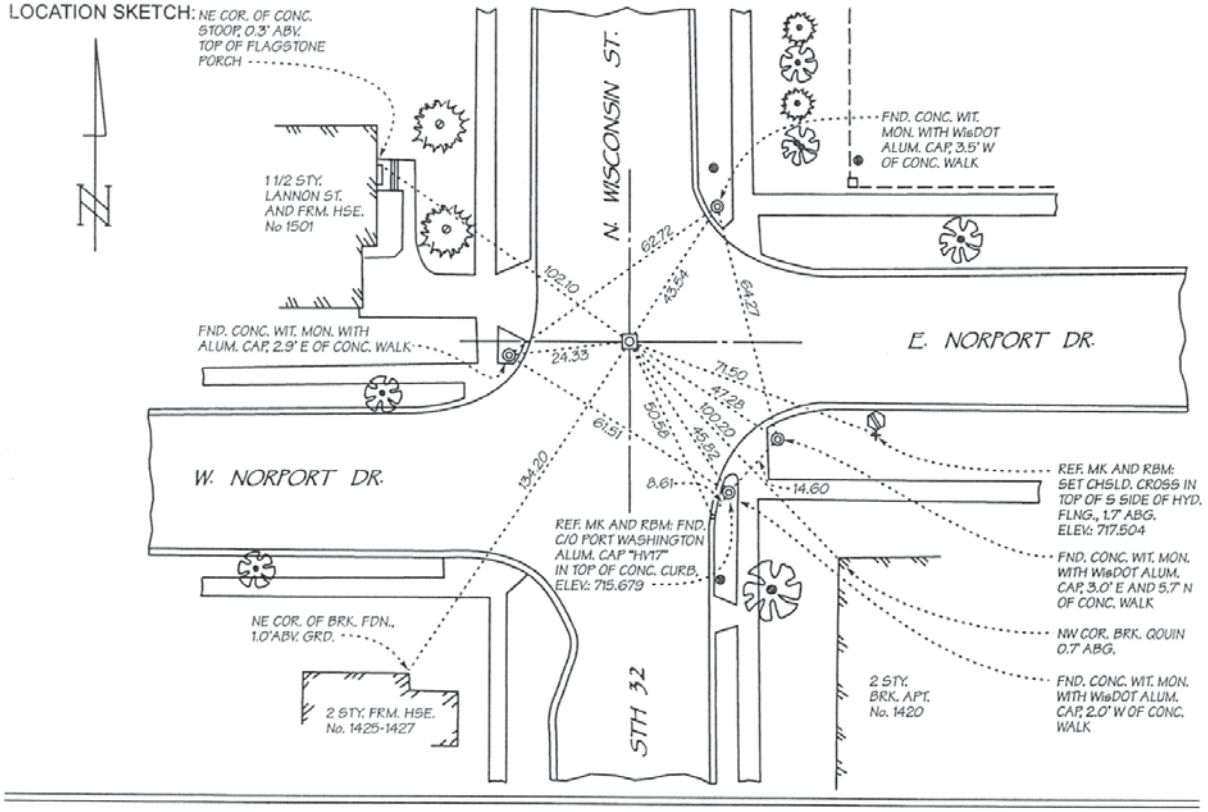
RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION

U.S. PUBLIC LAND SURVEY CORNER 21|21 / 21|21 **T** 11 **N, R** 22 **E,** Ozaukee **COUNTY, WISCONSIN**

HORIZONTAL: NORTH AMERICAN DATUM OF 1927	**HORIZONTAL: NORTH AMERICAN DATUM OF 1983/2011**
VERTICAL: NATIONAL GEODETIC VERTICAL DATUM OF 1929	**VERTICAL: NORTH AMERICAN VERTICAL DATUM OF 1988 (12)**
HOR. CONTROL: KAPUR & ASSOCIATES, INC. 1997	**HOR. CONTROL:** SEWRPC 2018
VERT. CONTROL: SEWRPC 2017	**VERT. CONTROL:**
NORTHING: 519,419.64 **USFT**	**NORTHING:** 519,426.80 **USFT**
EASTING: 2,565,716.10 **USFT**	**EASTING:** 2,534,176.48 **USFT**
ELEVATION: 716.422 **FT**	**ELEVATION:** **FT**
HOR. ACCURACY: 3rd ORDER, CLASS I	**HOR. ACCURACY:** 3rd ORDER, CLASS I (OBSERVED)
VERT. ACCURACY: 2nd ORDER, CLASS II	**VERT. ACCURACY:**

RBM ELEV. IN SKETCH BELOW TIED TO NGVD29 DATUM. CONVERSION FROM NGVD29 _____ FT DERIVES NAVD88 HEIGHT

LOCATION SKETCH:



SURVEYOR'S AFFIDAVIT:

STATE OF WISCONSIN) SS
OZAUKEE COUNTY)

I hereby certify that I set a SEWRPC brass cap in the concrete pavement to mark the location of this corner; replacing a cast iron plug with cross; said cast iron plug having been removed during street reconstruction in the summer of 2008; said cast iron plug having been set in the then existing concrete pavement to mark the location of this corner in October 1967 by Paul J. St. Arnauld, Wisconsin Department of Transportation Project Engineer, following street reconstruction; replacing a concrete monument with brass cap having been set to mark the location of this corner in December 1966 by James A. Eide, S-3, former Ozaukee County Surveyor; replacing in turn a P. K. nail and disc set in the then existing bituminous pavement then marking the location of this corner; said P. K. nail and disc having been found and accepted as marking the location of this corner in the conduct of surveys of land in the area by local surveyors; excavation of the area surrounding the corner location at that time by Mr. Eide did not reveal any subsurface physical evidence of any prior monumentation; that I have referenced the same as shown hereon; and that this record is correct and complete to the best of my knowledge and belief.

WISCONSIN ROBERT W. MERRY 2412 SHEBOYGAN WI LAND SURVEYOR

DATE OF SURVEY: 5 OCTOBER 2016

REGISTERED LAND SURVEYOR S - 2412

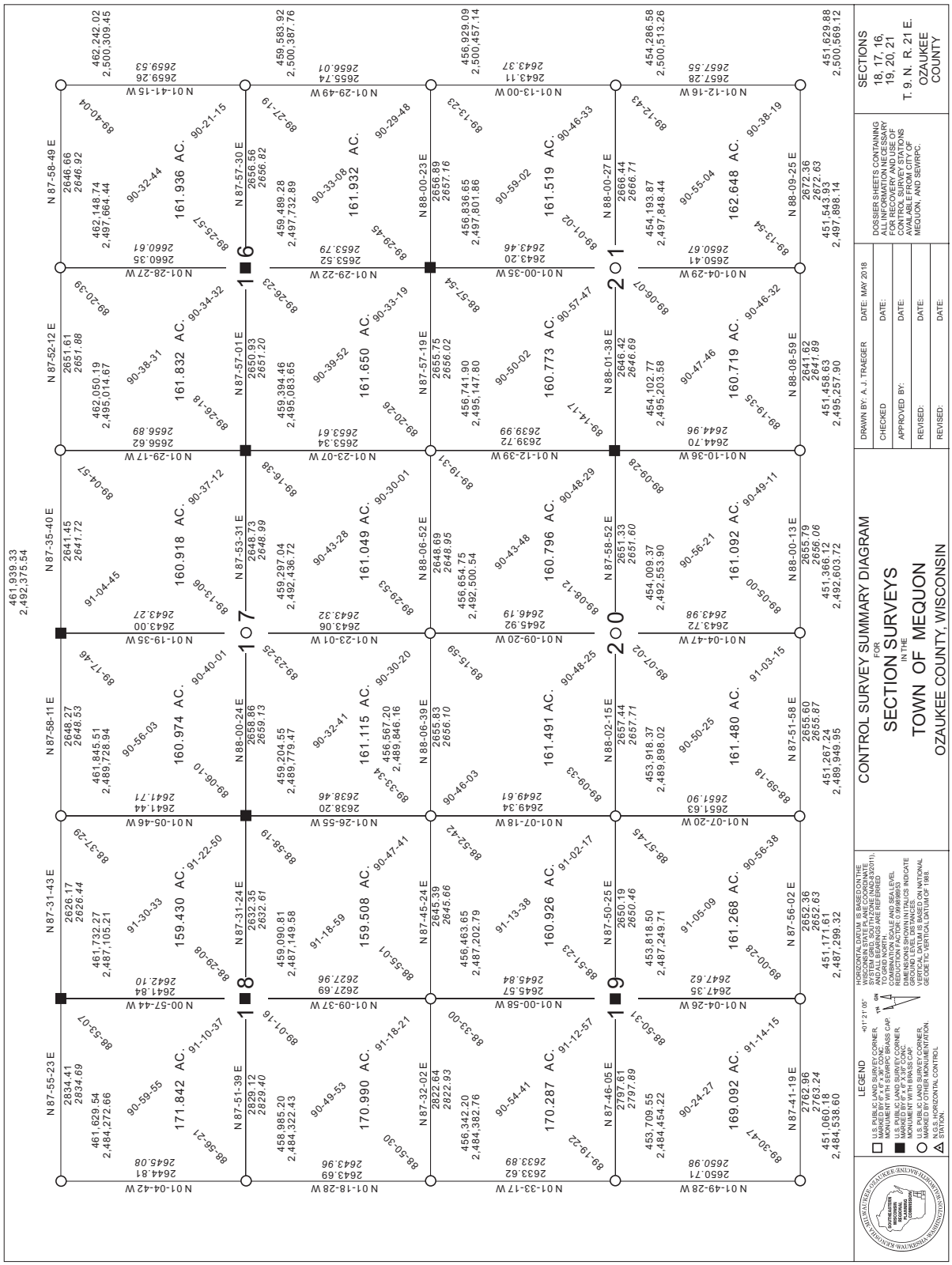
FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION (SEWRPC) CERTIFICATION APPLIES ONLY TO THE LOCATION SKETCH AND SURVEYOR AFFIDAVIT

