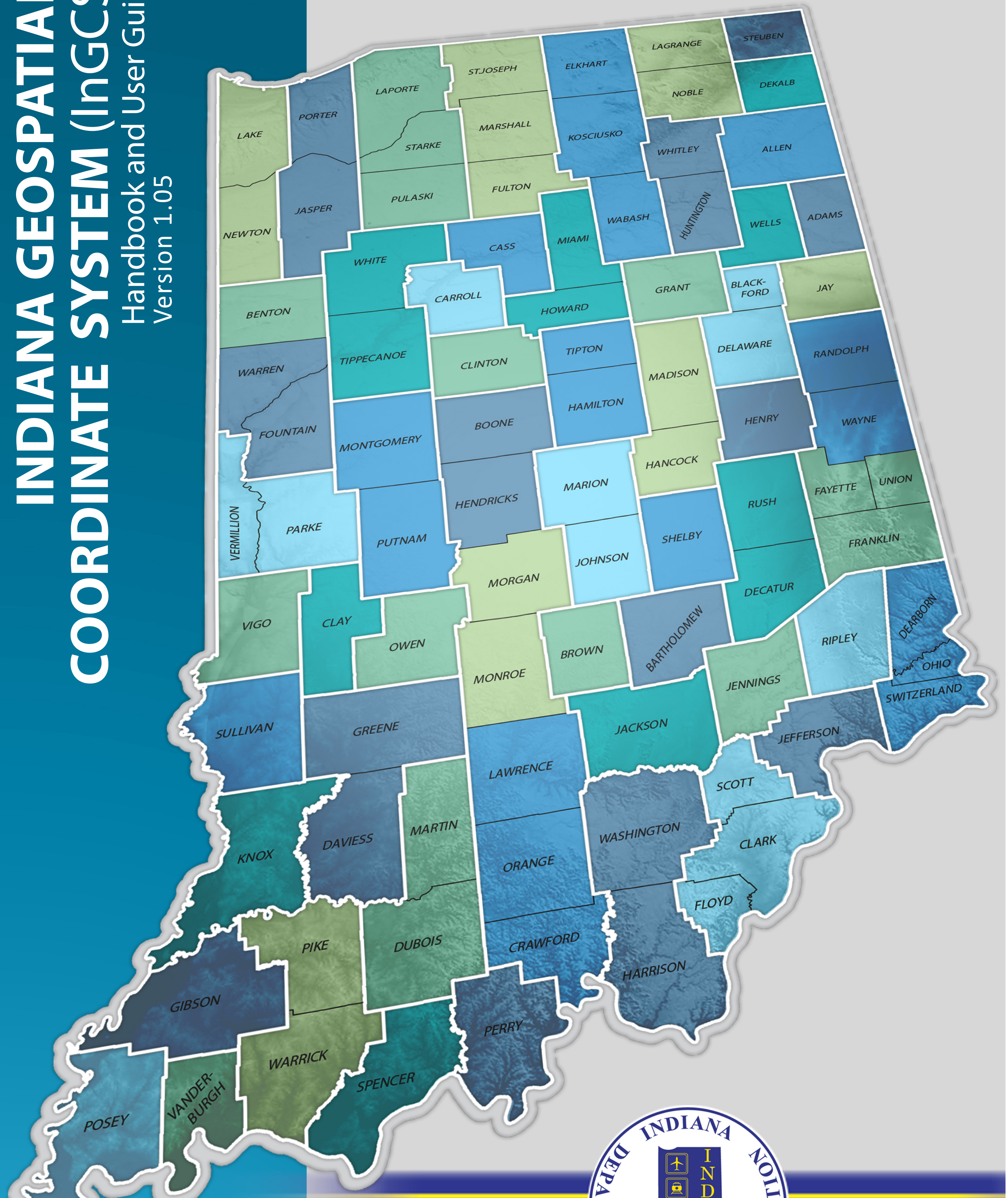
# INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)

Handbook and User Guide

Version 1.05




INDIANA DEPARTMENT OF TRANSPORTATION

INDOT

# Indiana
# Geospatial Coordinate System

Version 1.05

**Indiana Department of Transportation / Land & Aerial Survey Office – Indianapolis, IN**

## About the INDOT Land & Aerial Survey Office

The Land and Aerial Survey Office (LASO) has the primary role within the Construction Management & District Support of providing support for the design, planning, construction, maintenance and operation of a superior transportation system enhancing safety, mobility and economic growth for the state of Indiana. LASO is committed in its support of INDOT central and district offices, as well as contracted consultants, in delivering quality, environmentally sensitive transportation projects as efficiently as possible, on scope, on schedule and on budget.

LASO is comprised of two primary functional areas: the Land Surveying Section and the Aerial Survey Section. Together, they work as a team to provide high quality aerial imaging products and ground survey support. In addition to the two functional areas, LASO is also responsible for the maintenance and administration of the Indiana Statewide GNSS-GPS Real Time Network, known as the InCORS Network.

Our office is located in the Materials and Tests Division Building on the East side of Indianapolis, one block south of the intersection of Shortridge Rd. and Washington St. (US40).

## Disclaimer

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While every possible effort has been made to ensure the accuracy of information contained in this Handbook and User Guide, INDOT assumes no responsibilities for any damages or other liability whatsoever (including any consequential damages) resulting from your selection or use of the contents provided in this Handbook and User Guide.

## Abstract

This document contains the history, development, best practice methods, and technical creation of a new coordinate reference system for the state of Indiana. The Indiana Geospatial Coordinate System (InGCS) is based on a series of "low distortion" map projection zones whose parameters have been defined so that linear distortion is negligible within each zone. Distances computed between points in the grid coordinate system will nearly equal the actual horizontal distance between the same points on the ground. The InGCS has been designed such that it can be readily used with a wide variety of software platforms for surveying, engineering, GIS, construction, cartographic mapping applications, agriculture, emergency medical, etc. It is important to realize that rectangular grid coordinates for all of the InGCS zones may be calculated with formulas through computer programs that would have seemed too complicated in the past, but now may be considered routine. These same computer programs also make it a relatively simple procedure to perform transformations, that is, to change the coordinates of points from one coordinate system to another. While having numerous coordinate system zones for the state of Indiana may seem cumbersome, actual user application through highly precise GNSS and ground measurement devices provide for a level of mapping accuracy that is beneficial to all geospatial professionals.

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## Acknowledgements

*General Content:* The backbone and general format of this *Indiana Geospatial Coordinate System-Handbook and User Guide* is a product of the compilation of contents found within the following documents:

1. The Iowa Department of Transportation's *Iowa Regional Coordinate System Handbook and User Guide* Version 2.10 2014 (Dennis et al. 2014)
2. The Oregon Department of Transportation's *Oregon Coordinate Reference System Handbook and User Guide* Version 2.01 2014 (Armstrong et al. 2014)
3. The Wisconsin State Cartographer's Office's (SCO) *Wisconsin Coordinate Reference Systems* 2nd Edition 2015 (Wisconsin SCO 2015).

Additional information and graphics were retrieved from the National Geodetic Survey's website and Michael Dennis-Geodetic Analysis, LLC. Great thanks is extended to all those who contributed to the writings and preparation of these sources. The remaining portions of this document were derived from the sources cited, the Lead Author, and various graphics created and/or edited by Michael Howery, Dawn Hoesli, and Daniel Townsend of Lochmueller Group.

*Matt Badger:* I would like to thank my family, friends, peers, Lochmueller Group, John Ellingson-NGS, Michael Dennis-Geodetic Analysis, LLC., and the many others who provided their support, encouragement, and advice in this endeavor, beginning with the development of the I-69 "Evansville to Indianapolis" low distortion projections. I would also like to express my gratitude to the IGIC/ISPLS Geodetic Control Workgroup, the Indiana Department of Transportation, and the Federal Highway Administration for their support, involvement, and sponsorship of the InGCS. A sincere thanks also goes out to Seiler Instrument and Manufacturing Company, Inc. for providing several survey-grade GNSS units for Quality Control testing purposes prior to the approval and adoption of the InGCS by INDOT, and also to Dr. Zane Mitchell-Chairman, Engineering Department and Miles Mann-Physical Plant Assistant Director of the University of Southern Indiana for allowing the installation and construction of the CORS and passive station marks at USI's campus that are noted and discussed in this document. Thanks and recognition goes out to those persons at the many organizations and software vendors that offered their technical advice, recommendations, and for including the InGCS in their respective datasets and platforms, particularly Roger Lott-*European Petroleum Survey Group (EPSG)*, Melita Kennedy-*ESRI*, Sam Knight-*Blue Marble Geographics*, Joe Blecha-*Trimble Navigation*, Craig Williams-*Leica Geosystems*, David Carlson-*Carlson Software*, Brian Sloman-*MicroSurvey*, Jason Hooten-*Topcon*, Gary Crawford-*Autodesk, Inc.*, and Keith Raymond-*Bentley*. Thanks and recognition is also extended to Glen Schaefer, PE, PLS,-WisDOT (retired) and WisDOT for their recommendations and considerations when using the InGCS for a project in multiple coordinate zones. The InGCS itself along with this Handbook and User Guide would simply *not* be a reality were it not for the collective effort and backing of all. It is and always has been my hope that the InGCS be a valuable mechanism for creating a seamless workflow between land surveying, civil engineering, GIS, construction, precision agriculture, and other geospatial industries and their practitioners within Indiana and its neighboring states.

## Consultant & Subconsultant

**Lead Author**
Matthew G. Badger, PS
Survey Project Manager, LDP Developer
Lochmueller Group (Consultant)
Adjunct Instructor, Engineering Department
University of Southern Indiana

**Quality Control/Quality Assurance**
Matthew Healy, PS, EIT
Survey Project Manager
V.S. Engineering (Subconsultant)

## Technical Development Team

Eric N. Banschbach, PS
Manager, Land & Aerial Survey Office
Indiana Department of Transportation (INDOT)

Andrew “Dee” Baxter, PS
Survey Section Coordinator/InCORS Network Administrator
Indiana Department of Transportation (INDOT)

Joel Bump
Enterprise Data Manager-Management Information Systems Division
Indiana Department of Transportation (INDOT)

James “Chip” Campbell II, CP
Lead/Certified Photogrammetrist
Indiana Department of Transportation (INDOT)

Bryan F. Catlin, PS
Technical Supervisor
Marion County Surveyor’s Office
& Indiana Geographic Information Council (IGIC)

Derek Fuller, PS
GIS Analyst
Indiana Department of Transportation (INDOT)

David Gaston, PS
Hendricks County Surveyor
Indiana County Surveyor’s Association

John Kurtz, PS
R/W Engineering, Southeast District
Indiana Department of Transportation (INDOT)

## Technical Development Team (Continued)

Terry Livingston, PS
Survey Operations Manager, Southwest District
Indiana Department of Transportation (INDOT)

Mark McMahan, PS
Data Integration Coordinator
Indiana Department of Transportation (INDOT)

Don Mohid
Land & Aerial Survey Office
Indiana Department of Transportation (INDOT)

Ryan C. Swingley, PS
ESP Associates, P.A.
& Indiana Society of Professional Land Surveyors (ISPLS)

Philip S. Worrall
Executive Director
Indiana Geographic Information Council (IGIC)

## Additional Review

Michael L. Dennis, PE, RLS
Geodetic Analysis, LLC & National Geodetic Survey

## Living Document

This InGCS Handbook and User Guide is intended to be a "living document" and will be updated as new information becomes available.

The InGCS was created with public funds along with volunteer effort for the benefit of land surveying, civil engineering, GIS, construction, precision agriculture, and other industries within Indiana's geospatial community. Indiana is now one of several states that have created new coordinate reference systems based on "low distortion" map projections.

## Contact Information for Revision to Document

If there are topics that should be added, covered in more depth, clarified, modified, corrected, or revised to incorporate specific workflows, please contact:

Eric N. Banschbach, P.S.
Manager of the Land & Aerial Survey Office
Indiana Department of Transportation
120 South Shortridge Road
Indianapolis, Indiana 46219-6705

EBanschbach@indot.IN.gov
(317) 610-7251
www.in.gov/indot/2715.htm
www.in.gov/indot/InGCS.htm

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# List of Abbreviations

| | |
|---|---|
| ACSM | American Congress on Surveying and Mapping |
| ALTA | American Land Title Association |
| ANTCAL | Antenna Calibration |
| ARP | Antenna Reference Point |
| CAD | Computer-Aided Design |
| CADD | Computer-Aided Design and Drafting |
| CBL | Calibration Base Line |
| CM | Central Meridian |
| CONUS | Conterminous United States |
| CORS | Continuously Operating Reference Stations |
| CP | Certified Photogrammetrist |
| CPC | Central Processing Centers |
| CTRS | Conventional Terrestrial Reference System |
| DB | Data Base |
| DGFI | Deutsches Geodätisches Forschungsinstitut (German Geodetic Research Institute) |
| DORIS | Doppler Orbitography and Radiopositioning Integrated by Satellite |
| DOT | Department of Transportation |
| DSDATA | Digital Survey Data |
| DTM | Digital Terrain Model |
| ECEF | Earth Centered, Earth Fixed |
| EDM | Electronic Distance Measurement |
| EDMI | Electronic Distances Measuring Instrument |
| EIT | Engineer-in-Training |
| EOP | Earth Orientation Parameters |
| EPSG | European Petroleum Survey Group |
| ESRI | Environmental Systems Research Institute |
| FAA | Federal Aviation Administration |
| FDM | Facilities Development Manual (Wisconsin Department of Transportation) |
| FEMA | Federal Emergency Management Agency |
| GIS | Geographic Information System |
| GLO | General Land Office |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GR | General Recommendation |
| GRAV-D | Gravity for the Redefinition of the American Vertical Datum |
| GRS 80 | Geodetic Reference System 1980 |
| HARN | High Accuracy Reference Network |
| HPGN | High Precision Geodetic Network |
| HTDP | Horizontal Time-Dependent Positioning |
| IAC | Indiana Administrative Code |
| IC | Indiana Code |
| ICRS | International Celestial Reference System |
| IDB | Integrated Data Base |
| IERS | International Earth Rotation and Reference Systems Service |
| IGIC | Indiana Geographic Information Council |

| | |
|---|---|
| IGLD | International Great Lakes Datum |
| IGN | Institut Géographique National (National Geographic Institute (French)) |
| IGS | International GNSS Service |
| INDOT | Indiana Department of Transportation |
| INGCS | Indiana Geospatial Coordinate System |
| IOGP | International Association of Oil and Gas Producers |
| ISPLS | Indiana Society of Profession Land Surveyors |
| ITRF | International Terrestrial Reference Frame |
| ITRS | International Terrestrial Reference System |
| IUGG | International Union of Geodesy and Geophysics |
| LASO | (INDOT) Land and Aerial Survey Office |
| LCC | Lambert Conformal Conic (Projection) |
| LCRS | Location Control Route Survey |
| LDP | Low Distortion Projection |
| LIDAR | Light Detection and Ranging |
| LLR | Lunar Laser Ranging |
| LS | Land Surveyor |
| MSPCS | Modified State Plane Coordinate System |
| NAD | North American Datum |
| NATO | North Atlantic Treaty Organization |
| NAVD | North American Vertical Datum |
| NED | National Elevation Dataset |
| NGA | National Geospatial Intelligence Agency |
| NGD | New Geometric Datum |
| NGS | National Geodetic Survey |
| NGSIDB | National Geodetic Survey's Integrated Data Base |
| NGVD | National Geodetic Vertical Datum |
| NOAA | National Oceanic and Atmospheric Administration |
| NOS | National Ocean Service |
| NRP | North Reference Point |
| NSRS | National Spatial Reference System |
| OCRS | Oregon Coordinate Reference System |
| OM | Oblique Mercator (Projection) |
| OPUS | Online Positioning User Service |
| PDF | Portable Document Format |
| PE | Professional Engineer |
| PID | Permanent Identifier |
| PLS | Professional Land Surveyor |
| PLSS | Public Land Survey System |
| PPM | Parts Per Million |
| PS | Professional Surveyor |
| QA | Quality Assurance |
| QC | Quality Control |
| RC | Recalculated |
| RG | Geometric Mean Radius of Curvature |
| RLS | Registered Land Surveyor |
| RM | Reference Mark |
| RP | Reprojected, or Radius Point |

| | |
|---|---|
| RSO | Rectified Skew Orthomorphic (Projection) |
| RT | Real Time |
| RTK | Real Time Kinematic |
| RTN | Real Time Network |
| SBAS | Satellite-Based Augmentation System |
| SCO | (Wisconsin) State Cartographer's Office |
| SLR | Satellite Laser Ranging |
| SPCS | State Plane Coordinate System |
| SV | Satellite Vehicle |
| TBC | Trimble Business Center |
| TM | Transverse Mercator (Projection) |
| UAS | Unmanned Aircraft Systems |
| URL | Uniform Source Locator |
| USACE | United States Army Corps of Engineers |
| USGS | United States Geological Survey |
| UTC | Coordinated Universal Time |
| UTM | Universal Transverse Mercator (Coordinate System) |
| VLBI | Very Long Baseline Interferometry |
| VRS | Virtual Reference Station |
| WAAS | Wide Area Augmentation System |
| WGS | World Geodetic System |

# Chapter 1 Introduction

## 1.1 Background

The explosion in the use of geospatial technologies – in particular, Global Navigation Satellite System (GNSS)(umbrella term for the collection of multiple countries' satellite positioning systems), imaging systems, and Geographic Information Systems (GIS) – have made a sound understanding of spatial reference systems critical to successful use of these technologies.

Thanks to advances in the usability and sophistication of many common GIS and computer mapping programs, coordinate reference systems and coordinate values can be stored, computed, and transformed with relative ease. But, without an understanding of basic concepts, system designs, and limitations, erroneous data can easily result.

This Handbook and User Guide describes coordinate reference systems commonly used in the state of Indiana, the rationale behind these systems, the parameters used to define them, and data conversion and transformation among systems. The remainder of this Section summarizes the fundamentals required to understand more complex concepts described later.

*(Wisconsin SCO 2015)*

## 1.2 Map Projections and Coordinate Reference Systems

Geographic coordinates (latitude and longitude) are perhaps the best known method for describing a horizontal position on the surface of the Earth. Latitude and longitude are expressed in angular units, typically degrees, minutes, and seconds (e.g., 90° 45' 15'') or decimal degrees (e.g., 90.7541667°).

Measurements, computations, and computer applications are more difficult to manage using angular units; thus, latitude and longitude values are commonly converted to a rectangular coordinate system of "northings" (Y-axis) and "eastings" (X-axis) that can be expressed and easily understood in linear units such as meters or feet.

Converting a position from geographic to rectangular coordinate values requires the point to be projected from an ellipsoid (a mathematical representation of the Earth) to a "developable" map projection that can be made into a flat surface.

The Earth's quasi-spherical surface cannot be transformed to a flat map without creating significant distortions. Distortion is unavoidable. Distortion can affect shape, area, scale (distance), or direction depending upon the projection used. Many unique map projections exist, each intended to minimize a particular distortion. The conic projection and cylindrical projection are examples. However, no single projection can give an exact representation of the surface of the Earth.

The two most common projections used as reference surfaces for rectangular coordinate systems are the Lambert conformal conic (Figure 1.2-1) and the transverse Mercator (Figure 1.2-2).

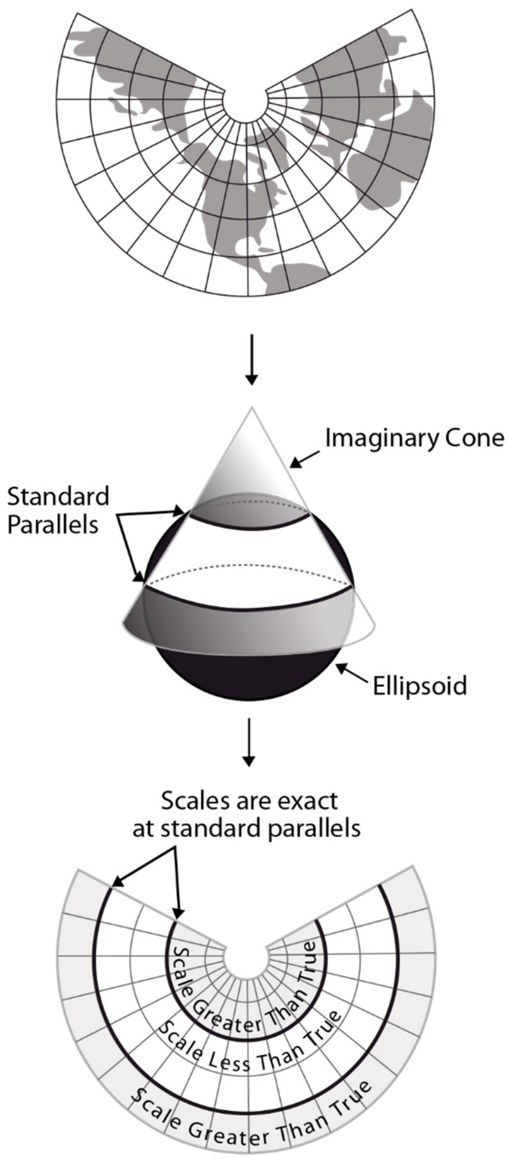



***Figure 1.2-1:*** *Lambert conformal conic projection.*

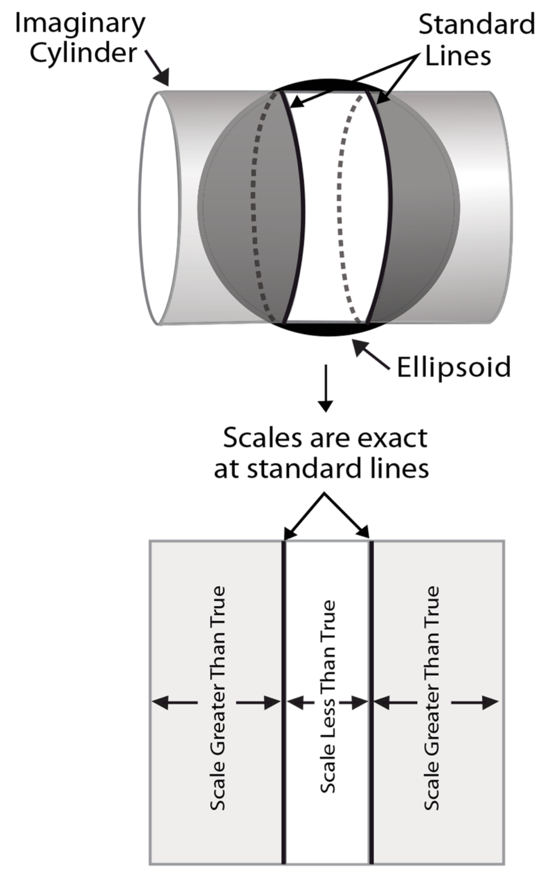



***Figure 1.2-2:*** *Transverse Mercator projection.*

*(Images courtesy of Wisconsin SCO.)*

These projections are designed to have varying scale, but retain the correct shape of the mapped area. Scale variation is greatest in north-south directions for Lambert conformal conic projections, and in east-west directions for transverse Mercator projections. For these reasons, Lambert conformal conic projections are typically used for geographic areas having larger east-west extents, while transverse Mercator projections are used for areas with larger north-south extents.

*(Wisconsin SCO 2015)*

## 1.3 Principles of Rectangular Coordinate Reference Systems

By itself, a map projection simply defines how the ellipsoid model of the Earth is transformed to a flat surface. By comparison, a rectangular coordinate reference system is defined by three elements:

1. A geodetic datum (and any adjustments to that datum)
2. Map projection referenced to the specified datum by a point of origin and orientation
3. Unit of measurement

Note that a map projection makes up only one part of the definition of a rectangular coordinate reference system. Also, a coordinate reference system may use more than one map projection. The State Plane Coordinate System, for example, uses both the transverse Mercator and Lambert conformal conic projections in the 48 conterminous states.

*(Wisconsin SCO 2015)*

## 1.4 Origin and Orientation

All coordinate reference systems must have a point of origin, typically expressed as a latitude and longitude coordinate pair. The true or natural origin of a rectangular coordinate system is often shifted by assigning a "false" easting and/or northing to the intersection of the central meridian and latitude of grid origin and assuring that all points within the region covered by the system will have positive coordinate values. This results in a "false origin", which is typically located west and south of the projection area, and has a coordinate value of 0,0.

The orientation of the most common coordinate reference systems is established through a central meridian. Only at the central meridian does a coordinate reference system's "grid north" line coincide with true north. Unlike the latitude-longitude system, the north-south lines of a grid system never converge toward the poles. The angular difference between grid and true north is known as the convergence angle. The convergence angle is typically a factor only for land surveying applications requiring a high degree of accuracy over long distances. See Figure 1.4-1.

*(Wisconsin SCO 2015)*

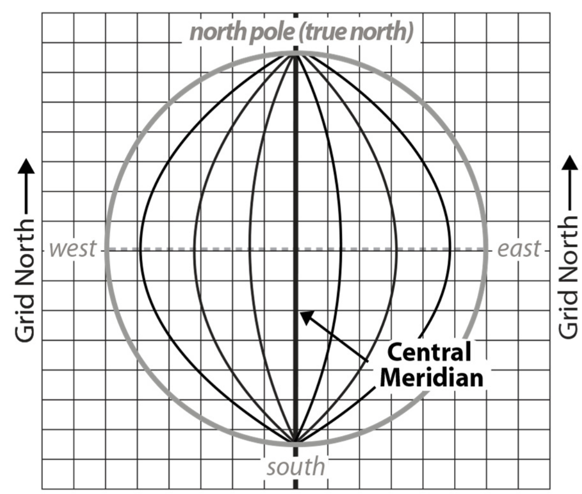



***Figure 1.4-1:*** *Relationship of True North and Map Coordinate Grid North.*

*(Image courtesy of Wisconsin SCO.)*

## 1.5 Unit of Measurement

Another key piece of coordinate system information is the linear unit of measurement applied to the system. While the definition of the coordinate system requires formal specification of linear units, users often convert coordinate values to other units of measure that better match the information with which they are working.

Rectangular coordinate systems typically use the meter, International Foot, or U.S. Survey Foot as the unit of measurement. *Most* surveying and mapping work conducted at the local level in the United States is based on the U.S. Survey Foot. States vary as to which "meters to feet" conversion method has been legislatively adopted for NAD 83 State Plane Coordinates. Some states have not yet elected to adopt a conversion method.

When a conversion from one of these units to the other is performed, it is important to determine which standard foot (U.S. Survey or International) is involved. The definitions of the U.S. Survey Foot (based upon the U.S. Metric Law of 1866) and the International Foot (based upon a redefinition of the meter on June 25, 1959), which are different by exactly 2 ppm (1 foot in every 500,000 feet), are as follows:

- *U.S. Survey Foot*: One meter = 39.37 inches "exact"
  - Stated differently: 1,200 meters = 3,937 U.S. Survey Feet "exact"
- *International Foot:* One foot = 0.3048 meters "exact"
  - Stated differently: One inch = 2.54 centimeters "exact"
  - Stated differently: 381 meters = 1,250 International Feet "exact"

Conversions between the U.S. Survey Foot, the Meter, and the International Foot that coincide at integers for all three units occur at increments of the following values:

- 499,999 U.S. Survey Feet = 152,400 Meters = 500,000 International Feet "exact"

*(Wisconsin SCO 2015)*

## 1.6 Scale Factor

Distances on the ellipsoid surface, called "geodetic distances," differ from corresponding grid distances projected onto the map projection surface. The ratio of projected distance to geodetic distance is known as the grid scale factor.

The design of a map projection often results in one or more places where the grid scale factor is held constant (equal to 1.0) and geodetic distances are the same as grid distances. The grid scale factor is equal to 1.0 along "standard lines". When project data does not lie at a point where the scale factor is 1.0, scale factors must be applied to obtain accurate grid distance values.

*(Wisconsin SCO 2015)*

## 1.7 Ground-to-Grid Ratio

A limitation of coordinate systems covering large areas, such as the state plane coordinate system, is that distances computed on the grid surface are not equivalent to actual ground distances. Surveying measurements are made on the surface of the Earth, while engineering designs and computer applications are referenced to the rectangular grid surface. Understanding the ground-to-grid ratio is crucial. To properly relate ground and grid distances, the grid scale factor and elevation scale factor, (together known as the “combined scale factor”) must be applied.

Ground-to-grid conversions are dependent on elevation, with differences between ground and grid values being more significant in areas of higher elevation. In Indiana, grid distances and ground distances can vary upwards of 80 ppm when using the State Plane Coordinate System and by more than 400 ppm when using the Universal Transverse Mercator system, zone 16. Ground-to-grid differences are negligible in the Indiana Geospatial Coordinate System.

Specifying whether coordinate values are grid or ground-based is another critical piece of coordinate system information.

*(Wisconsin SCO 2015)*

# Chapter 2 Geodetic Systems

## 2.1 Introduction

Geodetic systems describe the size and shape of the Earth, and are used to translate real positions on the Earth to positions shown on maps and in survey records. Geodetic systems are also referred to as "geometric reference systems" (i.e., "geodetic datums"). A geometric reference system is a mathematical model approximating the surface of the Earth and is physically referenced through a network of monumented survey points with precisely known coordinate positions.

A geometric reference system is used to locate and measure positions on the Earth. It is the basis for two-dimensional referencing in latitude/longitude or other (north/south and east/west) coordinate systems. Depending on the geometric reference system, a position on the Earth can have very different coordinates. Literally hundreds of different geometric reference system exist around the world.

These systems range from simple "flat Earth" models where the dynamics and curvature of the Earth are ignored due to the small geographic area covered by the system, to very complex systems that are intended to support global applications.

*(Wisconsin SCO 2015)*

## 2.2 Horizontal & Geometric Control Datums

The most basic expression of a horizontal position is through latitude and longitude, also known as geographic coordinates. These coordinates are expressed in the angular units of degrees, minutes and seconds (for example, 45° 15' 00"), or may be expressed in decimal degrees (for example, 45.25°).

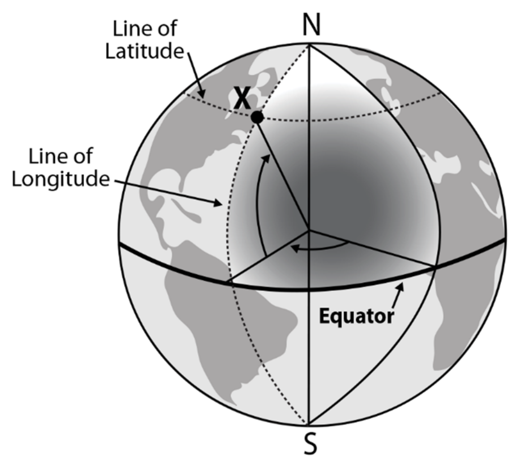



***Figure 2.2-1:*** *Location of Point "X" shown as a latitude/longitude coordinate point. (Image courtesy of Wisconsin SCO.)*

These coordinates are referenced to an approximate mathematical model known as an ellipsoid of revolution, or simply "ellipsoid" (sometimes referred to as a spheroid), of the surface of the Earth (see Figure 2.2-1). An ellipsoid is a geometric figure generated by the revolution of an ellipse about one of its axes.

When the ellipsoid model is oriented and positioned in space, it forms a "geometric reference system" (i.e., "geodetic datum"). The system is physically referenced (i.e., accessed, or "realized") through a geodetic network of measurements and monumented points that are recoverable and usable for field applications, and for which formally adjusted and published coordinate values are available.

Geometric reference systems are designed and established differently depending on use and the extent of coverage. The selection of a particular ellipsoid as the Earth model and the fixation of that ellipsoid with respect to the Earth's surface are key elements in defining a geometric reference system. Ellipsoids are generally chosen to "best fit" the area of the Earth that the geometric reference system will cover (see Figure 2.2-2).

Following are brief descriptions of commonly used horizontal and geometric control datums in the United States.

*(Wisconsin SCO 2015)*

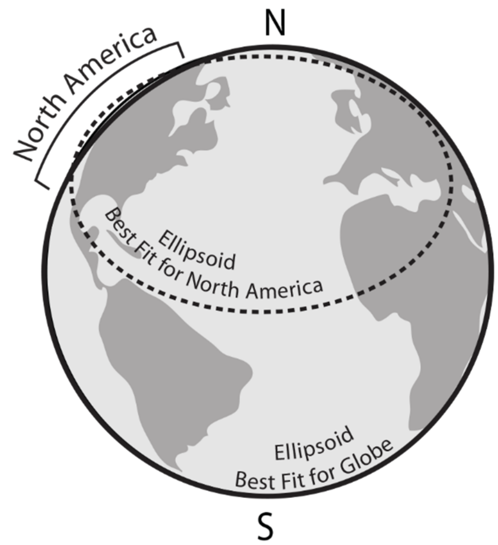



***Figure 2.2-2:*** *"Best fit" ellipsoids. (Image courtesy of Wisconsin SCO.)*

### 2.2.1 North American Datum of 1927

The North American Datum of 1927 (NAD 27) is a national geodetic control network published in the 1920s based on the Clarke 1866 ellipsoid. This ellipsoid model "best fit" the United States and Canada. The origin of this datum which fixes it with respect to the surface of the Earth is a single point, Station MEADES RANCH in Kansas.

*Bilby Tower (Osgood, Indiana)*

Field observations for NAD 27 were performed through massive triangulation networks. Astronomical observations were performed at triangulation stations both near ground level (typical heights of the personnel performing the observations) as well as atop wooden and (later) steel towers. Noteworthy to Indiana, these steel towers were designed by Jasper Bilby from Osgood, Indiana. These steel towers, later referred to as "Bilby Towers" in honor of Mr. Bilby, significantly reduced the time involved with erecting and dismantling the previous wood-constructed towers. This, in turn, increased the efficiency of the field crews and the speed at which they could perform their duties.


*BILBY Station Mark (Osgood, Indiana)*

NAD 27 is considered a *horizontal* datum because ellipsoidal heights are not available from this datum.

Over the decades, massive amounts of measurements and mapping by local, state, and federal agencies, and the private sector, have been referenced to NAD 27. As an example, all federally-produced topographic maps are based on this datum.

Over the years, subsequent geodetic control work was “made to fit” the horizontal network as it existed in 1927. This, coupled with improved technology and expanded knowledge of the shape of the Earth, caused measurement differences to accumulate resulting in a lesser quality system overall. Eventually, this led to the decision by the National Geodetic Survey (NGS) to redefine and readjust the datum.

*(Wisconsin SCO 2015)*

### 2.2.2 North American Datum of 1983

The North American Datum of 1983 (NAD 83), a fundamentally different datum, has for the most part replaced NAD 27. NAD 83 is a horizontal control datum common for the United States, Canada, Mexico, and Central America. It is based on a *(nearly) geocentric* origin and the Geodetic Reference System 1980 (GRS 80) ellipsoid, rather than the older, *non-geocentric* Clark 1866 ellipsoid used in NAD 27. The completion of NAD 83 removed significant local distortions that had accumulated over the years in NAD 27, making NAD 83 much more compatible with modern survey technologies and practices.