11220970 **97 –**

Source: SEWRPC.

Figure 6

SAMPLE CSSD



Source: SEWRPC.

Appendix C

From

SEWRPC ADDENDUM TO MEMORANDUM REPORT No. 206 "REVISED ESTIMATE OF THE COSTS OF CONVERTING THE LEGACY DATUMS WITHIN THE REGION TO NATIONAL DATUMS", AUGUST 2015

INTRODUCTION

The seven-county Southeastern Wisconsin Region has an extensive and accurate network of both horizontal and vertical control survey stations. The integrated horizontal and vertical control survey stations are comprised of the 11,985 U.S. Public Land Survey System (USPLSS) corners within the Region and accessories thereto. The horizontal network is referenced to the North American Datum of 1927 (NAD 27), while the vertical network is referenced to the National Geodetic Vertical Datum of1929 (NGVD 29). The survey methods used to create the horizontal control network ranged from using theodolites and tellurometers to using Global Positioning System (GPS) instrumentation. The survey methods used to create the vertical control network ranged from using differential spirit leveling with invar rods read optically to using coded invar rods read automatically by the level instrument.

The introduction of newer technologies, especially the use of GPS instrumentation, has made the use of the legacy control survey network inconvenient when relating to newer datums created by the Federal government. The Commission continues to maintain the legacy control survey network in five of the seven counties comprising its Region and continues to monitor the use of the network within those counties. From time to time the Commission retains consultants to develop processes and/or mathematical formulas to assist surveyors, public works engineers, and other users in the use of the networks. However, some county land information system managers continue to request that the Commission investigate the means by which the legacy networks could be converted to newer datums and to estimate the attendant costs.

This appendix proposes new methods for converting the Commission legacy horizontal datum, from NAD 27 to the latest newer datum and adjustment—the North American Datum of 1983 with the National Adjustment of 2011, (NAD 83 (2011)), and for converting the legacy vertical datum from the NGVD 29 to the North American Vertical Datum of 1988 adjustment of 2012, (NAVD 88 (2012)), and to do so cost effectively.

METHODOLOGY FOR CONVERSION OF HORIZONTAL CONTROL

The Commission staff has developed a method for the conversion of its legacy horizontal control survey coordinate positions to the new horizontal datum while maintaining the relative positions of the legacy control survey stations, and maintaining the original accuracy standards of the network. The method utilizes the measurements made in the creation of the legacy horizontal control survey network within the Region and minimizes the number of field observations required to position the control survey stations on the new datum and

on the corresponding map projection. As already noted, the legacy network utilizes monumented corners of the USPLSS as control survey stations and, in effect, recreates the USPLSS within the Region tying that system to the National geodetic control system.

The datum conversion method developed by the Commission staff can be applied by subareas of the Region as small as six square miles in extent, although more practical subareas would consist of USPLSS townships, or of entire counties. When applied at the township level, the method requires field observations to obtain the coordinate positions of the township corners on the new datum together with such observations on a carefully selected number of control survey stations—approximately eight—consisting of section and quarter-section corners within the township. Four of the eight corners could be the four corners marking the exterior boundaries of a six-section SEWRPC Control Survey Summary Diagram (CSSD) used by the Commission to display the legacy control survey network. Having determined the coordinate positions on the new datum of approximately 12 USPLSS corners—the coordinates of the remaining 157 corners are computed using the lengths of the quarter-section lines and the interior angles of the quarter sections within the township as determined in the legacy survey. This computation consists of a least squares adjustment[1] of the network within the township.

Upon completion of the determination of the coordinate positions of all of the stations—USPLSS corners—within the area concerned, a small random sample of stations would be selected and the coordinate positions of these stations determined by additional field observations, thus providing a check on the accuracy of the completed conversion. If discrepancies exceeding the desired accuracy standards are found appropriate adjustments or further field measurements would have to be made.

The method developed by the Commission staff significantly reduces the cost entailed in datum conversion from such costs entailed in application of the conversion method proposed in SEWRPC Technical Report No. 206. Importantly, the method preserves the integrity of the legacy control survey network within the Region, maintaining the relative positions in the form of quarter-section-line lengths and bearings as determined in the creation of the legacy network, and does so within the accuracy standards of that network.

Field Observations

As noted, the conversion method requires the conduct of a limited number of field observations to determine the coordinate positions on the new datum of a carefully selected number of existing legacy stations. The necessary field observations would be made using state-of-the-art GPS instrumentation and procedures.

The Wisconsin Department of Transportation (WisDOT) completed a network of Continuous Operating Reference Stations (WISCORS) within the Region and the State in 2015. These stations within and adjacent to the Region are shown on Figure 1, and serve as the primary control network within the Region, replacing the old First- and Second-Order triangulation and base line stations. Satellite measurements permit the creation of a mathematical model that supports an online processing technology known as Virtual Reference Station (VRS) technology. This technology permits real-time positioning without the need for base stations and with minimal observation times while achieving centimeter-level accuracy. The VRS[2] technology is proposed to serve as the basis of the field measurements needed to determine horizontal positions in the new datum.

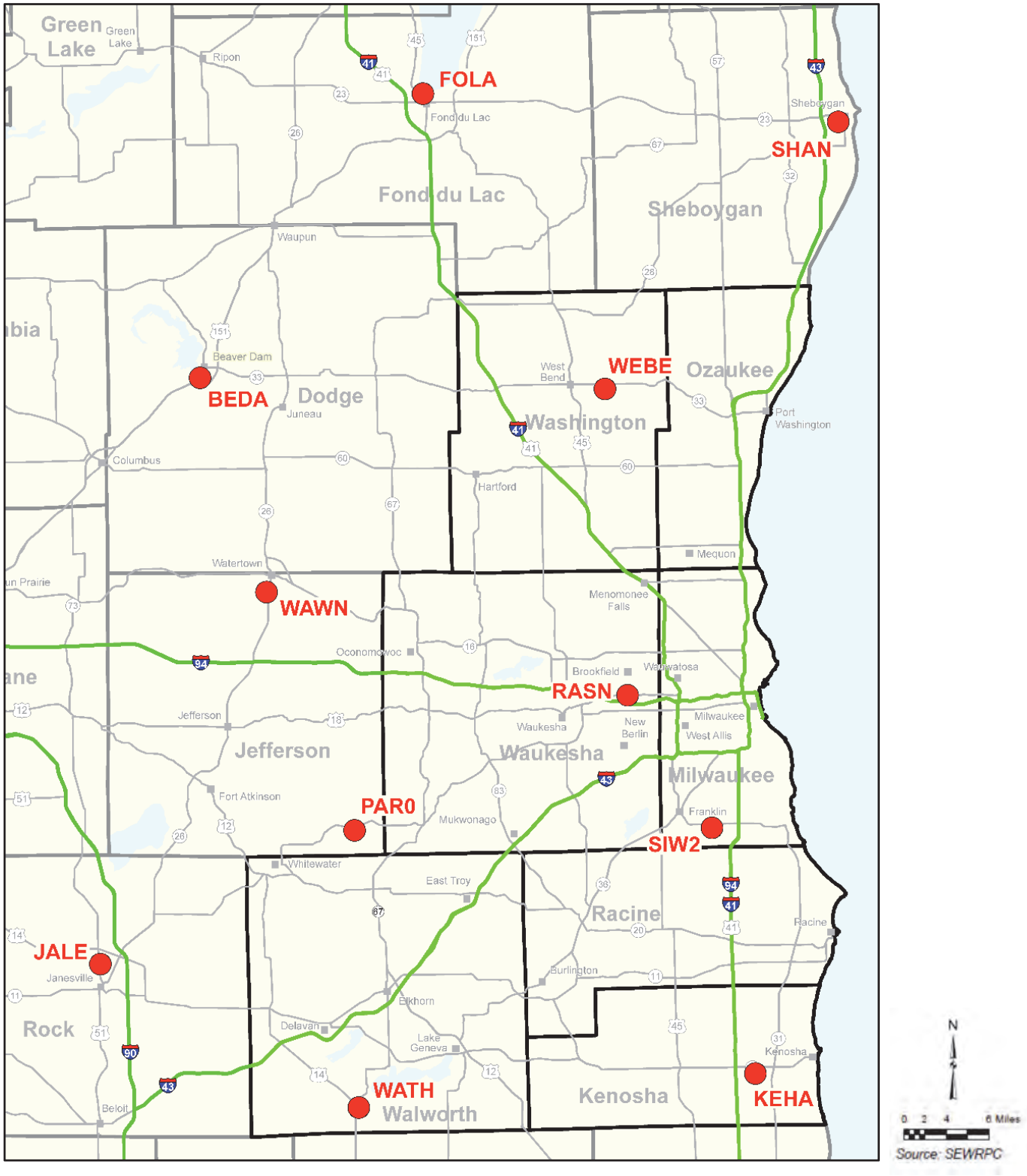
---

[1]*The term "least squares adjustment" refers to a mathematical procedure based on the theory of probability that derives the statistically most likely coordinate location of points defined by multiple measurements in a network. Moreover, a least squares adjustment defines a best-fit solution for weighed measurements finding a minimum for the sum of the squares of the measurement residuals. A measurement residual is the amount needed to correct a measurement for it to fit into the best-fit solution found by the least squares adjustment.*

[2]*For definition of VRS technology see Footnote 2, page 2, of Addendum.*

Figure 1

WISCORS STATIONS IN AND ADJACENT TO THE SOUTHEASTERN WISCONSIN REGION



The following protocol would be followed in making the necessary field observations:

1. For each of the control survey stations—USPLSS corners—to be occupied, a copy of the SEWRPC "Record of U.S. Public Land Survey Control Station" (dossier sheet) shall be obtained.

2. The dossier sheet shall be used to recover the station, and a minimum of two of the tie distances from the station to witness marks shown on the dossier sheets shall be measured to ensure that the station has not been disturbed.

3. The following potential sources of error shall be considered and adjusted for in the measurement process: positional dilution of precision (PDOP), number of satellites visible, mask angle, potential multipath, and solar activity.

4. Each observation shall have a minimum duration of 5 seconds using a 1-second epoch rate.

5. At the end of the observation, the antenna of the instrument shall be set near the ground so a complete loss of satellite lock occurs. The antenna shall then be repositioned over the monument for an additional observation.

6. A minimum of three observations shall be made at each station occupied. The second and third direct observation shall also have at a minimum a duration of 5 seconds using a 1-second epoch rate.

7. Steps 5 and 6 shall be repeated as necessary to obtain the desired minimum of three observations.

8. The Root Mean Square Error (RMSE) of the three observations shall be calculated for each coordinate component (Northing, Easting, and Elevation) at each of the stations occupied using the following equation.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}[Average_i - Check_i]^2}{N}}$$

Average$_i$ = Average position of the Northing, Easting, or Elevation at the USPLSS Corner

Check$_i$ = Northing, Easting, or Elevation value from the individual GPS observations at a USPLSS Corner

N = Number of observations at a USPLSS corner

9. The computed RMSE for the Northing, Easting, and Elevation components shall not exceed the following:

   Northing 0.06 foot
   Easting 0.06 foot
   Elevation 0.09 foot

10. Additional observations shall be performed as required to meet the maximum allowable RMSE. Any combination of observations may be used to achieve the acceptable RMSE, provided all coordinate components (Northing, Easting, and Elevation) are used in the solution.

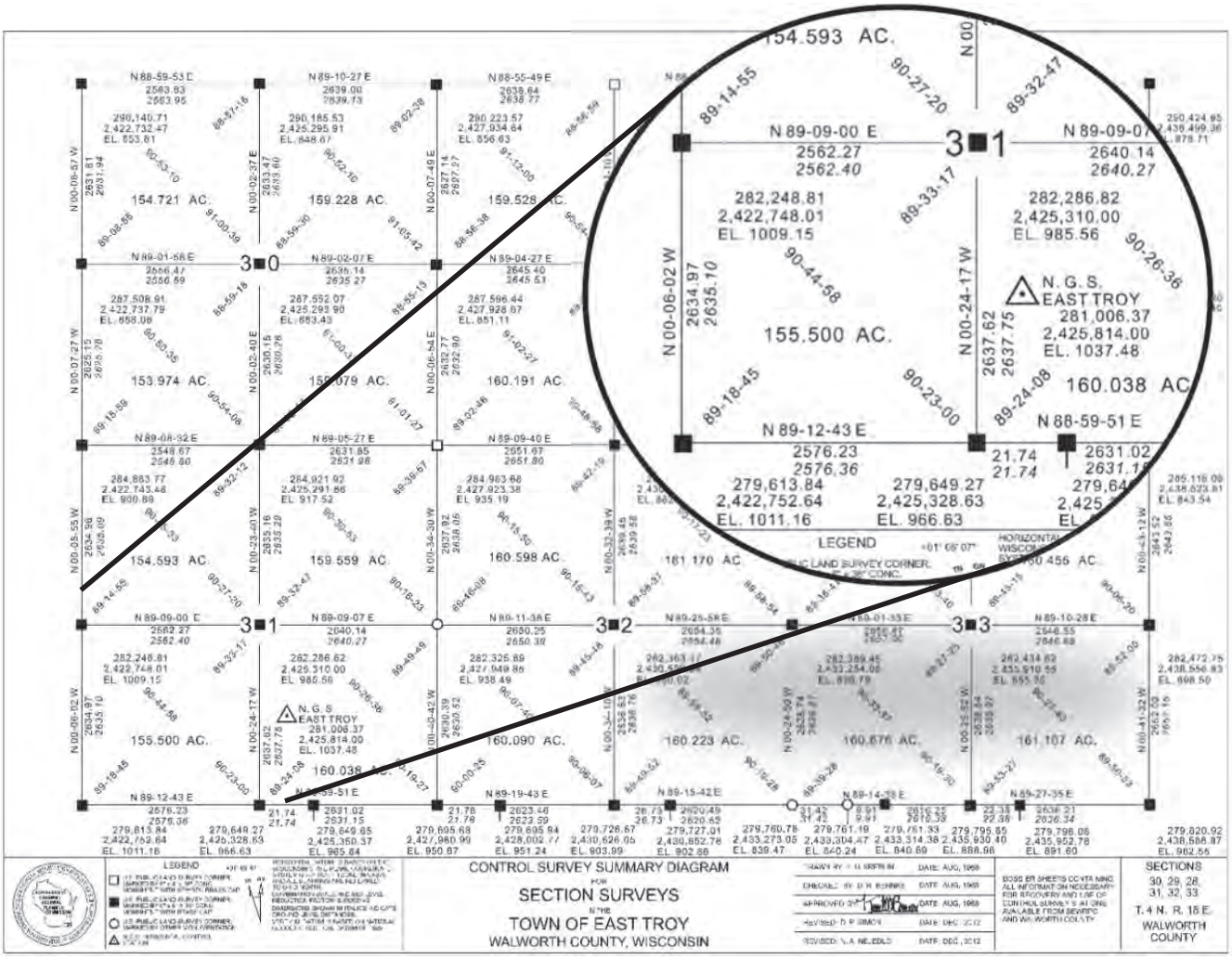
Computations

Two major computation phases are involved in the proposed horizontal datum conversion methodology. The first phase consists of the extraction of legacy system information. The second phase consists of a least squares adjustment converting the legacy positions to the new datum.