Since NAD 27 and NAD 83 were computed from differing sets of measurements referenced to different ellipsoids, there is no exact mathematical correlation between them. However, transformation software has been developed based upon models that can interpolate differences and apply that information to other data. The federal government has officially adopted NAD 83 as the nation’s legal horizontal datum, and NAD 83 is likewise recognized in legislation in nearly all states, including Indiana.

*(Wisconsin SCO 2015)*

### 2.2.3 North American Datum of 1983 (1986)

Data related to the North American Datum of 1983 was generally published and made available in 1986, thus the published adjustment is referred to as NAD 83(1986). This realization of NAD 83 was based mainly on triangulation, trilateration and doppler data; therefore, NAD 83(1986) was still considered only a horizontal datum as ellipsoidal heights were not available from this datum. Several datum adjustments have been applied to the NAD 83 datum since its initial 1986 definition and adjustment.

*(Wisconsin SCO 2015)*

### 2.2.4 North American Datum of 1983 (1997)

The NAD 83(1986) adjustment was published just as Global Positioning System (GPS) technology was coming into widespread use. The National Geodetic Survey (NGS) realized the potential for increased network accuracy through the use of GPS and undertook an effort to use the technology to establish a High Accuracy Reference Network (HARN) *in each state*. The cooperative network upgrading program began in Tennessee in 1986. The last field observations were completed in Indiana in September 1997.

In the span of these years, NGS performed multiple official network adjustments which resulted in new variations or “realizations” of NAD 83. The HARN realizations are named NAD 83(1987), NAD 83(1988), …, NAD 83(1997) where the number in parentheses usually identifies the year when the GPS observations were performed, otherwise known as the datum tag. Thus, Indiana’s HARN was referred to as NAD 83(1997).

Thanks to GPS, values of latitude, longitude *and ellipsoidal heights* are able to be obtained relative to NAD 83. Therefore, these and future realizations of NAD 83 are now considered 3Dimensional reference systems (or *Geometric Reference Systems*), rather than merely horizontal (2Dimensional) datums.

*(NGS, Wisconsin SCO 2015)*

### 2.2.5 North American Datum of 1983 (NSRS2007)

Upon completion of the state HARNs in 1997, the states now had geodetic control networks that were consistent within themselves, but the nation as a whole was somewhat lacking in consistency across state lines. The next step would be to pursue a *national* readjustment to "better match" the HARN networks, regardless of state lines, as well as to take advantage of GPS technology advances with regard to ellipsoid heights, and to respond to national geopositioning standard requirements for individual and network accuracy estimates for all stations in the national geodetic network.

In the mid-1990s, NGS began to establish a national network of continuously operating reference stations (CORS) to support the use of GPS technology. These CORS soon proved to be what would later be referred to as the very foundation of the National Spatial Reference System.

Upon embarking upon this endeavor, it was decided to only include GPS data collected from the CORS and the various campaign-style geodetic surveys performed from the mid-1980s through 2005. The NAD 83(CORS96) positional coordinates for roughly 700 CORS were held fixed (predominantly at the 2002.0 epoch for the stable North American plate, but 2007.0 in Alaska and western CONUS) to obtain consistent positional coordinates for the roughly 70,000 passive marks.

As a result of the NAD 83(NSRS2007) adjustment, the nation had, for the first time since 1986, a *single* harmonized adjustment.

Note: On NGS Datasheets, NGS decided to use the "NAD 83(2007)” tag as the permanent identifier of points with an NSRS2007 coordinate.

*(Armstrong et al. 2014, NGS, Wisconsin SCO 2015)*

### 2.2.6 North American Datum of 1983 (2011) epoch 2010.00

At the initial release of this Handbook and User Guide, NAD 83(2011) epoch 2010.00 was the current realization of NAD 83.The introduction of the epoch date behind the datum tag refers to the date for which published positional coordinates are valid. So for NAD 83(2011) epoch 2010.00, the published positional coordinates were valid as of midnight, January 01, 2010. An epoch date is a necessary part of a complete datum or reference frame name, because coordinates can change with time (i.e., they often have non-zero velocities relative to some chosen, stable coordinate reference).

Following is NGS’s report on NAD 83 (2011) epoch 2010.00: www.ngs.noaa.gov/web/surveys/NA2011/

The National Adjustment of 2011 Project
Alignment of passive control with the latest realization of the North American Datum of 1983:
NAD 83(2011), NAD 83(PA11), and NAD 83(MA11) Epoch 2010.00

The mission of NOAA's National Geodetic Survey (NGS) is to define, maintain, and provide access to the National Spatial Reference System (NSRS). The NSRS is the official reference system for latitude, longitude, height, scale, gravity, and orientation throughout the United States and its territories. It is the foundation for the nation's transportation, mapping, and charting infrastructure, and it supports a multitude of scientific and engineering applications.

As part of continuing efforts to improve the NSRS, on June 30, 2012, NGS completed the National Adjustment of 2011 Project. This project was a nationwide adjustment of NGS "passive" control (physical marks that can be occupied with survey equipment, such as brass disk bench marks) positioned using Global Navigation Satellite System (GNSS) technology. The adjustment was constrained to current North American Datum of 1983 (NAD 83) latitude, longitude, and ellipsoid heights of NGS Continuously Operating Reference Stations (CORS). The CORS network is an "active" control system consisting of permanently mounted GNSS antennas, and it is the geometric foundation of the NSRS. Constraining the adjustment to the CORS optimally aligned the GNSS passive control with the active control, providing a unified reference frame to serve the nation's geometric positioning needs.

Current NAD 83 CORS coordinates were determined by re-processing all CORS data collected from January 1994 to April 2011 in the NGS initial Multi-Year CORS Solution (MYCS1) project. The resulting CORS coordinates were published by NGS in September, 2011, and constitute a new realization referred to as NAD 83(2011), NAD 83(PA11), and NAD 83(MA11) Epoch 2010.00. The realization name has two parts: the datum tag in parentheses after NAD 83, and the epoch date in decimal years. The datum tag refers to the year the realization was completed (2011) and the tectonic plate to which the coordinates are referenced (2011 refers to the North America plate, PA11 to the Pacific plate, and MA11 to the Mariana plate). The epoch date indicates that the published coordinates represent the location of the control stations on January 1, 2010 -- an important consideration in tectonically active areas (such as the western U.S.). In this way, the CORS coordinates (and thus the passive marks constrained to the CORS) are consistent across both space and time. Additional information on the MYCS1 realization of NAD 83 is available on the NGS CORS Coordinates web page.

To create the passive control network, 4267 individual GNSS survey projects (stored in the NGS database) were combined into an overall network of 81,055 stations, including 1195 CORS used as constraints. The stations were connected by 424,711 GNSS vectors observed between April 1983 and December 2011. Because of a lack of vector connections between the conterminous U.S. (CONUS), Alaska, and the Pacific, these three regions were each adjusted separately: CONUS with 79,546 stations (including 1113 CORS), Alaska with 968 stations (including 58 CORS), and the Pacific with 541 stations (including 24 CORS). The entire Pacific was adjusted as two individual networks, one referenced to the Pacific tectonic plate and the other to the Mariana plate. CONUS was further split into a Primary and Secondary network based mainly on the age of the observations, as described below. The CONUS Primary network consisted of 62,364 stations (including 1097 CORS) and the Secondary network 22,503 stations (including only 45 CORS), where 5321 stations (including 29 CORS) were common between the two networks. Because of the large size of the two CONUS networks, they were adjusted using a Helmert blocking strategy. The Helmert approach breaks a large network into separate (but connected) smaller "blocks" to reduce computation time. The blocks are each adjusted individually and combined to give results identical to what would be obtained if the entire adjustment were performed simultaneously.

For the final constrained adjustments, the median network accuracy for all stations was 0.9 cm horizontal and 1.5 cm vertical (i.e., ellipsoid height) at the 95% confidence level. The median change in coordinates from the previous published values was about 2 cm horizontally and vertically. However, some station coordinates changed by more than 1 meter horizontally and 60 cm vertically. Although some of the large coordinate changes resulted from new data and adjustment strategies, most horizontal changes greater than about 6 cm occurred in geologically active areas and were likely due to tectonic motion.

Results of the 2011 national adjustment for 79,677 passive control marks are available on NGS Datasheets, including their network and local accuracies. Of these passive marks, 79,161 are referenced to the North America tectonic plate as the 2011 realization (including CONUS, Alaska, and the Caribbean); 345 are referenced to the Pacific plate as the PA11 realization (the central Pacific, including Hawaii, American Samoa, and the Marshall Islands); and 171 are referenced to the Mariana plate as the MA11 realization (the western Pacific, including Guam, Palau, and the Commonwealth of the Northern Mariana Islands). Although the passive marks are referenced to three different tectonic plates, all refer to a common 2010.0 epoch date. With the completion of the national adjustment, all passive marks on NGS Datasheets with NAD 83(2011), NAD 83(PA11), and NAD 83(MA11) Epoch 2010.00 coordinates will be consistent with results obtained using CORS and the NGS Online Positioning User Service (OPUS). Note that 183 stations were excluded from the final national adjustments due to lack of enabled vector connections; where possible, these stations will be reconnected to the network in subsequent individual adjustments.

A new NGS hybrid geoid model, GEOID12A, was developed by combining NAD 83(2011), NAD 83(PA11), and NAD 83(MA11) Epoch 2010.00 ellipsoid heights on leveled bench marks with a new gravimetric geoid model, USGG2012. The GEOID12A model is for converting between NAD 83(2011), NAD 83(PA11), and NAD 83(MA11) Epoch 2010.00 ellipsoid heights and orthometric heights in the respective vertical datums for different regions, such as the North American Vertical Datum of 1988 (NAVD 88) for CONUS and Alaska. Previous hybrid geoid models (such as GEOID09) should not be used to convert NAD 83(2011), NAD 83(PA11), and NAD 83(MA11) Epoch 2010.00 ellipsoid heights to orthometric heights.

A number of technical challenges were confronted in performing the 2011 national adjustment. One, as mentioned previously, was that the networks were referenced to three different tectonic plates (North America, Pacific, and Mariana plates, as mentioned above). In some cases, stations referenced to one plate were located on a different plate (e.g., stations in coastal California and the Caribbean were referenced to the North America plate). This was handled by modeling tectonic motion (including earthquakes) using the NGS Horizontal Time Dependent Positioning (HTDP) software to transform the GNSS vectors to NAD 83 at the common 2010.00 epoch date. For the 2011 national adjustment, HTDP version 3.1.2 was used for CONUS, Alaska, and the Caribbean, and version 3.2.2 was used for the Pacific.

Other technical issues addressed in the project include 1) appropriate down weighting of the up component of GNSS vectors to account for subsidence in the northern Gulf Coast region of CONUS; 2) use of variable weighted (stochastic) constraints for CORS based on formal accuracy estimates derived from the NGS MYCS1; 3) scaling of GNSS vector error estimates for all projects to ensure consistent weighting of observations; 4) use of down weighting (rather than removal) for vector rejections; 5) splitting the conterminous U.S. into a Primary and Secondary network, as mentioned above, such that vectors observed prior to about 1994 were assigned to the Secondary network. This allowed the Primary network to be adjusted separately without the problems associated with older observations (e.g., single frequency receivers, no antenna phase center models, poor orbit accuracy, incomplete satellite constellation, lack of CORS, etc.). Each of these technical challenges (and others) was satisfactorily resolved, and completion of the National Adjustment of 2011 Project represents a significant step toward a more integrated, consistent, and accurate NSRS.

For example, NAD 83(1986) is significantly different than NAD 83(CORS96), but NAD 83(CORS96) usually only differs by a few centimeters from NAD 83(HARN/HPGN), and NAD 83(CORS) only differs from NAD 83(2007) in the western US (they are considered functionally the same elsewhere in the US)

NAD 83(1986) was officially (according to the National Geospatial Intelligence Agency (NGA) http://Earth-info.nga.mil/GandG/coordsys/datums/NATO_DT.pdf) a 'zero transform' from WGS 84 although the Earth center and parameters for the two datum are slightly different. This 'zero transform' is commonly accepted by software vendors. This effectively made NAD 83(1986) and WGS 84(original) identical, except for extremely small difference in ellipsoid shape (maximum difference of 0.1 mm at the poles). This was referred to as NAD 83 "CONUS" (code NAR-C), and the "CONUS" designation continues to be used in various commercial software packages (although it is not used by the NGS). At the time this relationship was defined (1987), the location of Earth's center of mass was only known to about ±2 m, so these datums were considered the 'same', to within ±2 m. Presently, the Earth's center of mass is known to the centimeter level, and it is recognized that current realizations of NAD 83 and WGS 84 actually differ by about 1-2 m (depending on location). This legacy 'zero transform' is still commonly used by commercial software vendors, even though it is not actually correct, which has become a persistent source of confusion. Part of this confusion stems from the fact that "WGS 84" is the name of the ellipsoid and the datum, which is not typical geodetic practice (e.g., both NAD 83 and ITRF use the GRS 80 ellipsoid). Also, software vendors may have slight variations in datum naming conventions, especially those programs developed in foreign countries.

*(NGS)*

### 2.2.7 NAD 83(realization) Summary

Any particular "realization" of NAD 83 results in an associated set of coordinates on the stations that provide access to the datum, without changing how the datum is related to the Earth. In other words, given the same physical mark in the ground, each realization yields different coordinate values. The magnitude of these differences vary, both regionally for a common realization as well as from realization to realization on the same mark, but have typically been decreasing with each successive realization.

Like the Indiana East and West zones of the SPCS of 1983, the InGCS zones' parameters and reference ellipsoid (GRS 80) are identical for all realizations of NAD 83. In principle, lines of latitude and longitude are the same, but the coordinates of stations differ due to the how they are determined, as well as to motion (such as plate tectonics). The NAD 83 realization is therefore associated with the data. If the data are referenced to NAD 83(2011) epoch 2010.00, that will result in coordinates at a point that differ from other realizations. *The realization is a critical part of the metadata, but it has no effect on the map projection parameters.* That is, the relationship between latitude and longitude and the InGCS (or State Plane) northings and eastings is the same for all NAD 83 realizations.

Consider as an example how different realizations will result in different coordinates at a specific NGS survey control station in Indiana. Control station HATFIELD (PID HA0727) has provided surveyors access to the NAD 83 datum since its inception in 1986 (and to the NAD 27 datum for several decades prior). The NAD 83 geographic (geodetic) coordinates for this station have been updated four times relative to different NAD 83 datum realizations.

From Appendix D, the geographic coordinates of HATFIELD referenced to NAD 83(2011) epoch 2010.00 are 37°54'11.18210"(N), 87°14'32.43551"(W). These geographic coordinates yield InGCS "Spencer" zone coordinates (in U.S. survey feet) of N 173,921.638, E 731,900.029. Because of changes in the way the position of this station was determined (including different observation types, amount of data, computation methods, adjustment constraints, tectonic motion, etc.), the geographic coordinates were different for earlier realizations of NAD 83. From the NGS Datasheet, the coordinates of HATFIELD referenced to the original NAD 83(1986) realization were 37°54'11.19182"(N), 87°14'32.43972"(W), which give InGCS coordinates of 173,922.622 N, 731,899.694 E. The difference in coordinates between these two realizations of NAD 83 is 0.984 feet in the northing and 0.335 feet in the easting. It can be seen by this example that including datum realization information in database metadata and coordinate system definition files is a critical part of maintaining accurate coordinates for geospatial data.

*Station HATFIELD (Hatfield, Indiana)*

***Table 2.2.7-1:*** *Changes in coordinates for station HATFIELD throughout NAD 83 realizations.*

| NAD 83 Datum Tag | NAD 83 Geodetic Coordinates | | InGCS "Spencer" Zone Grid Coordinates (U.S. Ft) | | Changes in Grid Coordinates | |
|---|---|---|---|---|---|---|
| | North Latitude | West Longitude | Northing | Easting | Hz Dist. (U.S. Ft) | Grid Azimuth |
| 2011 | 37°54'11.18210" | 87°14'32.43551" | 173,921.6380 | 731,900.0293 | | |
| | | | | | 0.065 | 94° |
| 2007 | 37°54'11.18214" | 87°14'32.43632" | 173,921.6422 | 731,899.9644 | | |
| | | | | | 0.062 | 76° |
| 1997 | 37°54'11.18199" | 87°14'32.43707" | 173,921.6272 | 731,899.9043 | | |
| | | | | | 0.310 | 171° |
| 1993 | 37°54'11.18501" | 87°14'32.43770" | 173,921.9328 | 731,899.8544 | | |
| | | | | | 0.708 | 167° |
| 1986 | 37°54'11.19182" | 87°14'32.43972" | 173,922.6220 | 731,899.6939 | | |

Coordinate transformations between the various realizations of NAD 83 have been developed by NGS (such as NADCON). However, these transformations are not appropriate for all applications, and the documentation for each should be reviewed to ensure suitability. Typically, these transformations are *not* of sufficient accuracy for surveying and engineering applications. In such cases, more rigorous methods are necessary and can be done with respect to the desired NAD 83 reference coordinates, such as reprocessing data, recomputing coordinates, or performing custom local transformations.

*(Dennis et al. 2014)*

### 2.2.8 World Geodetic System (1984)

The WGS 84 geodetic referencing system was developed by the Department of Defense and is used by military and homeland security agencies and the National Geospatial Intelligence Agency (NGA). It is also the system used to describe orbits of GPS satellites.