The use of legacy system information is considered the most significant feature of the proposed methodology. The use of this information will not only serve to reduce costs, but will assist in validating the control station positioning, and serve to identify any issues that might arise in the conversion process such as not achieving the desired accuracy standards in a part of the network.

Figure 2

TYPICAL SEWRPC CONTROL SURVEY SUMMARY DIAGRAM



Source: SEWRPC.

The information from the legacy system required is found on CSSD. The first and most important piece of such information consists of the published grid distance between stations – USPLSS Corners. Also required are the interior angles between quarter-section lines. The angles will be extracted so that at corners of the quarter sections the interior angles are read clockwise. Figure 2 provides an example of a CSSD, and of the information that will be extracted for use in a least squares adjustment of the network.

Using the station – corner – identification system that is described in the next section (See Figure 3), Table 1 illustrates the format of the values to be extracted from CSSD to be used in the least squares adjustments.

Once the legacy spatial measurements have been extracted from the CSSDs, the second phase of the computations—the least squares adjustment—can be carried out. The complexity entailed in the management of compilations relating a control survey network consisting of almost 12,000 stations makes a single adjustment impractical. It is therefore, proposed to break the conversion compilations into manageable segments consisting of subareas of the Region. As already noted, these areas could be as small as six square miles, or as large as a county. A survey township would constitute a particularly practical subarea. Individual adjustments would be performed working serially so adjacent subarea boundary corners can be constrained to fit from previous adjustments.

Table 1

FORMAT OF INPUT TO LEAST SQUARE ADJUSTMENT

Code (A: Angle)	Backsight – At – Foresight	Angle (Degrees – Minutes – Seconds)
A	0418144-0418169-0418168	89-18-45
A	0418145-0418144-0418169	90-44-58
A	0418168-0418145-0418144	89-33-17
A	0418169-0418168-0418145	90-23-00
A	0418145-0418168-0318012	89-24-08
Code (D: Distance)	From - To	Grid Distance (US Survey Feet)
D	0418144-0418169	2634.97
D	0418144-0418145	2562.27
D	0418169-0418168	2576.23
D	0418145-0418168	2637.62
D	0418168-0318012	21.74

Source: SEWRPC.

The first step in the least squares computation is to constrain the legacy control positions. This provides verification of the accuracy of the legacy control survey network as documented by each CSSD and the completeness of the input of the spatial measurements. After acceptance of the CSSD spatial measurements, additional CSSDs can be added to the network until the defined adjustment area has been completed.

Once the individual areas have been completed in this manner, a final step prior to incorporating the new positional data is the application of an effective weighting strategy. This is critical given the use of legacy measurements integrating with the precise GPS field observed positioning. An effective strategy will allow displacement of the differences (measurement residuals) found between the measurement types, and account for the numerous possible measurement paths between unconstrained USPLSS corners. The algorithms in a least squares adjustment provide a rigorous means for this. Tolerance and weights could change once the network design is applied to the entire subarea concerned. However, a typical half mile length, the weight assigned for the grid distance would be 0.03 foot and interior angle at 30 arc seconds. USPLSS corner positions (new datum positons) that have been observed but not constrained in the network adjustment would be assigned weights of 0.1 foot (both Northing and Easting).

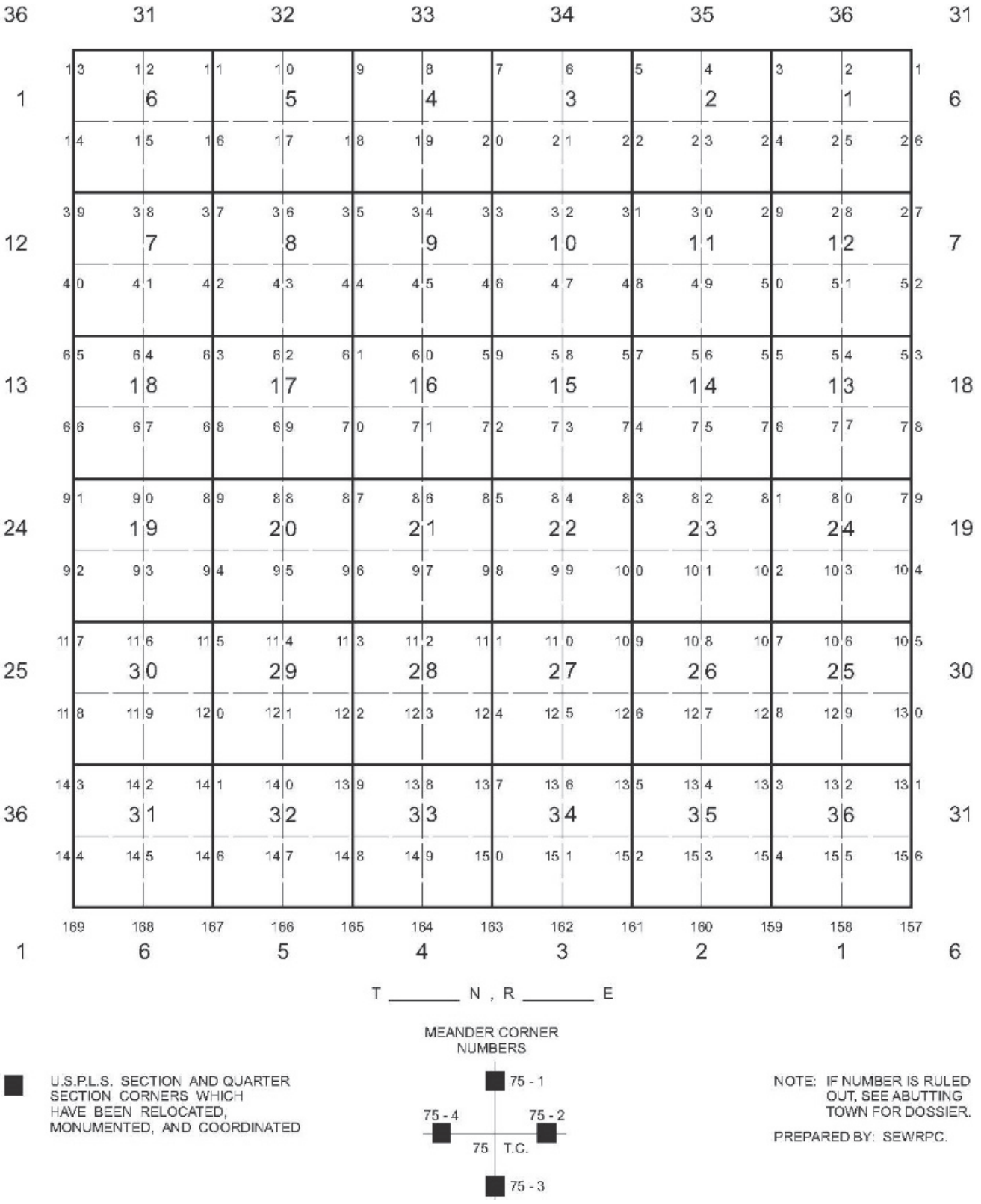
CONTROL SURVEY STATION NUMBERING

A control survey station numbering system will be required that provides a unique numeric identification for each control survey station in the network throughout the Region. This will allow stations to be used in multiple adjustments without conflict or duplication in the control networks. It is proposed to use the Commission's long-standing numbering system for this purpose. That system is illustrated in Figure 3.