When first established in 1987, the original realization of "WGS 84" was, for all practical purposes, identical to the original realization of NAD 83(1986). According to the NGA, there was a "zero transform" from the original WGS 84 to NAD 83(1986). In other words, both of these datums shared the same physical center of mass of the Earth (or position in space), as it was known at that time. See http://earth-info.nga.mil/GandG/coordsys/datums/NATO_DT.pdf for numerical details, noting that NAD 83(1986) is referenced therein as code "NAR-C," name "NORTH AMERICAN 1983," and region "US - CONUS," from which the nickname/handle for NAD 83(1986) of "NAD 83(CONUS)" surfaced. This "CONUS" designation continues to be used in various commercial software packages (although it is not used by the NGS). The exceedingly small distinguishing characteristic of these two datums lie in their ellipsoid parameters, i.e., their shapes. Refer to Table 2.2.8-1 to compare these parameters. Although their semi-major axes are identical, the minuscule difference in their flattening factor results in a mere maximum difference of 0.1 mm at the poles.

***Table 2.2.8-1:*** *Comparison of WGS 84 and GRS 80 Ellipsoid Parameters.*

| Ellipsoid Model | Semi-Major Axis (exact by definition) | Semi-Minor Axis (computed) | Flattening (exact by definition) |
|---|---|---|---|
| WGS 84 | 6 378 137 | 6 356 752.314245 | 1/298.257223563 |
| GRS 80 | 6 378 137 | 6 356 752.314140 | 1/298.257222101 |

The technology available at the time that the relationship between these datums was defined (1987) made it possible to determine the location of the Earth's center of mass to an accuracy of ±2 m. Parallel with the increasing accuracy of land surveying equipment, advances in technology has since led to the determination of the Earth's center of mass to be presently (2016) known to the centimeter level. As the leaps in accuracy of Earth center determination increased, WGS 84 itself has undergone a number of realizations. Table 2.2.8-2, from the National Geospatial-Intelligence Agency (NGA) (http://earth-info.nga.mil/GandG/publications/NGA_STND_0036_1_0_0_WGS84/NGA.STND.0036_1.0.0_WGS84.pdf), lists these realizations, their effective dates, and estimated accuracies. Note that "G" indicates that GPS measurements were used to obtain the coordinates while the number following the "G" indicates the GPS week number during which the coordinates were approved for implementation by NGA. The original TRANSIT realization of WGS 84 has no such designation.

***Table 2.2.8-2:*** *WGS 84 Reference Frame Realizations.*

| Name | Implementation Date | | Epoch | Accuracy |
|---|---|---|---|---|
| | GPS Broadcast Orbits | NGS Precise Ephemeris | | |
| WGS 84 – Original/Transit | 1987 | 1 Jan 1987 | N/A | ±2 m |
| WGS 84 (G730) | 29 Jun 1994 | 2 Jan 1994 | 1994.0 | ±10 cm |
| WGS 84 (G873) | 29 Jan 1997 | 29 Sep 1996 | 1997.0 | ±5 cm |
| WGS 84 (G1150) | 20 Jan 2002 | 20 Jan 2002 | 2001.0 | ±1 cm |
| WGS 84 (G1674) | 8 Feb 2012 | 7 May 2012 | 2005.0 | <1 cm |
| WGS 84 (G1762) | 16 Oct 2013 | 16 Oct 2013 | 2005.0 | <1 cm |

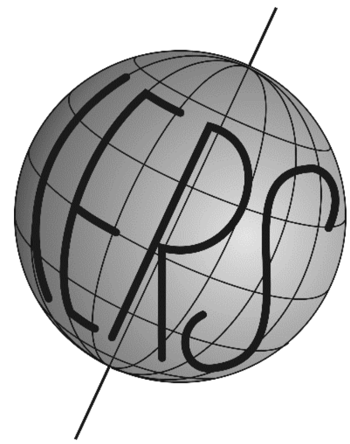
As a result of these realizations, the origins of the NAD 83 and WGS 84 datums have three-dimensionally drifted apart from one another. Today, it is recognized that the origins of the current realizations of NAD 83 and WGS 84 (i.e., NAD 83(2011) epoch 2010.00 and WGS 84(G1762) actually differ by ±2 m, yet the legacy "zero transform" is still commonly used by commercial software vendors (though it is not actually correct). This has become a persistent source of confusion. Part of the confusion stems from the fact that "WGS 84" is both the name of the ellipsoid *and* the datum, which is not typical geodetic practice (e.g., NAD 83 uses the "GRS 80" ellipsoid). Also, software vendors may have slight variations in datum naming conventions, especially those programs developed in foreign countries.

This confusion can also lead to positioning errors on the part of the user segment, particularly since GPS satellites broadcast their positions respective to the *current* WGS 84 realization, not the original. Depending upon the global positioning method used, the incorrect selection of an otherwise "seemingly" correct datum (because of naming convention) may result in positioning errors in the magnitude of the difference between the correct and incorrect datums. This is discussed in greater detail later in Chapter 6.

All of this underscores the importance of properly identifying datums used in projects. Merely identifying "NAD 83" or "WGS 84" is not specific enough to adequately define the reference frame of geodetic data. Additional information is needed that defines the realization or version of a particular datum, such as appending a datum tag and epoch, e.g. NAD 83(2011) epoch 2010.00 and WGS 84(G1762) epoch 2016.50.

*(Armstrong et al. 2014, Wisconsin SCO 2015)*

### 2.2.9 International Terrestrial Reference Frame (ITRF)




*(Image courtesy of IERS.)*

"The International Terrestrial Reference Frame (ITRF) is a set of points with their 3Dimensional cartesian coordinates which realize an ideal reference system, the International Terrestrial Reference System (ITRS), as defined by the IUGG resolution No. 2 adopted in Vienna, 1991.

According to the new structure of IERS implemented in 2001 three ITRS Combination Centres are responsible for the computation of ITRS realizations. After a validation procedure, one realization is defined to be the official ITRF solution. To the ITRF2008, IGN and DGFI contribute by computing ITRS realizations.

The International Terrestrial Reference System (ITRS) constitutes a set of prescriptions and conventions together with the modelling required to define origin, scale, orientation and time evolution of a Conventional Terrestrial Reference System (CTRS). The ITRS is an ideal reference system, as defined by the IUGG resolution No. 2 adopted in Vienna, 1991. The system is realised by the International Terrestrial Reference Frame (ITRF) based upon estimated coordinates and velocities of a set of stations observed by VLBI, LLR, GPS, SLR, and DORIS. The ITRS can be connected to the International Celestial Reference System (ICRS) by use of the IERS Earth Orientation Parameters (EOP)."

*(Note: Information from the International Earth Rotation and Reference Systems Service website, https://www.iers.org/IERS/EN/Home/home_node.html)*

## 2.3 Vertical Reference Datums

### 2.3.1 Introduction

As previously discussed, a horizontal control datum provides the basis for two-dimensional referencing. A vertical geodetic datum provides the basis for developing heights and depths. Developing heights and depths involves another Earth model and reference surface critical to geodetic systems – the *geoid*. The geoid is an equipotential surface of the Earth's gravitational field that best fits the global equivalent of "mean sea level" (see Figure 2.3.1-1).

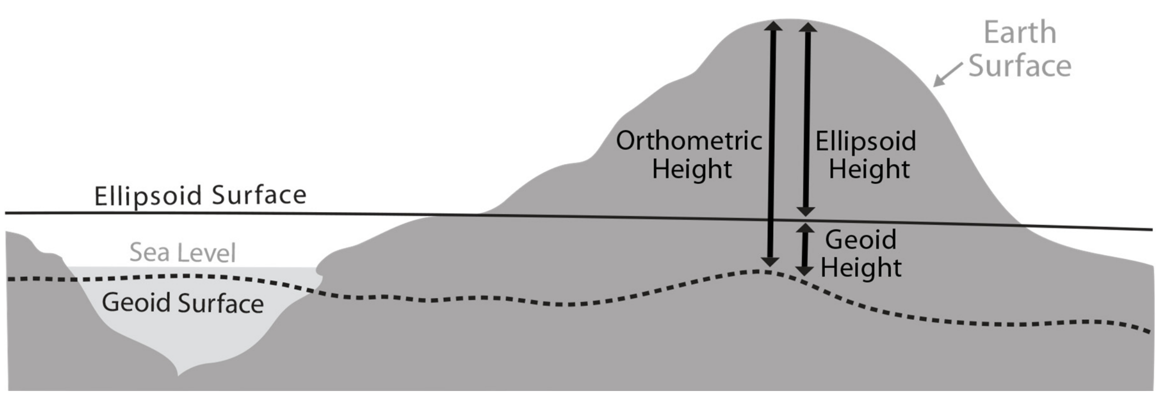



***Figure 2.3.1-1:*** *Relationship of "Heights" (Geoid, Ellipsoid, and Orthometric).*

*(Image courtesy of Wisconsin SCO.)*

A geoid [hybrid geoid model i.e., currently GEOID12B(Conus)] used in geodetic adjustments is comprised of a gravimetric scientific model constrained to a 'best fit' of a current monumented bench mark network (currently GPSBM2012B). This hybrid model is updated by the National Geodetic Survey (NGS) approximately every three to six years as more gravity and bench mark data becomes available, and as new computational methods are developed. When measuring with GNSS equipment, a geoid model such as GEOID12B(Conus) must be applied (geoid height 'N') to allow for the conversion of measured NAD 83 ellipsoid heights (h) to orthometric heights (H) [equation H=h-(N)] in the vertical datum NAVD 88.

GRAV-D (**G**ravity for the **R**edefinition of the **A**merican **V**ertical **D**atum) is a proposal by the National Geodetic Survey to re-define the vertical datum of the U.S. by 2022 (http://www.ngs.noaa.gov/GRAV-D/).

*(Armstrong et al. 2014, NGS, Wisconsin SCO 2015)*

### 2.3.2 Mean Sea Level and the Geoid

Mean sea level is determined over time by averaging the level of the seas including such factors as wind-created waves and changes due to tides. This imaginary sea level surface conforms to the Earth's gravitational field, which is similar, but much smoother, than the Earth's land surface.

The mean sea level surface can be conceptually extended under the continents, and as such, is a close approximation of the geoid. However, due to measurement inconsistencies and non-periodic changes in sea level, the relationship between the geoid and mean sea level is not exact or consistent.

*(Wisconsin SCO 2015)*

### 2.3.3 Elevation and Heights

An elevation of a point is the distance the point is above or below a datum. An orthometric height of a point is the distance the point is above or below the geoid. Traditionally called "elevation," the orthometric height is the mathematical combination of the ellipsoid height minus the geoid height at a point (see Figure 2.3.1-1). The mathematical models of the geoid heights are continually updated and refined as additional measurements are incorporated. In Indiana, the geoid generally lies about 33 meters below the GRS 80 ellipsoid, the ellipsoid for NAD 83. In Indiana, geoid heights are always a negative value.

Modeled geoid heights vary according to the mathematics used to produce them. Some modeled heights are accurate to a few centimeters. Since geoid models vary and are frequently updated, knowing the specific model used in computations is a critical piece of elevation information.

*(Wisconsin SCO 2015)*

### 2.3.4 National Geodetic Vertical Datum of 1929

Until 1973, the National Geodetic Vertical Datum of 1929 (NGVD 29) was known as the Sea Level Datum of 1929, or more commonly, "mean sea level." For this vertical datum, mean sea level was determined by continuously measuring the rise and fall of the ocean at 26 tide gage stations along the U.S. and Canadian coastlines. Highs and lows of tides, caused by changing effects of gravitational forces from the sun and moon, are averaged out over a tidal "epoch," a period of at least 19 years. This information, together with a national network of level lines, formed NGVD 29.

*(Wisconsin SCO 2015)*

### 2.3.5 North American Vertical Datum of 1988

By the 1980s, thousands of in-ground monuments (bench marks) across the nation were either damaged or destroyed, thousands of new bench marks had been added, and many existing bench marks had moved due to the effects of crustal motion, post-glacial rebound, subsidence, or frost. Distortions of as much as two meters nationally required a need for new leveling data and a new vertical datum.

The North American Vertical Datum of 1988 (NAVD 88) was established in 1991 from a simultaneous, least squares, minimally-constrained adjustment of Canadian, Mexican, and United States leveling observations. It was held "fixed" on a single existing bench mark elevation at Father Point/Rimouski located in the mouth of the St. Lawrence River, Quebec, Canada. The selection of this point was made primarily to ensure consistency between NAVD 88 and the International Great Lakes Datum of 1985 (IGLD 85), but it also minimized the impact of NAVD 88 on U.S. Geological Survey mapping products, such as the 7.5-minute quadrangle series. Additional tidal bench mark elevations were not held because the tide gauges themselves do no measure “true” mean sea level, but rather local mean seal level (which does not define a surface of constant geopotential). Constraining to tide gauges for NGVD 29 distorted that adjustment. In addition, thousands of U.S. Geological Survey third-order bench marks were not included in the adjustment because NGS did not have complete data on the marks.

NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights and is the only current vertical datum that works seamlessly with GNSS observation measurements and NAD 83. Additionally, NGVD 29 is no longer supported by NGS, and published heights for NGVD 29 on NGS bench marks will not be updated. The Federal Emergency Management Agency (FEMA) attempts to base all digital flood insurance map modernization projects on NAVD 88 unless there is significant local opposition to changing the mapping from the previously-used NGVD 29 datum.

In Indiana, the difference between the NGVD 29 and NAVD 88 datums is minimal. The difference ranges from approximately 0.1 to 0.7 feet with an average difference of approximately 0.4 feet (see Figures 2.3.5-1 and 2.3.5-2). The National Geodetic Survey's "VERTCON" and the U.S. Army Corps of Engineers' "Corpscon" computer programs are capable of computing modeled transformations between NGVD 29 and NAVD 88 heights.

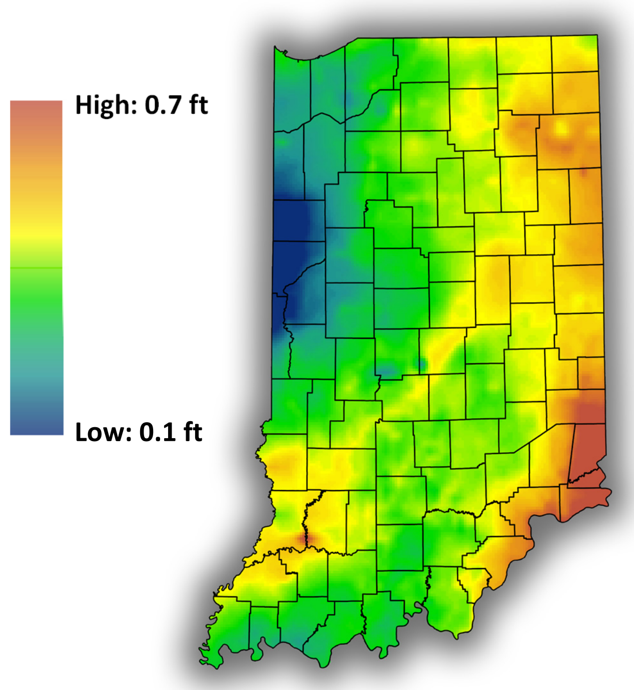



***Figure 2.3.5-1:*** *Approximate Height Change (NGVD 29 & NAVD 88) throughout Indiana.*

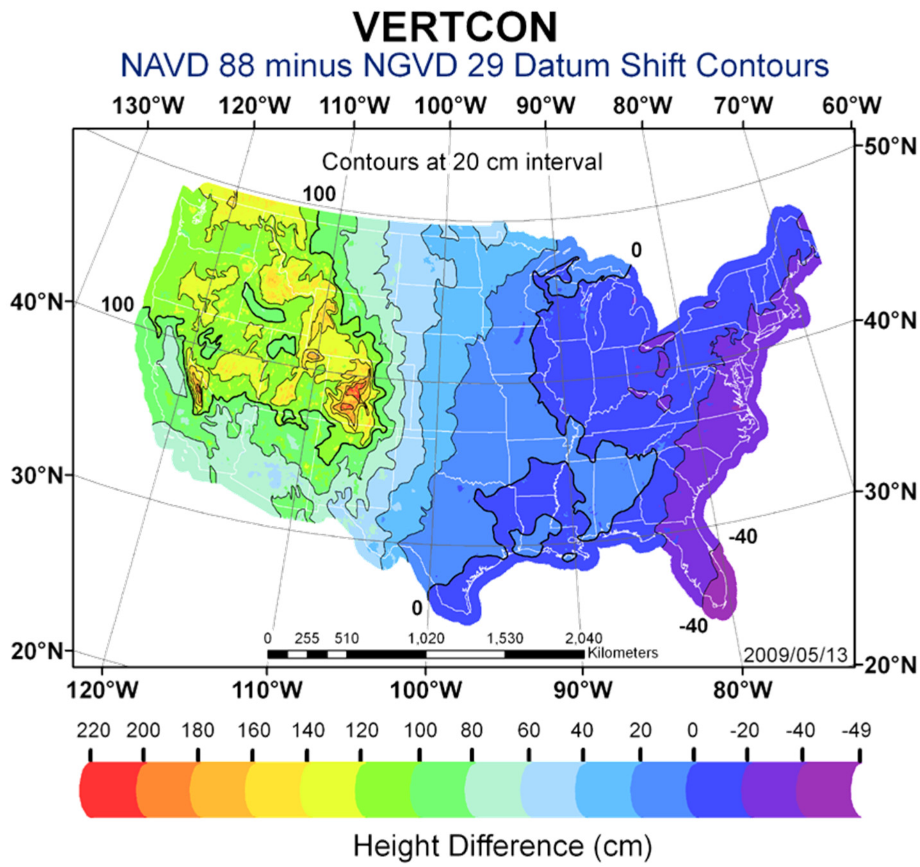



***Figure 2.3.5-2:*** *Approximate Height Change*
*(NGVD 29 & NAVD 88) throughout the contiguous U.S.*
*(Image courtesy of NOAA's National Geodetic Survey.)*

*(Armstrong et al. 2014, NGS, Wisconsin SCO 2015)*

### 2.3.6 Vertical Calibration

A complete 3D coordinate system definition must include a vertical "height" component. Yet the InGCS pertains exclusively to horizontal grid coordinates. So although the vertical component is essential for most applications, it is not part of the InGCS and must be defined separately. Typically, the vertical component consists of ellipsoid heights relative to the current geometric datum, such as NAD 83(2011) epoch 2010.00 (when using GNSS) and/or orthometric heights relative to the North American Vertical Datum of 1988 (NAVD 88).

These two types of heights are related (at least in part) by a hybrid geoid model, such as GEOID12B. Enhancements to the portion of the hybrid geoid model that covers Indiana are currently under way (as of 2016) through what's known as a height modernization project. This will improve the link between published NAVD 88 orthometric heights on NGS bench marks and ellipsoidal heights, allowing users to more accurately tie their local project to NAVD 88 without having to conduct extensive differential level circuits and site calibrations, localizations, etc.

Still yet, there will inevitably be projects that are written with scopes requiring ties to local vertical control that may or may not be relative to NAVD 88. In those cases, some sort of vertical adjustment, calibration, or transformation to properly match the *local* vertical control will need to be performed. The approach used for the vertical component usually varies from project to project and requires professional judgment to ensure it is defined correctly. Providing such recommendations is beyond the scope of this Handbook and User Guide.

*(Dennis et al. 2014)*

## 2.4 Future U.S. National Datums

Efforts are currently underway by the National Geodetic Survey to replace NAD 83 and NAVD 88 circa 2022.

> "NAD 83 and NAVD 88, although still the official horizontal and vertical datums of the National Spatial Reference System (NSRS), have been identified as having shortcomings that are best addressed through defining new horizontal and vertical datums.
>
> Specifically, NAD 83 is non-geocentric by about 2.2 meters. Secondly, NAVD 88 is both biased (by about one-half meter) and tilted (about 1 meter coast to coast) relative to the best global geoid models available today. Both of these issues derive from the fact that both datums were defined primary using terrestrial surveying techniques at passive geodetic survey marks. This network of survey marks deteriorate over time (both through unchecked physical movement and simple removal), and resources are not available to maintain them.
>
> The new reference frames (geometric and geopotential) will rely primarily on Global Navigation Satellite Systems (GNSS) such as the Global Positioning System (GPS) as well as an updated and time-tracked geoid model. This paradigm will be easier and more cost-effective to maintain."
> *(NGS, http://www.geodesy.noaa.gov/datums/newdatums/index.shtml)*

Figures 2.4-1, 2.4-2, and 2.4-3 reflect the approximate horizontal and height changes that will occur when the new reference frames are adopted.

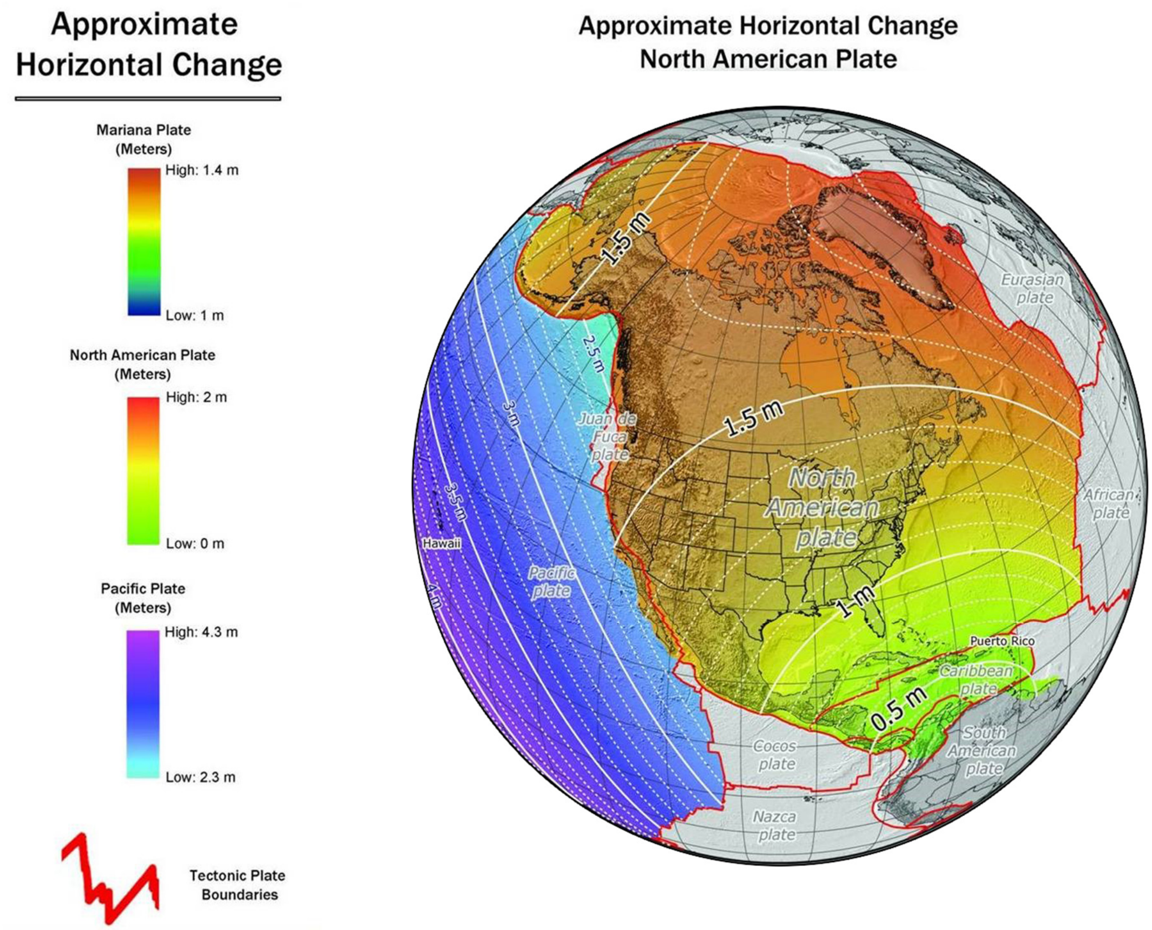



***Figure 2.4-1:*** *Approximate Horizontal Change-North American Plate.*
*(Image courtesy of NOAA's National Geodetic Survey.)*

Figure 2.4-1 assumes the same epoch of 2022.0 for both NAD 83 and the New Geometric Datum. It gives a general idea as to the change, but more realistic estimates can be created but using 2010.0 for NAD 83 and 2020 or 2022 for the New Geometric Datum.

Figure 2.4-2 also assumes the same epoch of 2022.0 for both NAD 83 and the New Geometric Datum. Ellipsoid height change is not as sensitive to epochs as is horizontal change.

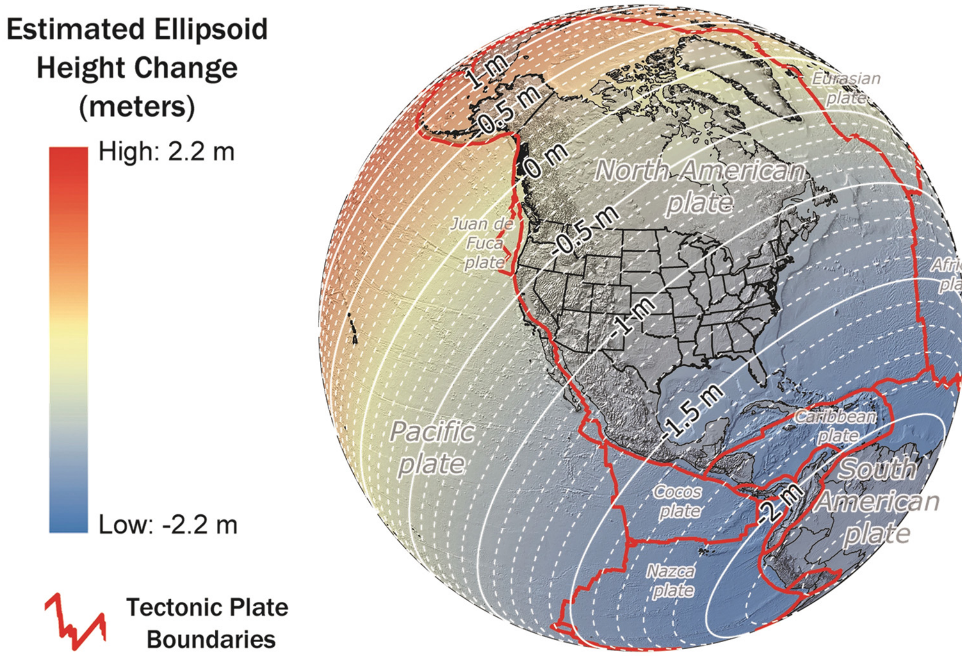



***Figure 2.4-2:*** *Approximate Ellipsoid Height Change. (Image courtesy of NOAA's National Geodetic Survey.)*

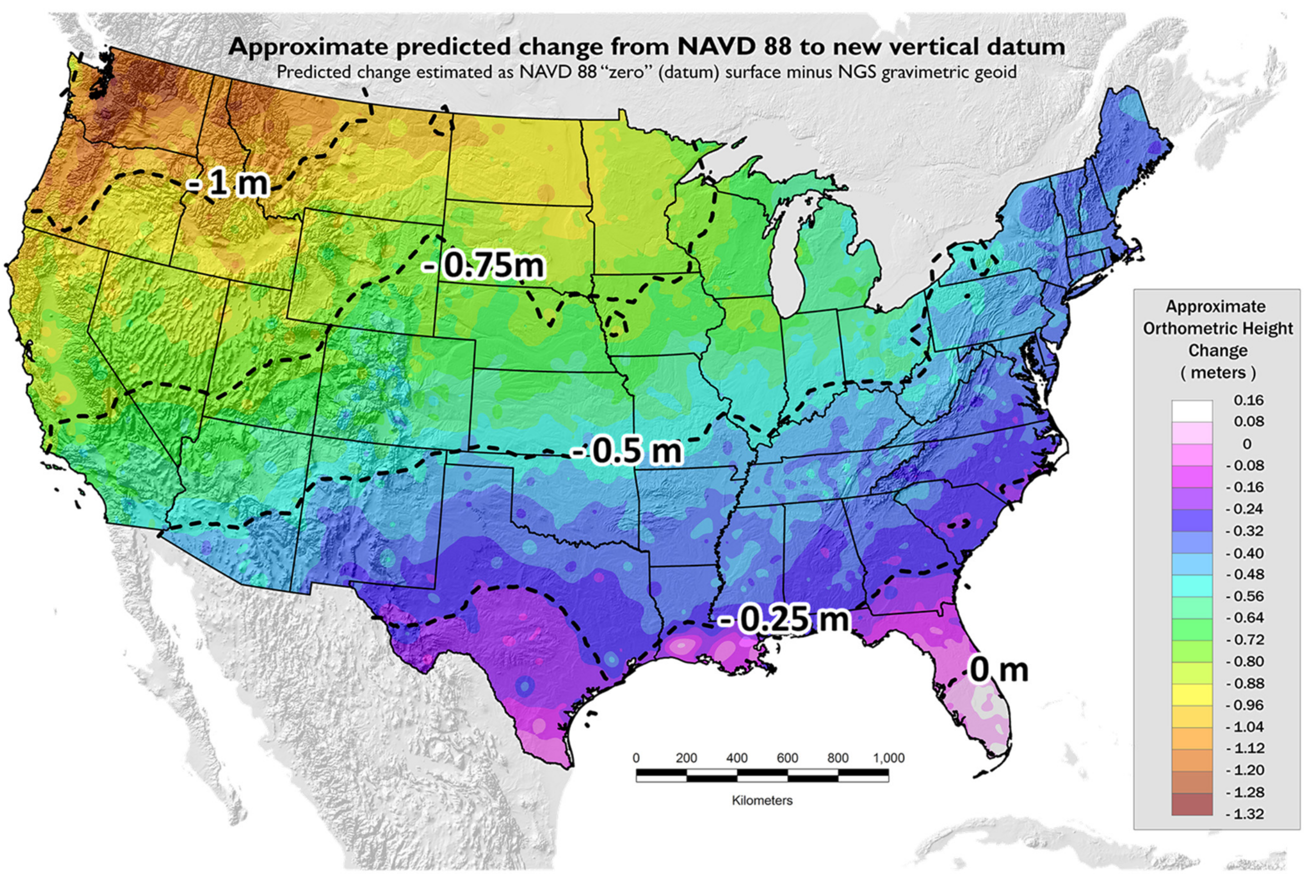



***Figure 2.4-3:*** *Approximate Orthometric Height Change. (Image courtesy of NOAA's National Geodetic Survey.)*

So what does/might this mean for the existing NAD 83-based SPCS, modified SPCS, the InGCS, other LDPs, or other NAD 83-based local coordinate reference systems and the projects that are based upon them? To answer that question, we should review "what happened" to NAD 27-based coordinate reference systems and projects after NAD 83 was introduced.

At the definition level, the East and West zones of the Indiana State Plane Coordinate System incurred the following changes, listed in Tables 2.4-1 and 2.4-2:

***Table 2.4-1:*** *Indiana SPCS Parameters: NAD 27.*

| Indiana State Plane Coordinate System Parameters | | |
|---|---|---|
| *Horizontal Datum: NAD 27* | | |
| | West Zone (1302) | East Zone (1301) |
| Projection Type | Transverse Mercator | Transverse Mercator |
| Reference Ellipsoid | Clarke 1866 | Clarke 1866 |
| Central Meridian | 87°05"00" (W) | 85°40"00" (W) |
| Central Meridian Scale Factor | (1-(1/30,000)) | (1-(1/30,000)) |
| Latitude of Grid Origin | 37°30"00" (N) | 37°30"00" (N) |
| False Northing | 0 (U.S. Feet) | 0 (U.S. Feet) |
| False Easting | 500,000 (U.S. Feet) | 500,000 (U.S. Feet) |

***Table 2.4-2:*** *Indiana SPCS Parameters: NAD 83.*

| Indiana State Plane Coordinate System Parameters | | |
|---|---|---|
| *Horizontal Datum: NAD 83* | | |
| | West Zone (1302) | East Zone (1301) |
| Projection Type | Transverse Mercator | Transverse Mercator |
| Reference Ellipsoid | GRS 80 | GRS 80 |
| Central Meridian | 87°05"00" (W) | 85°40"00" (W) |
| Central Meridian Scale Factor | (1-(1/30,000)) | (1-(1/30,000)) |
| Latitude of Grid Origin | 37°30"00" (N) | 37°30"00" (N) |
| False Northing | 250,000 (Meters) | 250,000 (Meters) |
| False Easting | 900,000 (Meters) | 100,000 (Meters) |

While the GRS 80 ellipsoid is the global reference ellipsoid for NAD 83, the Clarke 1866 ellipsoid was used as NAD 27's regional (not global) reference ellipsoid. Their origins differ by more than 230 meters.

As can be seen in Tables 2.4-1 and 2.4-2, the numeric values of each zones' Central Meridian, Central Meridian Scale Factor, and Latitude of Grid Origin remained the same from NAD 27 to NAD 83, while the False Northings and False Eastings changed significantly. This was done so as to minimize confusion as to which horizontal datum a set of grid coordinates would be respective to.

Many projects in Indiana that were originally based upon survey control marks with positions relative to NAD 27 are still active and are based upon the same values yet today, even though three decades have passed since NAD 83 was released. Examples include manufacturing facilities, coal mines, power plants, etc. Once the master survey control network for a site such as one of these has been established (i.e., control monuments have been set and allowed time to cure/pass a full freeze/thaw cycle, etc., field observations have been made, least squares adjustments have been performed, and the results published to the necessary parties), the grid coordinates and/or orthometric heights ("elevations") associated with those monuments typically serve that site in perpetuity, *regardless* of advances in regional, national, or global geometric and/or geopotential datums. In essence, these local survey markers and their associated values *become* the *local* realization (provide access) to the horizontal and vertical components of the project site.

The primary and simple reason being that all associated *initial* and *future* physical improvements to the site are based upon the numerical values associated with the physical survey marks *local* to the site as determined when the project began. Examples of initial improvements include auger cast displacement piles, finished floor elevations, steel columns, wall lines, anchor bolts for machinery, piping systems, utility lines (under and above ground) and associated features (manholes, shutoff valves, fire hydrants, light poles, etc.), drainage structures, curbs, etc.

When the corresponding *initial* design plans are prepared, grid coordinates and/or elevations may be cited for certain column line and/or arc intersections, pier or floor elevations, perimeter road centerlines and/or profiles, etc., as shown in Figure 2.4-4., so as to communicate the planned positions of these features to the layout and construction crews.