Under the Commission system, the number identifying each station, while unique within each township, it is not unique for corners located along common range lines between two townships, or for common corners along township lines. The Commission system would be modified by adding a prefix to each corner number specifying the township and range. Corners along the eastern and southern boundaries of every township would be numbered

Figure 3

PROPOSED CONTROL SURVEY STATION – USPLSS CORNER – NUMBERING SYSTEM



Source: SEWRPC.

according to the normal township numbering system. However, corners along the northern and western boundaries would be numbered using the numbers of the corners in the adjacent township. This provides a unique number for every corner and eliminates the possibility of corners having two numbers as would be the case if numbered by individual township. The northern boundaries of townships containing closing corners would be numbered as followed by the Commission system aside from the added town and range prefix.

DEMONSTRATION APPLICATION OF METHODOLOGY

A demonstration application of the horizontal datum conversion methodology developed by the Commission staff was carried out in July 2015. A typical 6-square-mile area consisting of Sections 28 through 33 in Township 4 North, Range 18 East, Town of East Troy, Walworth County, was selected for the demonstration.

The legacy data for the demonstration area are shown on Figure 4. The monuments marking four corners of the area, together with the monument marking the Southwest corner of Section 29 which is near the center of the area, were occupied and the coordinate positions of these corners on NAD 83 (2011) were determined by a GPS survey. The survey was conducted in accordance with the protocol set forth in this appendix. The newly determined coordinate positions for these five corners are shown on Figure 5.

The ground level lengths of the quarter-section lines within the area, together with the interior angles of the quarter sections, were extracted from the legacy data shown on the diagram comprising Figure 4. The ground level lengths of the quarter-section lines were reduced to grid lengths using the combination elevation and scale reduction factor for the State Plane Coordinate System based upon the new datum. A least square adjustment of the network was then used to compute the State Plane Coordinates[3] of the remaining 30 stations—corners—within the area. The resulting values are shown on the diagram comprising Figure 5. The grid distances and bearings of the one-quarter section lines on the new datum were then determined by inverse computation from the new coordinate values. The grid distances were then converted to ground level distances using the combination factor for the new coordinate system. The areas of the quarter-sections were computed using the new ground level distances and bearings of the quarter-section lines. These results are also shown on the diagram comprising Figure 5.

Examination of the two diagrams comprising Figures 4 and 5 will show that the maximum change in the ground level length of the quarter-section lines between the legacy and new datums was 0.13 foot. The maximum change in the bearings of the quarter-section lines was 7 seconds of arc. The maximum change in the computed areas of the one-quarter sections was 0.011 acre.

Seven of the computed USPLSS corners were selected for an independent performance evaluation. These corners are identified on the diagram comprising the Figure 5. The monuments marking these corners were occupied and the coordinate position of these corners on the new datum determined by GPS survey. A comparison of the computed and the surveyed values is provided in Table 2. The maximum difference in the coordinate values of 0.23 foot falls well within the desired accuracy standard specified for the legacy network within the Region.

---

[3]*The NAD 83 state plane coordinate values are defined in meters. For this appendix the metric values were converted to feet using the ratio of 39.37 inches per meter exact to 12 inches per U.S. Survey Foot, which approximates 1 meter equaling 3.280833333 U.S. Survey Feet.*

Table 2

NAD83/2011 COMPUTED POSITIONS VERSUS GPS OBSERVED INDEPENDENT POSITIONS

	Computed		GPS Observed (July 23, 2015)			Delta (USFT)	
USPLSS Corner	Northing (USFT)	Easting (USFT)	Northing (USFT)	Easting (USFT)		Northing	Easting
0418123	287,734.64	2,404,333.97	287,734.73	2,404,333.98		0.09	0.01
0418150	282,482.37	2,407,019.81	282,482.60	2,407,019.82		0.23	0.01
0418167	279,705.08	2,396,443.96	279,705.12	2,396,443.88		-0.04	0.08
			GPS Observed (March 5, 2015)				
0418115	290,233.03	2,396,397.43	290,233.00	2,396,397.53		-0.03	0.10
0418116	290,194.98	2,393,758.74	290,194.87	2,393,758.84		-0.11	0.10
			GPS Observed (February 9, 2015)				
0417130	287,518.28	2,391,200.65	287,518.24	2,391,200.67		-0.04	0.02
0418131	284,893.05	2,391,206.35	284,893.08	2,391,206.29		0.03	-0.06
				Average:		0.03	0.01
				Maximum Difference:		0.23	0.10
				Minimum Difference:		-0.11	-0.08
				Standard Deviation:		0.11	0.07

Source: SEWRPC.

METHODOLOGY FOR CONVERSION OF VERTICAL CONTROL

The foregoing text deals only with the datum conversion relating to horizontal positions. As noted in the addendum to which this appendix is attached, a similar problem exists relating to the vertical control survey network within the Region. The elevation data provided by the legacy vertical control survey network are based upon the NGVD 29. The National Geodetic Survey in 1977, began a new adjustment project that became the new vertical datum, the North American Vertical Datum of 1988 (NAVD 88). As is the case for horizontal positions, no precise mathematical relationship exists between the legacy and new datums. The Commission in 1995, published SEWRPC Technical Report No. 35, *Vertical Datum Differences in Southeastern Wisconsin.* That report provided a means for converting elevations from the legacy datum to the new datum and provided an iso-hypsometric map to facilitate the conversion of orthometric heights and elevations from one datum to the other. The iso-hypsometric map provided in SEWRPC Technical Report No. 35 was based on the interpolation of datum differences computed for points located on a 10,000-foot grid using VERTCON. The validity of VERTCON was checked by using the datum differences at the 435 NGS (former U.S. Coast and Geodetic Survey) bench marks within the Region as published by NGS.

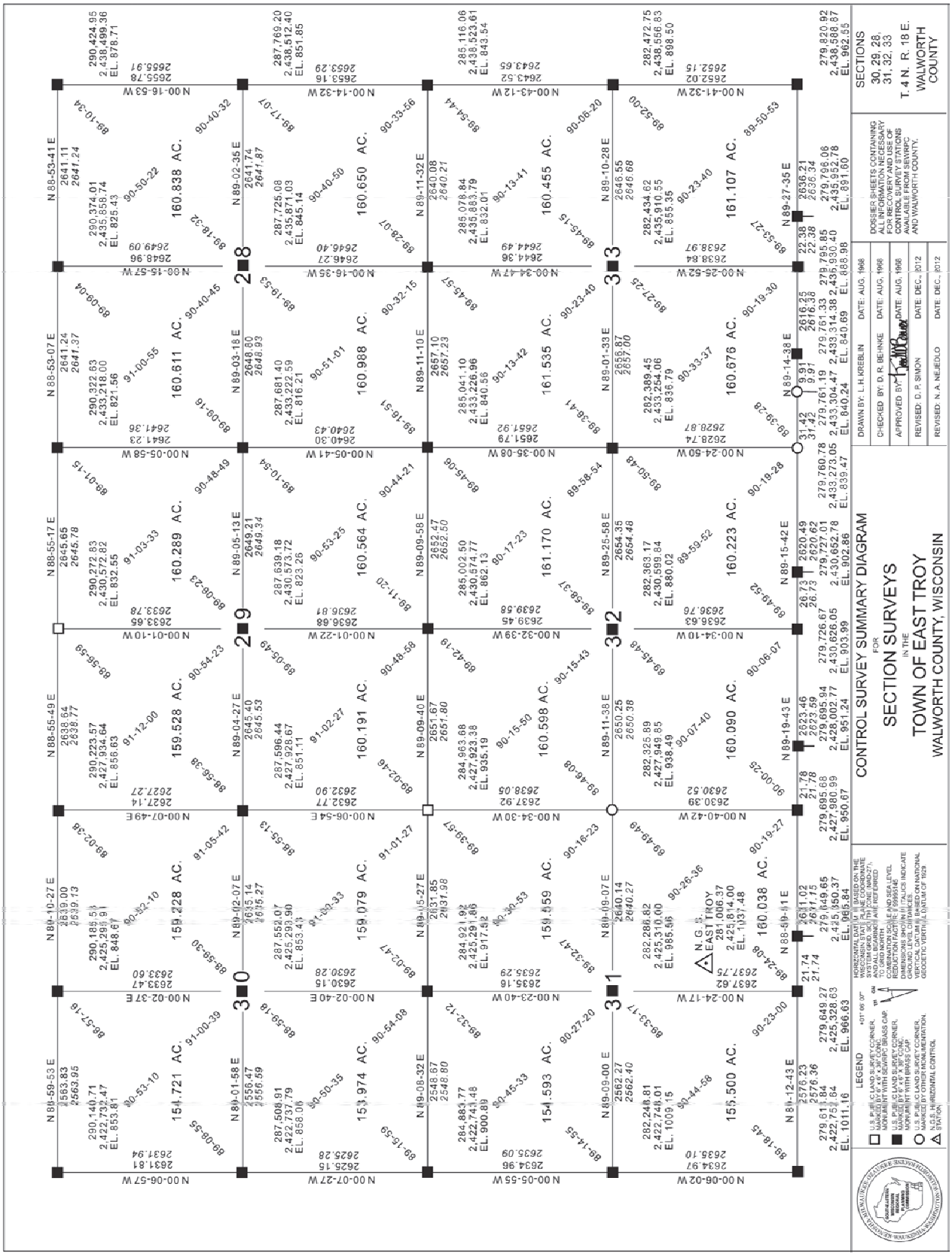
Since the completion of SEWRPC Technical Report No. 35, the Wisconsin Department of Transportation (WisDOT) in conjunction with NGS completed the Wisconsin Height Modernization Program (WI-HMP) within the Region. This program provided high-order orthometric height data on a carefully distributed network of substantial monumented bench marks. The locations of these bench marks are shown on Figure 6. The orthometric heights determined for these bench marks are referred to NAVD 88 (2012).

It is proposed to effect the conversion of elevations between the legacy and new datum by establishing accurate, measured legacy datum elevations on each of the 460 height modernization stations within the Region, thus, establishing an accurate, measured relationship between the two datums on each of the stations. The legacy datum elevations would be established by differential level surveys connecting the Commission legacy bench marks to the height modernization stations. Such transfer should involve no more than the survey of approximately one-half mile of high-order differential level lines for each transfer.

Using the accurate differences between the two datums as determined by actual differential level survey for each datum, a new iso-hypsometric map of the Region can be prepared. This map may be expected to be more accurate than the map provided in SEWRPC Technical Report No. 35. This map can then be used to transfer orthometric heights and elevations between the two datums to Second-Order, Class II accuracy standards.

Figure 4

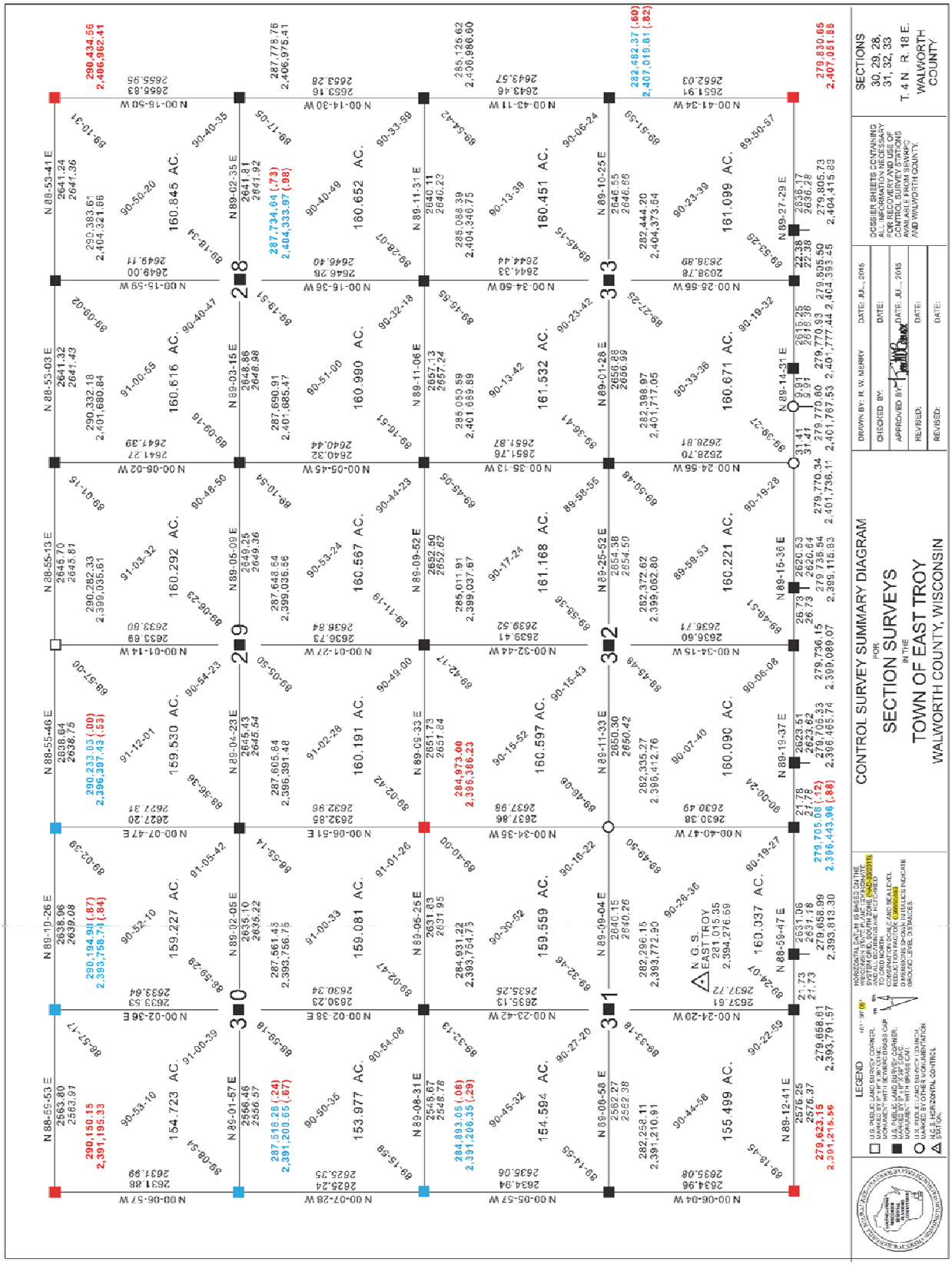
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 27



Source: SEWRPC.