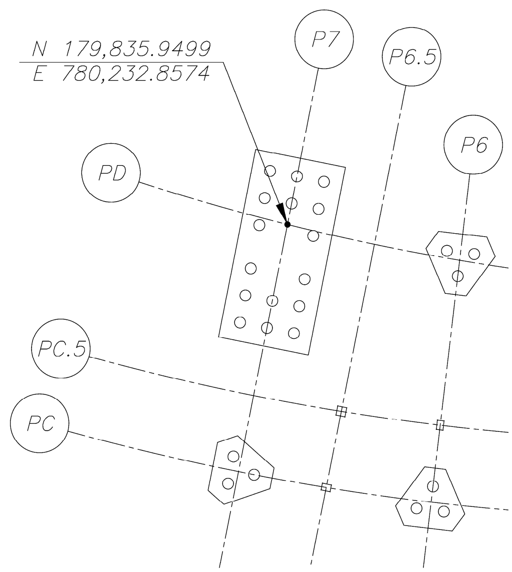



***Figure 2.4-4:*** *Column lines and arcs.*

When *future* design plans are prepared for improvements, such as facility expansion (horizontally and/or vertically), new machinery and assembly lines in existing space, rerouting piping systems, etc., the most intuitive workflow would be to simply perpetuate the horizontal and vertical datums *as originally determined*. By doing this, the coordinates and elevations listed on both old and new design plans for common column line intersections, wall lines, etc. will match. It would not only be impractical but also uneconomical to "update" these sites to a newer horizontal or vertical datum just for the sake of being on the most current datum or realization thereof. (That being said, being able to produce the values associated with the most current datum and realization for the survey control network marks may have its advantages at a facility such as this, e.g., being able to properly align aerial photography relative to both the NSRS and the project datum, communicating georeferenced data to public agencies' GIS, etc.)

Consider the changes in grid coordinates for NGS control station HATFIELD (PID HA0727) from the original NAD 83(1986) realization to the current realization, NAD 83(2011) epoch 2010.00 and the potential impact that magnitude could incur on a manufacturing facility. If a survey crew were to *mistakenly* layout column lines or other position-critical features respective to the NAD 83(2011) epoch 2010.00 realization when all original features were designed and built respective to NAD 83(86), all features would be in error/misconnected with existing features by approximately 0.71 feet. Depending upon construction tolerances for the specific application, this error may reveal itself later if it results in the misalignment of new and existing features.

The same concept applies vertically as it does horizontally. Citing the same mark, the difference between station HATFIELD's NGVD 29 and NAVD 88 values differ by 0.31 feet. Selecting the incorrect vertical datum on the same manufacturing facility would result in earthwork volumetric errors, possibly directing water to flow in the wrong direction, could set a finished floor below flood protection grade, vertically misalign critical features, etc.

***The potential horizontal and vertical discrepancies that could result from using the incorrect datum or realization for this site reinforces the importance of properly tying a robust, 3Dimensional, master survey control network to the National Spatial Reference System (NSRS) and preparing a thorough metadata table that lists not only the adjusted grid coordinates and orthometric heights of the survey control marks, but also the controlling horizontal and vertical datums, realizations, epochs, date of fieldwork, projection, foot definition, etc. and including it on survey plats, design plans, as-builts (record documents), etc., as the same concept is true for almost every local project site. With proper metadata, practitioners may have the ability to properly convert or transform georeferenced data (e.g., boundary corners, utility lines, aerial photography, etc.) to or from earlier or later datums, realizations, epochs, etc.***

"Local project sites" are not limited to manufacturing facilities with columns lines, building lines, etc. They can include Department of Transportation projects (highways, bridges, etc.), public utility facilities, county GIS, control networks for County Surveyor Section Corner perpetuation, commercial sites, residential subdivisions, boundary surveys, precision agriculture, etc.; however, this manufacturing facility provides an example of how projects based upon NAD 27 are still "active" yet today, and how projects based upon the InGCS, the SPCS, UTM, etc. today per the current realization of NAD 83 could very well still be valid and "active" even after the New Geometric Datum (NGD) is released circa 2022.

Concerning the SPCS, it will most likely be up to a consortium between the states and the National Geodetic Survey as to what changes are made, and even then, it may be on a state-by-state basis. Some states may elect to simply change the controlling datum from NAD 83 to the New Geometric Datum (whatever the official name) as well as their existing zones' False Northings and False Eastings. Other states may opt to reduce the number of SPCS zones until a maximum distortion threshold is met, or opt for a single zone covering the entire state. Depending upon the size, shape, terrain relief and terrain characteristics of a particular state, a single-zone LDP may rival or exceed the linear distortion performance of the existing, multi-zone SPCS for that state.

This approach could conceivably prove beneficial for certain statewide or regional GIS applications and statewide orthophotography projects that place more emphasis on geodata being properly and accurately georeferenced than the selected projection exhibiting the grid vs. ground performance preferred in land surveying and civil engineering projects; whereas geographically smaller, more numerous LDPs defined by county boundaries would primarily serve the local, design level of surveying, civil engineering, and GIS activities and applications where both accurately georeferenced data and grid vs. ground performance come into play. The end result could provide satisfactory results for both levels of industry as well as a seamless workflow between the two.

Concerning the parameters of the InGCS' zones, a simple and practical solution *may* be to conceptually mimic the changes that were made to the parameters of the East and West zones of the Indiana State Plane Coordinate System between NAD 27 and NAD 83, as follows:

- Change the controlling geometric datum from *the current realization of NAD 83* to *the current realization of the New Geometric Datum*.
- With the NGD's origin expected to be approximately 2.2 meters different than NAD 83's origin, the False Northings and False Eastings of the InGCS' zones should be changed significantly; otherwise, there would only be ±4' difference in grid coordinates between datums, which would doubtlessly cause needless confusion.
    - The existing False Northings and False Easting for all (NAD 83) InGCS zones are as follows:
        - False Northing: 36,000 m (118,110 U.S. Survey Feet) "exact"
        - False Easting: 240,000 m (787,400 U.S. Survey Feet) "exact"
    - A plausible alternative for the False Northings and False Northings of future (NGD) InGCS zones that would again likely satisfy the "Design Criteria for the InGCS" set forth in Chapter 5 is as follows:
        - False Northings: 152,400 m (499,999 U.S. Survey Feet) "exact"
        - False Eastings: 72,000 m (236,220 U.S. Survey Feet) "exact"
- Like the Indiana SPCS, all other parameters could remain the same.

These *minimal* changes would likely expedite inclusion in geospatial software systems and the EPSG Geodetic Parameter Dataset.

Users are encouraged to visit the URL listed near the beginning of this Section and attend education seminars, workshops, webinars, etc. for more information concerning the "New Datums" coming circa 2022.

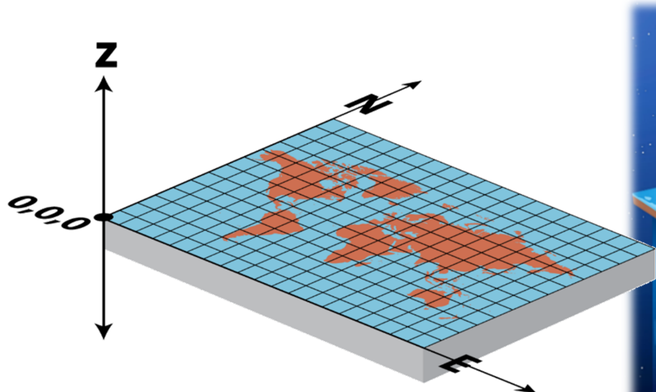
# Chapter 3 Map Projections

## 3.1 Flat Earth versus Spherical Earth and Map Projections

### 3.1.1 Flat Earth

Disregarding the fact that the Earth really is round (oblate spheroid), envision for a moment that the Earth were actually flat, i.e., not just conceptually or as projected on a flat map, but truly, realistically, (etc., etc.,) *flat*. This (alternate) reality would exhibit the following characteristics, in regards to "coordinate systems":

- With the Earth *already* flat, there would be no need to design map *projections* as there would be no spherical shape to project from.
- Since there would be no map *projections*, there would be no associated map *distortions*.
  - Directions...
  - Distances...
  - Areas...
  - Shapes would ***ALL BE TRUE!***
- Without zero map distortions:
  - "Grid=Ground" would be a reality.
  - Grid, elevation, and combined scale factors would not apply.
- There would potentially be no *need* for more than one, three-dimensional Cartesian coordinate system assigned (not *"projected"*) to cover the Earth.
  - One horizontal datum
    - One bearing system
    - One system of grid coordinates
  - One vertical datum




### 3.1.2 Spherical Earth and Map Projections

Returning to reality, the Earth is not flat; rather, *somewhat* spherical and is thus best represented on a globe. Map projections portray the curved surface of all or part of the Earth on a flat surface.

Seeing the proverbial glass half empty, all map projections misrepresent (or distorts) the Earth's curved surface in some form or fashion, i.e., *map distortion is unavoidable*. An example of distortion can be seen reviewing the relative sizes of Greenland, Mexico, and South America as projected onto Geradus Mercator's *Mercator* projection. It would *appear* that Greenland and South America are nearly the same size, when in fact Greenland's true area is much closer to that of Mexico.

However, seeing the glass half full, a map projection *can* preserve one or more of the following characteristics: directions, distances, areas, and shapes. Selecting the appropriate projection type for a specific purpose is in the hands of the practitioner. In the case of Mercator's projection, comparing relative sizes was never the *intent* of this projection. The Mercator projection was developed for navigation purposes, as any line drawn across the map would show a constant compass *direction*.

Map projections have a seemingly infinite number of applications, including world-wide navigation using a single map (as in the case of the Mercator projection), state-wide aerial photography, regional or county-wide low distortion projections and localized projects for design and construction.

## 3.2 Conformal Map Projections

In conformal map projections, linear distortion is the same in every direction. That is, the scale at any particular point is the same in any direction and figures on the surface of the Earth tend to retain their original form on the map.

Low distortion map projections (like those within the InGCS) are based on true conformal projections designed to cover specific portions of urban and rural areas of the state. The term "low distortion" refers to minimizing the linear horizontal distortion from two affects: 1) representing a curved surface on a plane, and 2) departure of the elevated topography from the projection surface due to variation in topographic height of the area covered.

The U.S. State Plane Coordinate System made sole use of the following three *conformal* map projections: transverse Mercator, oblique (Hotine) Mercator, and Lambert conformal conic, explained in the following three sections.

*(Dennis et al. 2014)*

### 3.2.1 Lambert Conformal Conic Projection

The Lambert conformal conic projection (created in 1772 by Johann Heinrich Lambert), is one of the most commonly used low distortion projections. As the name implies, the Lambert projection is conformal (preserves angles with a unique scale at each point). This projection superimposes a cone over the sphere of the Earth, with either one reference parallel tangent (or above the globe in the case of a low distortion projection) or with two standard parallels secant (a straight line that intersects with the globe in two places). Specifying a 'central meridian' orients the cone with respect to the ellipsoid.

Scale error (distortion with respect to the ellipsoid) is constant along the parallel(s). Typically, it is best used for covering areas long in the east–west direction, or, for low distortion applications, where topographic height changes more-or-less uniformly in the north-south direction. The Lambert conformal conic projection for relatively large regions, such as counties or groups thereof, is designed as a single parallel Lambert projection. The cone of the projection is typically scaled up from the ellipsoid to 'best fit' an area and range of topographic height on the Earth's surface.

*(Armstrong et al. 2014)*

### 3.2.2 Transverse Mercator Projection

The transverse Mercator (ellipsoidal) map projection was originally presented by mathematician Carl Friedrich Gauss in 1822. It is a conformal projection with a developable surface that can be visualized as a cylinder superimposed over the reference ellipsoid in a "transverse" orientation, i.e., with the cylinder axis in the equatorial plane. The curved surface of the cylinder coincides with a "central meridian" along which the scale is constant. This projection is used for many State Plane zones and the familiar UTM (Universal Transverse Mercator) map projection series, and it is probably one of the most commonly used projections for large-scale mapping. This projection works particularly well for areas long in the north–south direction, and for low distortion applications where topographic height changes more-or-less uniformly in the east-west direction.

*(Armstrong et al. 2014)*

### 3.2.3 Oblique Mercator (RSO) Projection

Various forms of the oblique Mercator (OM) projection have been developed, and the ellipsoidal form used for the OCRS (as well as State Plane) was published by Martin Hotine in 1947(8). Hotine called it the Rectified Skew Orthomorphic (RSO) projection, and it still goes by this name in some publications and software. It is an oblique form (rotated cylinder) of the Mercator conformal map projection. The 'Initial Line' is the centerline (projection skew axis) and is specified with <u>one point</u> and an <u>azimuth</u> (or skew angle) which may be positive or negative (right or left).

This projection is typically used for long linear features that run at an 'angle' to what would otherwise be normal north-south or east-west conventions. Here, the projection centerline is along a geodesic, at an oblique angle (rotated cylinder), and the process is to specify the projection local origin latitude and longitude together with the centerline (Initial Line) azimuth to be the line that runs parallel and centered near the alignment of the key object or landform such as a coast line, river, or island chain feature of the Earth. Along this Initial Line the scale is true (one) much like the normal Mercator projection and perpendicular from this line the scale varies from one.

This projection works well when the areas of study are relatively close to this line. The specified 'grid origin' is located where north and east axes are zero. In contrast, the 'natural origin' of the projected coordinates is located where the 'Initial Line' of the projection crosses the 'equator of the aposphere' (a surface of constant total curvature), which is near (but not coincident with) the ellipsoid equator. The ellipsoid is conformally mapped onto the aposphere, and then to a cylinder, which ensures that the projection is strictly conformal. However, unlike the TM projection, where the scale is constant along the central meridian, the scale (with respect to the ellipsoid) is not quite constant along the Initial Line (rather it is constant with respect to the aposphere). But the variation in scale along the Initial Line is small for areas the size of those states that have made use of the oblique Mercator projection for their SPCS or their LDPs, such as Alaska (SPCS) and Oregon (LDPs).

*(Armstrong et al. 2014)*

## 3.3 Two General Types of Map Projection Distortion

### 3.3.1 Linear distortion

The difference in horizontal distance between a pair of grid (map) coordinates when compared to the true (ground) horizontal distance is shown by δ in Tables 3.3.1-1 and 3.3.1-2 (and schematically in Figures 3.3.1-1 and 3.3.1-2). This may be expressed as a ratio of distortion length to ground length: E.g., feet of distortion per mile; parts per million (= mm per km). Note: 1 foot / mile = 189 ppm = 189 mm / km.

**Linear distortion can be positive or negative:**
Negative distortion means the grid (map) length is shorter than the “true” horizontal (ground) length. Positive distortion means the grid (map) length is longer than the “true” horizontal (ground) length.

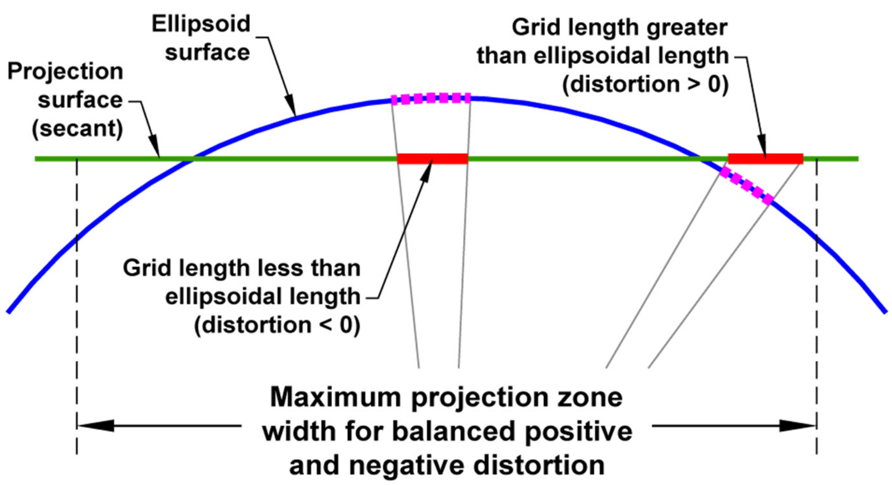



***Figure 3.3.1-1:*** *Linear Distortion due to Earth curvature. (Image courtesy of Michael Dennis.)*

***Table 3.3.1-1:*** *Maximum linear distortion for various projection zone widths.*

| Maximum zone width for secant projections (km and miles) | Maximum linear horizontal distortion, δ | | |
|---|---|---|---|
| | Parts per Million (mm/km) | Feet per mile | Ratio (absolute value) |
| 25 km (16 miles) | ±1 ppm | ±0.005 ft/mile | 1 : 1,000,000 |
| 57 km (35 miles) | ±5 ppm | ±0.026 ft/mile | 1 : 200,000 |
| 81 km (50 miles) | ±10 ppm | ±0.05 ft/mile | 1 : 100,000 |
| 114 km (71 miles) | ±20 ppm | ±0.1 ft/mile | 1 : 50,000 |
| 180 km (112 miles) | ±50 ppm | ±0.3 ft/mile | 1 : 20,000 |
| 255 km (158 miles) e.g., SPCS* | ±100 ppm | ±0.5 ft/mile | 1 : 10,000 |
| 510 km (317 miles) e.g., UTM† | ±400 ppm | ±2.1 ft/mile | 1 : 2,500 |

*State Plane Coordinate System; zone width shown is valid between ~0° and 45° latitude
†Universal Transverse Mercator; zone width shown is valid between ~30° and 60° latitude