Figure 5

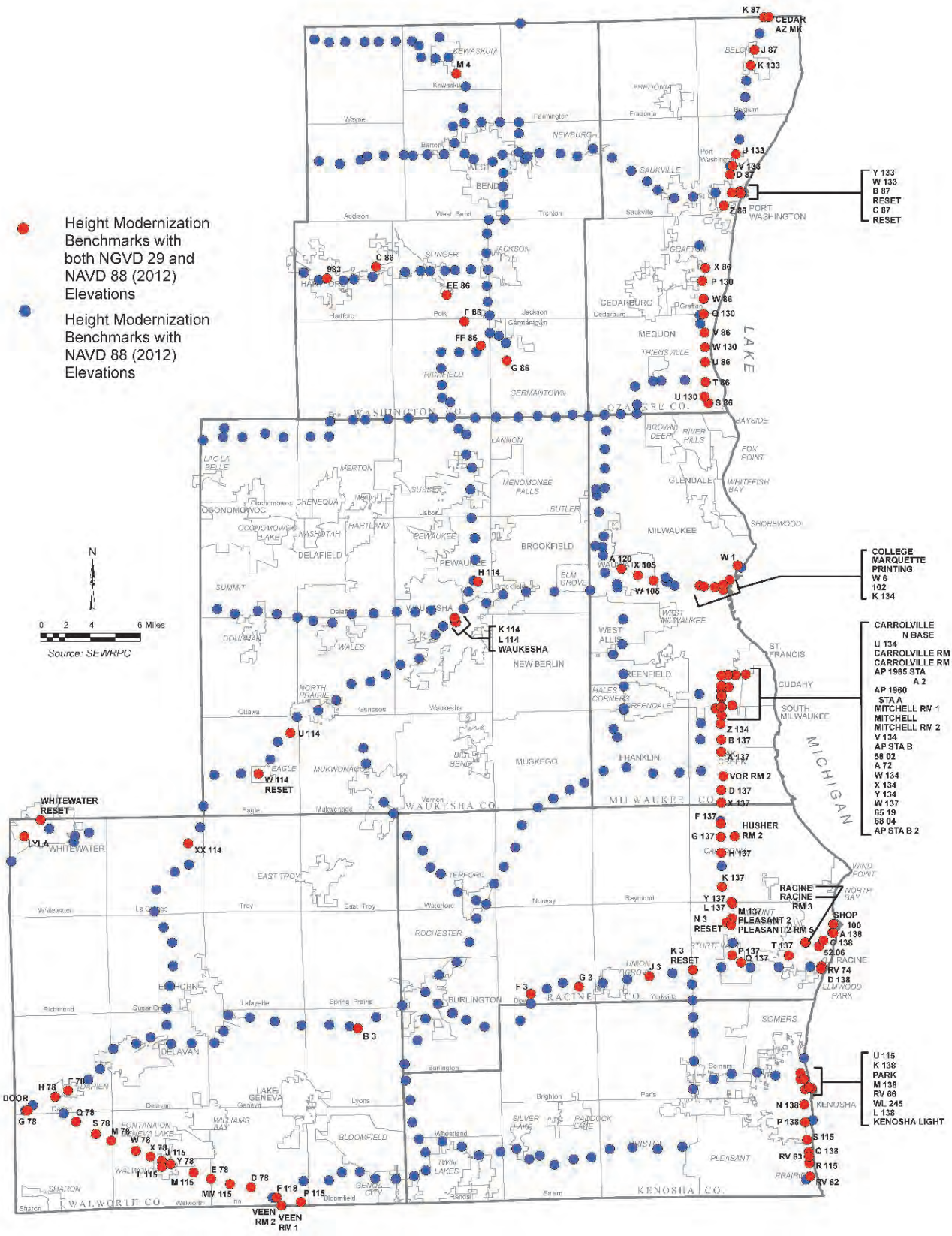
SEWRPC CONTROL SURVEY SUMMARY DIAGRAM – NAD 83 (2011)



Source: SEWRPC.

Figure 6

WISCONSIN HEIGHT MODERNIZATION BENCH MARKS WITHIN THE SOUTHEASTERN WISCONSIN REGION



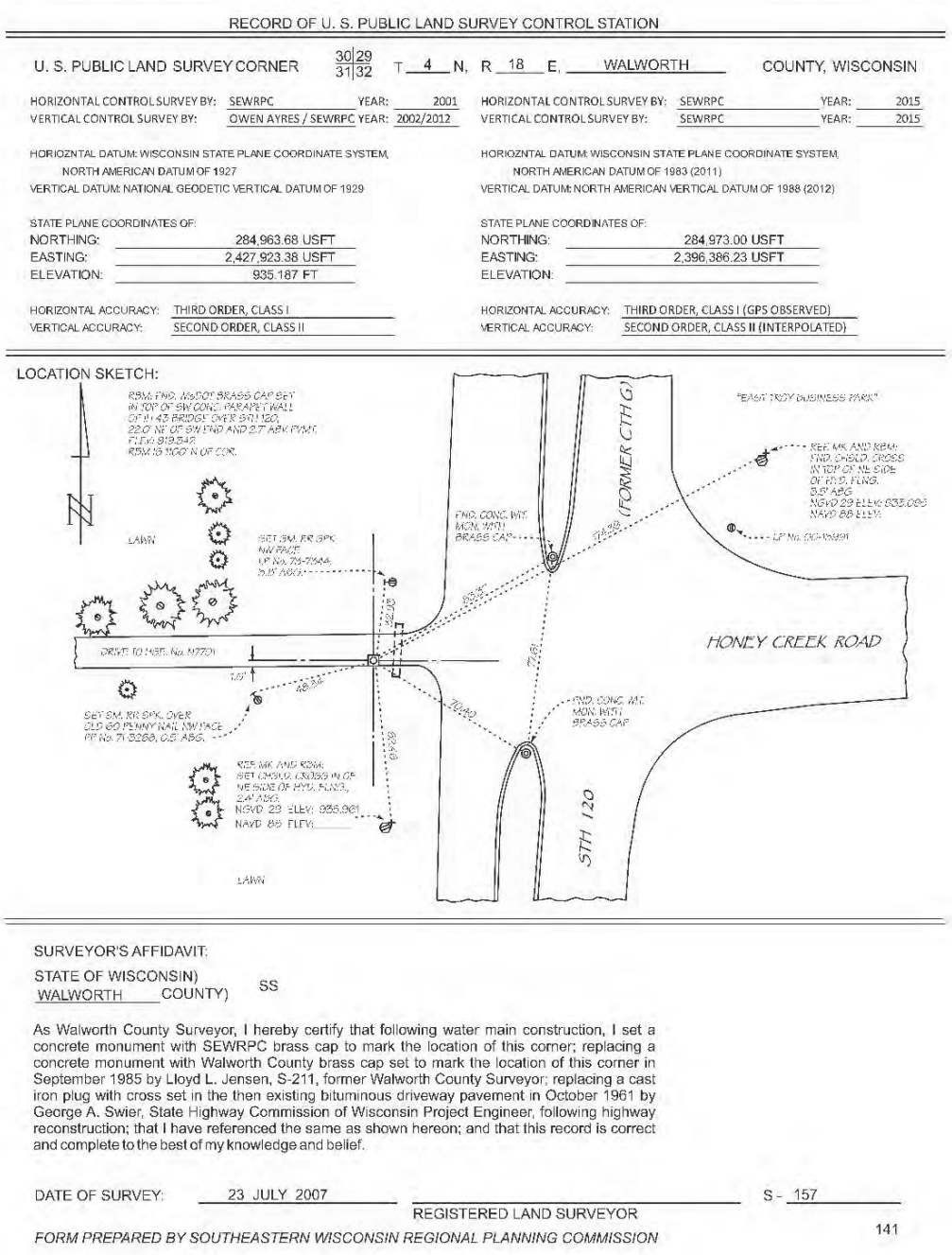
Source: SEWRPC.

REVISED "RECORD OF USPLSS CONTROL STATION" DOCUMENTS

The Commission has prepared and maintains a document known as "Record of U.S. Public Land Survey Control Station" for each of the more than 11,000 control survey stations – USPLSS corners within, and in a few cases, adjacent to the Region. These documents are commonly referred to as "dossier" sheets. As a control survey station is converted from the legacy to the new datums, a new dossier sheet will have to be provided. A revised format will be required for the dossier sheets and a proposed format is provided in Figure 7. The proposed format provides for the display of dual horizontal positions and vertical heights of the station.

Figure 7

REVISED "RECORD OF U.S. PUBLIC LAND SURVEY CONTROL STATION"



RECORD OF U. S. PUBLIC LAND SURVEY CONTROL STATION

U. S. PUBLIC LAND SURVEY CORNER 30|29 / 31|32 T 4 N, R 18 E, WALWORTH COUNTY, WISCONSIN

HORIZONTAL CONTROL SURVEY BY: SEWRPC YEAR: 2001
VERTICAL CONTROL SURVEY BY: OWEN AYRES / SEWRPC YEAR: 2002/2012

HORIOZNTAL DATUM: WISCONSIN STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1927
VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM OF 1929

STATE PLANE COORDINATES OF:
NORTHING: 284,963.68 USFT
EASTING: 2,427,923.38 USFT
ELEVATION: 935.187 FT

HORIZONTAL ACCURACY: THIRD ORDER, CLASS I
VERTICAL ACCURACY: SECOND ORDER, CLASS II

HORIZONTAL CONTROL SURVEY BY: SEWRPC YEAR: 2015
VERTICAL CONTROL SURVEY BY: SEWRPC YEAR: 2015

HORIOZNTAL DATUM: WISCONSIN STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (2011)
VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM OF 1988 (2012)

STATE PLANE COORDINATES OF:
NORTHING: 284,973.00 USFT
EASTING: 2,396,386.23 USFT
ELEVATION:

HORIZONTAL ACCURACY: THIRD ORDER, CLASS I (GPS OBSERVED)
VERTICAL ACCURACY: SECOND ORDER, CLASS II (INTERPOLATED)

LOCATION SKETCH:

SURVEYOR'S AFFIDAVIT:

STATE OF WISCONSIN) SS
WALWORTH COUNTY)

As Walworth County Surveyor, I hereby certify that following water main construction, I set a concrete monument with SEWRPC brass cap to mark the location of this corner; replacing a concrete monument with Walworth County brass cap set to mark the location of this corner in September 1985 by Lloyd L. Jensen, S-211, former Walworth County Surveyor; replacing a cast iron plug with cross set in the then existing bituminous driveway pavement in October 1961 by George A. Swier, State Highway Commission of Wisconsin Project Engineer, following highway reconstruction; that I have referenced the same as shown hereon; and that this record is correct and complete to the best of my knowledge and belief.

DATE OF SURVEY: 23 JULY 2007 _____ S - 157
REGISTERED LAND SURVEYOR

FORM PREPARED BY SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

141

Source: SEWRPC.

COSTS

The costs of the various major work elements involved in datum conversion were estimated separately for the horizontal and vertical components of the work entailed. The costs were developed by analyzing the major work elements of each of the two conversions.

For the horizontal datum conversion, six major work elements were considered:

1. The extraction of the data required from the legacy control survey network. These data include the location and monumentation of existing control survey stations—USPLSS corners; the lengths of the quarter-section lines; the interior angles of the quarter-sections; and attendant combination scale and sea level reduction factors.
2. The necessary field observations including the recovery of a set of carefully located and distributed legacy control survey stations and the conduct of the GPS observations on these stations as required to determine the coordinates of the stations concerned referred to NAD 83 (2011).
3. The determination of the coordinate positions of all of the other stations in the network concerned utilizing the data extracted from the legacy network.
4. Selection of an approximately 10 percent sample of the stations having computed coordinates for occupation and GPS survey to check the coordinate values of the selected stations.
5. Preparation of new "Record of U.S. Public Land Survey Control Station" document—dossier sheet—for each of the control survey stations concerned.
6. Preparation and publication of a project completion report.

For each of these major work elements, estimates were made of the direct and indirect labor costs, of the associated overhead costs, and an allowance for contingencies. These costs are set forth in Table 3. The costs of such items as mileage, equipment, and report preparation would need to estimated on a job-by-job basis, assuming that the Commission performs the work entailed. Estimates were made of the cost of implementation of the horizontal datum conversion for the seven-county Region as a whole; and for implementation by subarea—namely by survey township. These costs are presented in Tables 3 through 5. In any consideration of these costs estimates, it should be recognized that precise estimates, of the costs of completion of the work by a specific county, or by specific subarea, are possible only on the basis of a more detailed study design for the conduct of the work by the area concerned. Consequently, the costs of the work elements set forth in the Tables 3 through 5 must be considered tentative and changes in the allocation of costs to work elements must be expected as the work proceeds. It should be noted that if the datum conversion is implemented by subarea, the cost of completing a larger area, such as a county or the Region, as a whole, will be somewhat higher.

The costs of the work would have to be borne by those individual county land information systems that desire the horizontal datum conversion to be completed. Work could be accomplished for the county as a whole or by subareas, particularly survey townships. The estimated cost by county is provided in Table 4 and by typical township in Table 5.

For the vertical datum conversion, four major work elements were considered:

1. The high-order differential level circuits required to determine accurate elevations referred to NGVD 29 for each of the 460 Height Modernization stations within the Region. The total length of the level lines was estimated at approximately 250 miles.
2. The computation of the surveyed vertical datum differences at each of the 460 height modernization stations.
3. Preparation of a new iso-hypsometric map of the Region by interpolation of the datum differences found at the 460 height modernization stations.
4. Preparation and publication of a project completion report.

Table 3

COST ESTIMATE – HORIZONTAL DATUM CONVERSION - SEVEN COUNTY REGION

Description	Cost
Extraction of Legacy Measurements	$49,600
Field Observations	
• Labor	179,520
Contingency for Additional Field Observations and Time for Inclusion into Least-Squares Adjustments	19,680
Determination of Coordinate Positioning using selected NAD83/2011 field observation and extracted legacy measurements	33,000
Preparation of new "Record of U.S. Public Land Survey Control Station" documents and Control Survey Summary Diagrams	118,400
Total	$400,200[a]

[a]*Vehicle mileage and equipment costs must be estimated on a job-by-job basis; therefore, no line items are included for these costs in the table.*

Source: SEWRPC.

Table 4

COST ESTIMATE – HORIZONTAL DATUM CONVERSION – INDIVIDUAL COUNTY

Description	Cost						
	Kenosha County	Milwaukee County	Ozaukee County	Racine County	Walworth County	Washington County	Waukesha County
Extraction of Legacy Measurements	$5,080	$4,400	$4,400	$6,360	$10,520	$7,960	$10,880
Field Observations • Labor	18,240	16,200	15,960	23,040	38,400	28,800	38,880
Contingency for Additional Field Observations and Time for Inclusion into Least-Squares Adjustments	1,920	1,500	1,800	2,520	3,840	3,240	4,860
Determination of Coordinate Positioning using selected NAD83/2011 field observation and extracted legacy measurements	3,520	2,640	3,520	4,400	7,040	4,400	7,480
Preparation of new "Record of U.S. Public Land Survey Control Station" documents and Control Survey Summary Diagrams	12,136	10,656	10,360	14,800	25,456	19,240	25,752
Individual County Total	$40,896 [a]	$35,396 [a]	$36,040 [a]	$51,120 [a]	$85,256 [a]	$63,640 [a]	$87,852 [a]

[a]*Vehicle mileage and equipment costs must be estimated on a job-by-job basis; therefore, no line items are included for these costs in the table.*

Source: SEWRPC.

For each of these major work elements, estimates of the costs were made in the same manner as for the horizontal datum conversion work.

As a practical matter, the work entailed in vertical datum conversion should be completed for the Region as a whole. These costs are presented in Table 6. The costs of the work would have to be borne by the individual county land information systems. The costs could be distributed among the counties on the basis of any system agreed to by the seven-county land information systems. One such possible system would utilize the proportional area that each county comprises of the Region. The application of this system is illustrated in Table 7.

Table 5

COST ESTIMATE - HORIZONTAL DATUM CONVERSION - TYPICAL TOWNSHIP

Description	Cost
Extraction of Legacy Measurements	$ 960
Field Observations • Labor	3,600
Contingency for Additional Field Observations and Time for Inclusion into Least-Squares Adjustments	720
Determination of Coordinate Positioning using selected NAD83/2011 field observation and extracted legacy measurements	880
Preparation of new "Record of U.S. Public Land Survey Control Station" documents and Control Survey Summary Diagrams	1,480
Total	$7,640[a]

[a]*Vehicle mileage and equipment costs must be estimated on a job-by-job basis; therefore, no line items are included for these costs in the table.*

Source: SEWRPC.

Table 6

COST ESTIMATE – VERTICAL DATUM CONVERSION - SEVEN COUNTY REGION

Description	Cost Breakdown
High Order Differential Level Circuits to Determine Accurate NGVD 29 Elevations on 460 Height Modernization Bench Marks within Region	$177,408
Compilation and Computations Supporting the Vertical Differences of the Height Modernization Bench Marks	26,400
Preparation of new Iso-Hypsometric Map	8,800
Preparation and Publication of Project Completion Report	13,200
Preparation of new "Record of U.S. Public Land Survey Control Station" documents and Control Survey Summary Diagrams	76,960
Total	$302,768

Source: SEWRPC.

Table 7

COST ESTIMATE - VERTICAL DATUM CONVERSION - INDIVIDUAL COUNTY

Description	Percent of Regional Area	Cost
Kenosha County	10.3	$31,185
Milwaukee County	9.0	27,249
Ozaukee County	8.8	26,644
Racine County	12.7	38,452
Walworth County	21.4	64,792
Washington County	16.2	49,048
Waukesha County	21.6	65,398
Total	100.0	$302,768

Source: SEWRPC.