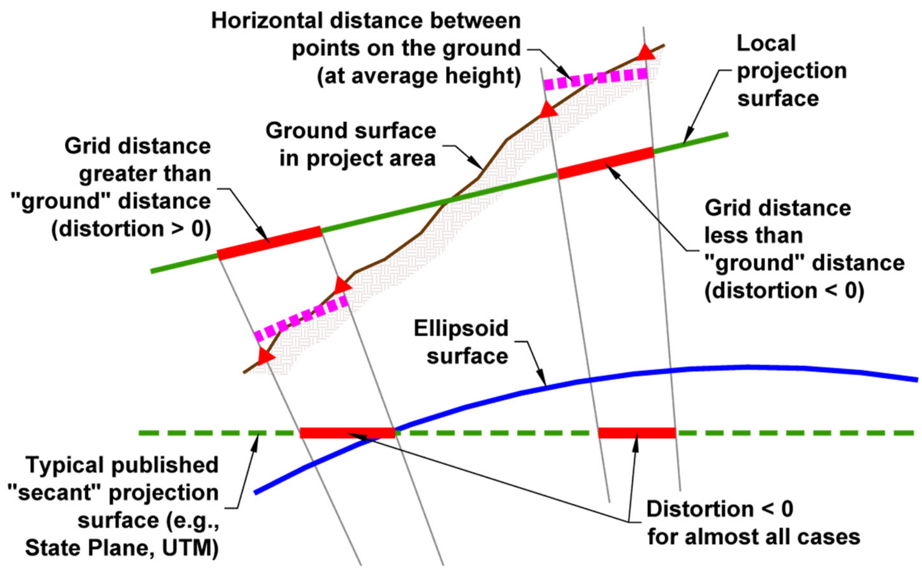



***Figure 3.3.1-2:*** *Linear Distortion due to Earth curvature. (Image courtesy of Michael Dennis.)*

***Table 3.3.1-2:*** *Linear distortion at various heights with respect to projection surface.*

| Height below (-) and above (+) projection surface | Maximum linear horizontal distortion, δ | | |
|---|---|---|---|
| | Parts per Million (mm/km) | Feet per mile | Ratio (absolute value) |
| ±30 m (±100 ft) | ± 4.8 ppm | ±0.025 ft/mile | ~1 : 209,000 |
| ±120 m (±400 ft) | ±19 ppm | ±0.10 ft/mile | ~1 : 52,000 |
| ±300 m (± 1,000 ft) | ±48 ppm | ±0.25 ft/mile | ~1 : 21,000 |
| +600 m (+ 2,000 ft)* | -96 ppm | -0.50 ft/mile | ~1 : 10,500 |
| +1,000 m (+ 3,300 ft)** | -158 ppm | -0.83 ft/mile | ~1 : 6,300 |
| +4,400m (+ 14,400 ft)† | -688 ppm | -3.6 ft/mile | ~1 : 1,500 |

*Approximate mean topographic height of North America (US, Canada, and Central America)
**Approximate mean topographic height of western coterminous US (west of 100° longitude)
†Approximate maximum topographic height in coterminous US

***Rule of Thumb:*** A 30 m (100-ft) change in height causes a 4.8 ppm change in linear distortion

Creating an LDP and minimizing distortion by the methods described in this document only makes sense for conformal projections. For conformal projections (e.g., transverse Mercator, Lambert conformal conic, Stereographic, oblique Mercator, regular Mercator, etc.), linear distortion is the same in every direction from a point. For all non-conformal projections (such as equal area projections), linear distortion generally varies with direction, so there is no single unique linear distortion (or "scale") at any point.

*(Dennis et al. 2014)*

### 3.3.2 Angular Distortion

For conformal projections, this equals the convergence (mapping) angle (γ). The convergence angle is the difference between grid (map) north and true (geodetic) north. Convergence angle is zero on the projection central meridian, positive east of the central meridian, and negative west of the central meridian, as shown in Table 3.3.2-1.

The magnitude of the convergence angle increases with distance from the central meridian, and its rate of change increases with increasing latitude.

Table 3.3.2-1 shows "convergence angles" at a distance of one mile (1.6 km) east (positive) and west (negative) of projection central meridian (for both transverse Mercator and Lambert conformal conic projections).

***Table 3.3.2-1:*** *Convergence angle 1 mile from central meridian at varying latitudes.*

| Latitude | Convergence angle 1 mile from CM | Latitude | Convergence angle 1 mile from CM |
|---|---|---|---|
| 0° | 0° 00' 00" | 50° | ±0° 01' 02" |
| 10° | ±0° 00' 09" | 60° | ±0° 01' 30" |
| 20° | ±0° 00' 19" | 70° | ±0° 02' 23" |
| 30° | ±0° 00' 30" | 80° | ±0° 04' 54" |
| 40° | ±0° 00' 44" | 89° | ±0° 49' 32" |

Usually, convergence is not as much of a concern as linear distortion, and it can only be minimized by staying close to the projection central meridian (or limiting surveying and mapping activities to equatorial regions of the Earth). Note that the convergence angle is zero for the regular Mercator projection, but this projection is not suitable for large-scale mapping in non-equatorial regions. In topographically-rugged areas (such as much of the western U.S.), distortion due to variation in ground height is greater than that due to curvature. ***The total linear distortion of grid (map) coordinates is a combination of distortion due to Earth curvature and distortion due to ground height above the ellipsoid.***

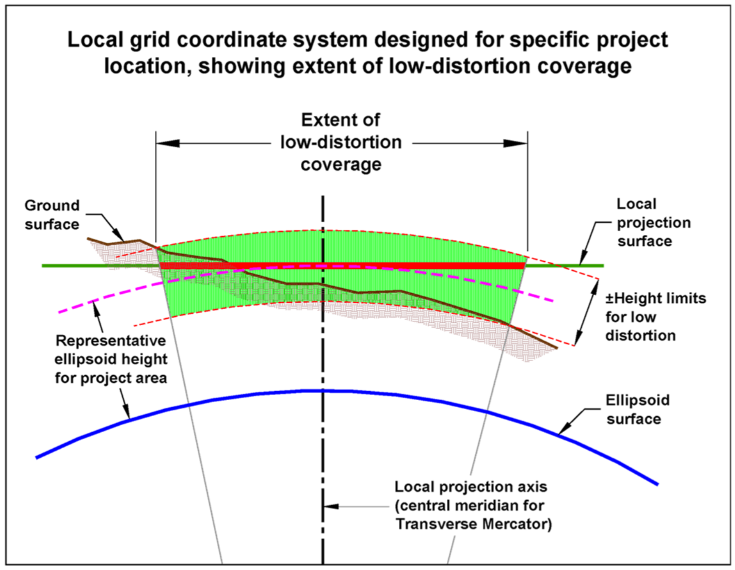
*(Dennis et al. 2014)*

## 3.4 Six Steps for Designing a Low Distortion Projection (LDP)

The following "Six Steps" are from Michael Dennis' (2016), "*Ground Truth – Optimized Design of Low Distortion Projections Version 23 (rev 2)*" (p. 12-17).

**1. Define distortion objective for area of interest and determine *representative* ellipsoid height, $h_0$ (not elevation)**

**Note:** *This is just to get the design process started.* Ellipsoid height by itself is unlikely to yield the final design scale, except for small areas, due to curvature and/or systematic change in topographic height.




*Effect of scaling the projection to a representative height above the ellipsoid. (Image courtesy of Michael Dennis.)*

- A common objective for "low distortion" is ±20 ppm (±0.1 ft/mile), but this may not be achievable due to range of topographic height and/or size of design area. The following "rules of thumb" can help guide the initial design. However, often it is possible to achieve better results than these guidelines indicate, because both height and areal extent affect distortion simultaneously, and one can be used to compensate for the other.
    - Size of design area. **Distortion due to curvature is within ±5 ppm for an area 35 miles wide.** Note that this width is perpendicular to the projection axis (e.g., east-west for TM and north-south for LCC projections. The effect is not linear; range of distortion due to curvature increases rapidly with increasing zone width and is proportional to the square of the zone width, i.e., doubling the zone width increases the distortion by about a factor of four (for this case, doubling zone width to 70 miles quadruples the distortion range to about ±20 ppm).
    - Range in topographic ellipsoid height. **Distortion due to change in topographic height is within about ±5 ppm for a ±100 ft range in height.** Note that this is essentially linear, i.e., a range of ±400 ft in height corresponds to a range of about ±20 ppm distortion.
- The average height of an area may not be appropriate (e.g., for projects near a mountain).
    - There is no need to estimate height to an accuracy of better than about ±20 ft (±6 m); this corresponds to about 1 ppm distortion. In addition, the initial projection scale determined using this height will likely be refined later in the design process.

**2. Choose projection type and place projection axis near centroid of project area**

**NOTE:** *This is just to get the design process started.* In cases where the topography generally changes in one direction, offsetting the projection axis can yield substantially better results.

- Select a well-known and widely-used *conformal* projection, such as the transverse Mercator (TM), Lambert conformal conic (LCC), or Oblique Mercator (OM).
    - When minimizing distortion, it will not always be obvious which projection type to use, but for small areas (< ~35 miles or ~55 km wide perpendicular to the projection axis), usually both the TM and LCC will provide satisfactory results. However, significantly better performance can be obtained in many cases when a projection is used with its axis perpendicular to the general topographic slope of the design area (more on this below).
    - In nearly all cases, a two-parallel LCC should ***not*** be used for an LDP with the NAD 83 datum definition (but note that some software may not support a one-parallel LCC). A two-parallel LCC should not be used because the reason there are two parallels is to make the projection secant to the ellipsoid (i.e., the central parallel scale is less than 1). This is at odds with the usual objective of scaling the projection so that the developable surface is at the topographic surface, which is typically above the ellipsoid, particularly in areas where reduction in distortion is desired.
    - The OM projection can be very useful for minimizing distortion over large areas, especially areas that are more than about 35 miles (55 km) long in an oblique direction. It can also be useful in areas where the topographic slope varies gradually and more-or-less uniformly in a direction other than north-south or east-west. The disadvantage of this projection is that it is more difficult to evaluate, since another parameter must be optimized (the projection skew axis azimuth). In addition, this projection is more complex, and may not be available in as many software packages as the TM and LCC projections.
    - The oblique stereographic projection can also be used, but it is highly unlikely that it will perform better than the TM, LCC, or OM projections since it does not curve with the Earth in *any* direction.
    - When choosing a projection, bear in mind that universal commercial software support, although desirable, is not an essential requirement for selecting a projection. In the rare cases where third parties must use a coordinate system based on a projection not supported in their software, it is possible for them to get on the coordinate system implicitly, for example by using a best-fit procedure based on coordinate at common points (i.e., “calibration” or “localization”).
- Placing the projection axis near the design area centroid is often a good first step in the design process (or, for the OM projection, parallel to the long axis of the design area).
    - In cases where topographic height increases more-or-less uniformly in one direction, dramatically better performance can be achieved by offsetting the projection axis from the project centroid. In such cases a projection type should be chosen such that its projection axis is perpendicular to the topographic slope (e.g., for topography sloping east-west, a TM projection should be used; for slope north-south an LCC projection should be used. The axis is located such that the developable surface best coincides with the topographic surface.
    - Often the central meridian of the projection is placed near the east-west “middle” of the project area in order to minimize convergence angles (i.e., the difference between

geodetic and grid north). The central meridian is the projection axis only for the TM projection; its location has no effect on distortion for the LCC projection.

3. **Scale projection axis to representative ground height, $h_0$**

**NOTE:** *This is just to get the design process started.* Ellipsoid height by itself is unlikely to yield the final design scale, except for small areas, due to curvature and/or systematic change in topographic height.

- Compute map projection axis scale factor "at ground": $k_0 = 1 + \frac{h_0}{R_G}$
  - For TM projection, $k_0$ is the central meridian scale factor.
  - For one-parallel LCC projection, $k_0$ is the standard (central) parallel scale factor.
  - For OM projection, $k_0$ is the scale at the local origin.
- $R_G$ is the geometric mean radius of curvature, $R_G = \frac{a\sqrt{1-e^2}}{1-e^2 \sin^2 \varphi}$ , where

  $\varphi$ = geodetic latitude of point, and for the GRS 80 ellipsoid:
  $a$ = semi-major axis = 6,378,137 m (exact)
  $e^2$ = first eccentricity squared = $2f - f^2$
  $f$ = geometric flattening = 1 / 298.257222101

- Alternatively, can initially approximate $R_G$ since $k_0$ will likely be refined in Step #4:

***Table 3.4-1:*** *Geometric mean radius of curvature at various latitudes for the GRS 80 ellipsoid.*

| Latitude | $R_G$ (meters) | $R_G$ (feet) | Latitude | $R_G$ (meters) | $R_G$ (feet) |
|---|---|---|---|---|---|
| 0° | 6,357,000 | 20,855,000 | 50° | 6,382,000 | 20,938,000 |
| 10° | 6,358,000 | 20,860,000 | 60° | 6,389,000 | 20,961,000 |
| 20° | 6,362,000 | 20,872,000 | 70° | 6,395,000 | 20,980,000 |
| 30° | 6,367,000 | 20,890,000 | 80° | 6,398,000 | 20,992,000 |
| 40° | 6,374,000 | 20,913,000 | 90° | 6,400,000 | 20,996,000 |

4. **Compute distortion throughout project area and refine design parameters**

- Distortion computed at a point (at ellipsoid height h) as $\delta = k\left(\frac{R_G}{R_G+h}\right) - 1$
  - Where $k$ = projection grid point scale factor (i.e. distortion with respect to ellipsoid at a specific point). Note that computation of $k$ is rather involved, and is often done by commercially available software.
  - Multiply $\delta$ by 1,000,000 to get distortion in parts per million (ppm).
- Best approach is to compute distortion over entire area and generate a distortion map (this ensures optimal low-distortion coverage).
  - Often requires repeated evaluation using different $k_0$ values.
  - May warrant trying different projection axis locations and different projection types.
- General approach for computational refinement:
  - Compute distortion statistics, such as mean, range, and standard deviation.
  - Changing the projection scale only affects the mean distortion; it has essentially no effect on the variability (standard deviation and range).
  - The only way to reduce distortion variability is by moving the projection axis and/or changing the projection type. The usual objective is to minimize the distortion standard deviation and range. Once this is done, the scale can be changed so that the mean distortion is near zero.

  - Finally, check to ensure the desired distortion is achieved in important areas, and also check to ensure overall performance is satisfactory (using a map showing distortion everywhere in the design area).

5. **Keep the definition SIMPLE and CLEAN!**
   - Define $k_0$ to no more than SIX decimal places, e.g., 1.000175 (exact).
     - *Note:* A change of one unit in the sixth decimal place (±1 ppm) equals distortion caused by a 20 ft (6 m) change in height.
     - For large areas with variable relief, scale defined to five decimal places (±10 ppm) is often sufficient.
   - Define the central meridian and latitude of grid origin to nearest whole arc-minute; for moderate to large areas they can often be defined to the nearest five arc minutes (e.g., central meridian = 121°15’00” W).
   - Define grid origin using whole values with as few digits as possible (e.g., false easting = 50,000 for a system with maximum easting coordinate value < 100,000). Note that the grid origin definition has no effect *whatsoever* on the map projection distortion.
     - It is strongly recommended that the coordinate values everywhere in the design area be distinct from other coordinate system values for that area (such as State Plane or UTM) in order to reduce the risk of confusing the LDP with other systems. For multi-zone LDPs, it could similarly be helpful to keep coordinates between the zones distinct, if possible.
     - Often it is desirable to define grid origins such that the northings and eastings do not equal one another anywhere in the design area.
     - In some applications, there may be an advantage to using other criteria for defining the grid origin. For example, it may be desirable for all coordinates in the design area to have the same number of digits (such as six digits, i.e., between 100,000 and 999,999). In other cases it may be useful to make the coordinates distinct from State Plane by using larger rather than smaller coordinates, especially if the LDP covers a very large area. In multi-zone systems, it may also be helpful to define grid origins such that the values correlate to zone numbers (e.g., a false easting of 3,000,000 m for a zone designated as #3). This approach was used for the Iowa Regional Coordinate System (Dennis et al., 2014).
6. **Explicitly define linear unit and geometric reference system (i.e., geodetic datum)**
   - Linear unit, e.g., meter (or international foot, or US survey foot, or…?)
     - The international foot is shorter than the US survey foot by 2 ppm. Because coordinate systems typically use large values, it is critical that the type of foot used be identified (the values differ by 1 foot per 500,000 feet).
     - Because of the possibility of confusion between the international and US survey foot, it is recommended that the design parameters for the LDP be in meters (this approach is used in most State Plane zones). Output coordinates can then be specified for which type of foot is desired. It can be difficult to detect an implementation that used the incorrect type of foot, since they differ by only 2 ppm.
   - Geometric reference system (geodetic datum), e.g., North American Datum of 1983 (NAD 83)
     - The reference system realization (i.e., “datum tag”) should not be included in the coordinate system definition (just as it is not included in State Plane definitions). However, the datum tag is an essential component for defining the spatial data used within the coordinate system. For NAD 83, the NGS convention is to give the datum tag in parentheses after the datum name, usually as the year in which the datum was

"realized" as part of a network adjustment. Common datum tags for NGS control are listed below:
    - "2011" for the current NAD 83 (2011) epoch 2010.00 realization, which is referenced to the North America tectonic plate.
    - "2007" for the (superseded) NSRS2007 (National Spatial Reference System of 2007) realization. Functionally equivalent to the superseded "CORS" datum tag and referenced to an epoch date of 2002.00 for most of the coterminous US.
    - "199x" for the various supersede HARN (or HPGN) realizations, where x is the last digit of the year of the adjustment (usually done for a particular state). HARN is "High Accuracy Reference Network" and HPGN is "High Precision Geodetic Network".

- The objective of LDP design is to cover the largest area with the least distortion possible. These goals are at odds with one another, since distortion increases as the size of the projected area increases. Thus LDP design is an optimization problem that does not typically yield a single unique "best" solution. Because of this, it is important that LDPs be designed collaboratively to allow input of all stakeholders affected by the design. This allows stakeholders to work together and resolve conflicting objectives and select optimal designs before a system is finalized. An added benefit to this approach is that the participants gain "ownership" over the design which leads to greater satisfaction in the final product. This is all important because once a design is implemented, it can be very difficult to change, especially since the design can be incorporated into project plans, software, and even state statute.

# Chapter 4 History of Coordinate Systems at the Indiana DOT

## 4.1 Alignments

Prior to the introduction of electronic distance measuring instruments (EDMIs, or EDMs), total stations, electronic data collection devices, Global Positioning Systems (GPS), Global Navigation Satellite Systems (GNSS), LiDAR, and computerized mapping on INDOT projects, most plans and maps were prepared using 2D (horizontal) alignments based upon arbitrary directions or directions based upon north (from magnetic, solar, or Polaris observations) by employing transits or theodolites, engineer's steel tapes, dumpy levels, right angle prisms, and other survey equipment. The field notes and sketches were then manually reduced while calculations were performed with slide rules, curve tables, etc. The final products were hand drafted using the stations and offsets from the horizontal alignments. There was no real geographic basis to this system.

*(Dennis et al. 2014)*

## 4.2 Arbitrary Plane Coordinate Systems

Soon after the introduction of electronic data collection devices and computerized mapping on INDOT projects, it was realized that utilizing plane coordinate systems made mapping easier than solely using alignments with curves and angles. While it made mapping easier, there was still no geographic basis, i.e., there was no direct tie between project coordinates and values of latitude and longitude. Each project had its own coordinate system that had an arbitrary origin and an estimated relationship to north.

For example, a physical survey marker at the extreme southwest corner of a project's limits could have been arbitrarily assigned project coordinates of North 5,000.000 East 5,000.000, while "project north" could have been based upon the direction from this marker to another marker somewhere else in the project, a bearing continued from a previous DOT project, Polaris observation, recorded deed, etc. There was also no quick way of tying these projects together, so all these various projects could be thought of as independent pieces of a geographic puzzle that future practitioners would be burdened with by having to spend additional time determining how they correctly fit together (see Figure 4.2-1).

***Figure 4.2-1:*** *Fitting surveys with arbitrary plane coordinate systems together.*

*(Dennis et al. 2014)*

## 4.3 Indiana State Plane Coordinate Systems

In a paper presented before the Surveying and Mapping Division of the American Society of Civil Engineers in 1935, it was reported that during 1932 and 1933, at the request of an engineer employed by the North Carolina Highway Commission, the Coast and Geodetic Survey cooperated with the State of North Carolina to develop a system of plane coordinates. This led to development of state plane coordinate systems for the 48 states and was completed in 1934.

In September 1936, the Federal Board of Surveys and Maps made a recommendation that its member organizations adopt the system of plane coordinates devised for each state by the Coast and Geodetic Survey. It was also recommended that, wherever practicable, they show the appropriate State Plane Coordinate Systems as supplementary projections on all maps and charts produced by them which may have value and use for engineering purposes, but which because of their nature or extent require a geographic base.

When INDOT began considering the National Geodetic Survey's state plane coordinate systems for Indiana (East and West zones) as foundations for survey control on its projects, design engineers and surveyors were concerned that differences in length would be too noticeable when compared with computed inverses between state plane coordinate pairs and distances measured using modern survey equipment.

Although not preferred for use on INDOT *survey* projects, the Indiana State Plane Coordinate System still maintains some *limited* advantages for general mapping and aerial imagery applications at a statewide level. Examples include:

- Depicting physical, cultural, and human geography over large areas of the state.
- Works well for mapping long linear facility lines such as highways, electrical transmission, and pipelines, which crisscross the state.
- Provides for a common reference (map projection) for conversions and transformations between other coordinate systems (including the zones of the InGCS).

*(Dennis et al. 2014)*

### 4.3.1 Indiana State Plane Coordinate Systems Definitions

**INDIANA EAST ZONE (Designation 1301)**
Indiana State Plane East – North American Datum of 1983 (NAD 83)
Transverse Mercator Projection

| | |
|---|---|
| Central Meridian: | 85° 40’ 00” W |
| Central Meridian Scale Factor: | (1-(1/30,000)) |
| Latitude of Grid Origin: | 37° 30’ 00” N |
| False Northing: | 250,000 m |
| False Easting: | 100,000 m |
| Max scale error: | ±30 ppm |

***Note:*** The above listed maximum scale error is distortion with respect to the ellipsoid, occurring along the central meridian, not the topographic surface. The actual linear distortion at the topographic surface is typically greater, with an approximate ceiling of 80 ppm for the Indiana East zone, and it changes at a rate of ±4.8 ppm per 100-ft change in height.

**East Zone County Coverage:**
Adams, Allen, Bartholomew, Blackford, Brown, Cass, Clark, Dearborn, Decatur, DeKalb, Delaware, Elkhart, Fayette, Floyd, Franklin, Fulton, Grant, Hamilton, Hancock, Harrison, Henry, Howard, Huntington, Jackson, Jay, Jefferson, Jennings, Johnson, Kosciusko, LaGrange, Madison, Marion, Marshall, Miami, Noble, Ohio, Randolph, Ripley, Rush, St. Joseph, Scott, Shelby, Steuben, Switzerland, Tipton, Union, Wabash, Washington, Wayne, Wells, Whitley

**INDIANA WEST ZONE (Designation 1302)**
Indiana State Plane West –North American Datum of 1983 (NAD 83)
Transverse Mercator Projection

| | |
|---|---|
| Central Meridian: | 87° 05’ 00” W |
| Central Meridian Scale Factor: | (1-(1/30,000)) |
| Latitude of Grid Origin: | 37° 30’ 00” N |
| False Northing: | 250,000 m |
| False Easting: | 900,000 m |
| Max scale error: | ±30 ppm |

***Note:*** The above listed maximum scale error is distortion with respect to the ellipsoid, occurring along the central meridian, not the topographic surface. The actual linear distortion at the topographic surface is typically greater, with an approximate ceiling of 70 ppm for the Indiana West zone, and it changes at a rate of ±4.8 ppm per 100-ft change in height.

**West Zone County Coverage:**
Benton, Boone, Carroll, Clay, Clinton, Crawford, Daviess, Dubois, Fountain, Gibson, Greene, Hendricks, Jasper, Knox, Lake, LaPorte, Lawrence, Martin, Monroe, Montgomery, Morgan, Newton, Orange, Owen, Parke, Perry, Pike, Porter, Posey, Pulaski, Putnam, Spencer, Starke, Sullivan, Tippecanoe, Vanderburgh, Vermillion, Vigo, Warren, Warrick, White

## 4.4 Modified State Plane Coordinate Systems

One solution to this problem, although geodetically “messy” (so to speak), is to create a “Modified State Plane Coordinate System (MSPCS)” for each project. There are several technical variations of MSPCS (some of which are listed below), but they all involve modifying the native SPCS so that horizontal ground distances match very closely to project grid coordinate inverses of the modified system within the limits of the specific projects, otherwise known as “scaling to ground.” Other than horizontal ground distances matching very closely to project coordinate inverses within these projects, this solution retains the orientation (a.k.a. “basis or bearings”) of each project to the native state plane coordinate system zone’s grid bearings. The MSPCS has been the most prevalent approach conducted on INDOT survey projects, particularly since GNSS use has become more widespread on survey projects, and even more so after the publication of the Indiana High Accuracy Reference Network (HARN) by the National Geodetic Survey as NAD 83(1997).

MSPCS Method #1: One method of creating a MSPCS is to scale all the project coordinates about the true or natural origin or the SPCS (i.e., North 0.000, East 0.000) by a factor that will closely agree with survey measurements. This method provides project coordinates that closely agree with survey measurements, but it also causes confusion. Although the project coordinates may indeed “look” like valid state plane coordinates for the project region, they can vary from the “true” state plane coordinates in the magnitude of several feet.

MSPCS Method #2: Another method is to select a point central to the project limits, hold it fixed to its actual state plane coordinate values, and then scale all other project coordinates about it by a factor that will closely agree with survey measurements. While this gives each project a true geographic basis at one central point (state plane coordinates = project coordinates), it creates the potential for causing confusion. One concern is that scaled project coordinates can be mistaken for true state plane coordinates, as they may be "relatively" close to one another, e.g., less than a foot.

In either of these first two methods, if subsequent users were to assume that these projects' "project coordinates" were state plane coordinates and then use other survey control that in fact have "true" state plane coordinates to collect supplemental survey data or perform constructing staking activities, there could be very costly mistakes made. In the case of construction staking, features such as a building structure, levee wall, underground pipeline, etc. could be constructed in the incorrect location relative to the original project control and coordinates that the design or construction plans were based upon.

MSPCS Method #3: Yet another method is to select a point somewhat central to the project limits, truncate the numerically-large state plane coordinates of that point to smaller values, and then scale all other project coordinates about it by a factor that will closely agree with survey measurements. Take for example Station HATFIELD in Table 4.4-1:

***Table 4.4-1: Truncated values of Station HATFIELD.***

| NGS Station "HATFIELD" (PID "HA0727") | |
|---|---|
| NAD 83(2011) epoch 2010.00<br>Indiana State Plane, West Zone Coordinates<br>U.S. Survey Feet | Truncated<br>Project Coordinates<br>U.S. Survey Feet |
| North 967,030.61 | North 67,030.61 |
| East 2,906,870.43 | East 6,870.43 |

Like the first two methods, this provides project coordinates that will closely agree with survey measurements, but there is now a substantially-reduced chance of confusing project coordinates with state plane coordinates. A drawback of this method is in its defining characteristic, i.e., none of the points within the project limits have a true geographic basis (state plane coordinates ≠ project coordinates), making it more difficult to quickly and seamlessly overlay geographic imagery.

Although the basic concept of creating MSPCS may be advantageous to very closely match horizontal ground distances with project coordinates on a project-to-project basis, it has historically impeded workflows and been the culprit of confusion, frustration, and errors by subsequent practitioners. The exact details of how the native state plane coordinates were modified would need to be reproduced for each new user agency or company when working on these projects. MSPCS created for local projects are, by their very design, local in usefulness. The "closeness" of horizontal ground distances matching project grid coordinate inverses can quickly diminish as the horizontal limits of the original project region are increased. This is particularly the case if the terrain heights change significantly or if the project is long in a direction perpendicular to the SPCS projection axis (e.g., central meridian of transverse Mercator systems).

In addition, once a native SPCS is "modified," it is no longer truly geographic (native coordinates ≠ project coordinates ≠ latitude and longitude), which causes problems when combining with other datasets. For example, geographic imagery overlays would only be approximate, and properly tying adjacent projects together that have differently-created MSPCS would be unnecessarily difficult.

*(Dennis et al. 2014)*

***Retaining the direct tie between project coordinates as determined from the native (published) map projection parameters and the underlying geometric datum's positions of latitude and longitude goes hand in hand with referencing the project to the NSRS and is a critical element in creating a seamless workflow between users in various geospatial industries, as well as utilizing legacy project data in future projects.***


## 4.5 Site-Specific Low Distortion Projections (Micro-LDPs)

Though seldom used to conduct INDOT survey projects, Site-Specific Low Distortion Projections are another approach to provide project grid coordinate inverses that match very closely to horizontal ground distances. Site-Specific LDPs, like SPCS, should be based upon conformal map projections, such as the transverse Mercator, Lambert conformal conic and the oblique Mercator. Similar to MSPCS, Site-Specific LDPs should yield project coordinates that do not resemble SPCS within the same local area.

Site-Specific LDPs can offer both the convenience of retaining the tie between project coordinates and the underlying geometric datum's positions of latitude and longitude, along with providing project grid coordinate inverses that match very closely to horizontal ground distances; however, there are two major drawbacks associated with Site-Specific LDPs. Like MSPCS, Site-Specific LDPs are by their own design, local in usefulness. Also like MSPCS, because Site-Specific LDPs are designed for specific local projects, their projection parameters are typically only available by specifically submitting requests to the appropriate local public agencies (if in the cases of public projects), researching local courthouses for survey plats pertaining to those projects, or contacting those who were involved in those projects. For future users to properly work on these projects or make use of legacy data contained within them, they will need these parameters to input into their geospatial software systems.

***Future users in different geospatial industries would have a seamless workflow if the geodetic parameters of a Site-Specific LDPs were officially approved and adopted by the proper governing entity, such as a state's DOT, and then made available in commercial geospatial software.***

## 4.6 Proliferation of Local Project Coordinate Systems

In addition to the disadvantages listed in the previous sections for local project coordinate systems, all of these approaches conceivably have ***no limit*** in the proliferation of *dissimilar* coordinate systems, regardless of size, shape, *or in proximity to or overlapping of other local projects* (even if they are all based on the same geometric datum). Moreover, the chances are exceedingly slim that any of these dissimilar local systems would ever be officially approved and adopted by a local, state, or federal agency and/or be made available in commercially-available geospatial software. Take for example Figure 4.6-1 below.

***Figure 4.6-1:*** *Various industries and land developments.*

Several different industries and land developments are shown in this graphic. There is a corresponding multitude of diverse planning, surveying, engineering, construction, etc. projects that could occur either simultaneously or sequentially within this relatively small geographical region.

Consider in nearly all of the surveying projects involved in this close vicinity that the decisions had been actively and purposefully made to decline the use of available UTM or State Plane Coordinate Systems because of their poor grid vs. ground performance. In lieu of these *predefined* systems, a combination of the aforementioned local project coordinate systems had instead been *custom designed* for each project; all with the same *individual* goals of minimizing the differences between their projects' grid coordinates and horizontal ground distances *within their respective project limits*. The following notable workflow hindrances would then result:

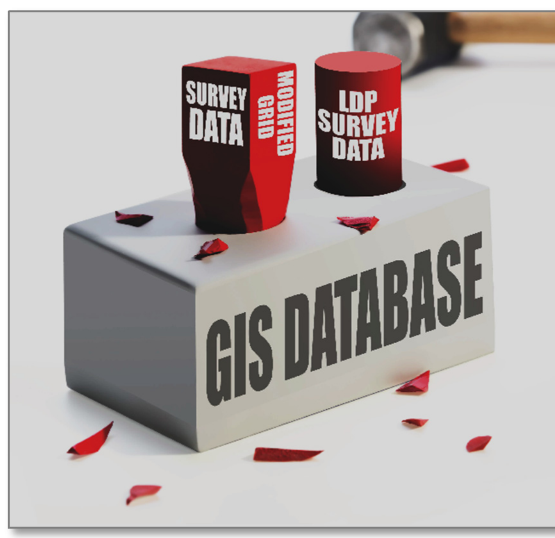
- No common grid coordinate system, i.e., northings and eastings.
- No common bearing system
- Unnecessary difficulties in relating one system to another *or* to the appropriate city or county GIS system (which may have been based upon UTM or State Plane *simply* because they were *predefined* in the GIS software)

### 4.7 Regional Low Distortion Projections


Somewhat of a combination of the most attractive characteristics of State Plane Coordinate Systems and Site-Specific LDPs are Regional Low Distortion Projections (LDPs). Regional LDPs are, for the most part, designed to cover regions larger than MSPCS or Site-Specific LDPs, and are usually defined nominally by political boundaries, such as counties, but can be designed to complement a specified terrain region, with no consideration of political boundaries. Prior to the InGCS, there were but few LDPs used on INDOT projects, most of which were seated in southwestern Indiana.

Regional LDPs (like those within the InGCS) should be based on true conformal map projections designed to cover specific portions of urban and rural areas of the state. As stated elsewhere in this document (and again here for emphasis), for conformal projections (e.g., transverse Mercator, Lambert conformal conic, Stereographic, oblique Mercator, regular Mercator, etc.), linear distortion is the same in every direction from a point. That is, the scale at any particular point is the same in any direction and figures on the surface of the Earth tend to retain their original form on the map. The term “low distortion” refers to minimizing the linear horizontal distortion from two affects: 1) representing a curved surface on a plane and 2) departure of the elevated topography from the projection surface due to variation in topographic height of the area covered.

The advantages of Regional LDPs include:



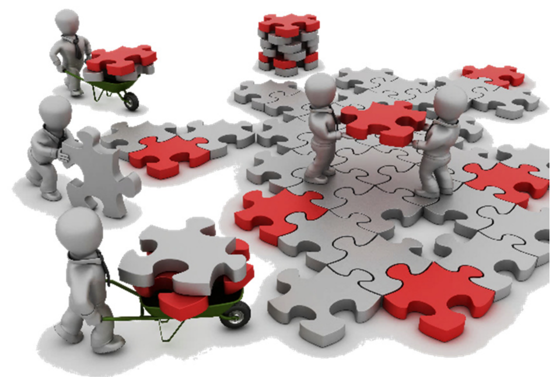

- Grid coordinate distances closely match horizontal distances measured on the ground, satisfying the grid vs. ground performance preferred on land surveying and civil engineering projects.
- Allows for larger areas to be covered with less distortion.
- Reduced convergence angle (depending upon the location of the central meridians being compared).
- “Clean” zone parameter definitions compatible with common surveying, engineering, and GIS software.
- Ease in converting between other coordinate reference systems of the same geometric datum and transforming between other datums.
- Retains the direct tie between project coordinates and the underlying geometric datum’s positions of latitude and longitude.
- Maintains a relationship to the National Spatial Reference System (NSRS)
- Can cover entire cities, counties, and states (in some instances), making them useful for regional mapping and GIS.

An LDP or set of LDPs is most successful when they are made available in most, if not all, geospatial software platforms. Without being made easily accessible in software by the appropriate vendors, it is likely that many users would just as well keep to the status quo of creating modified state plane systems or employing other methods for project coordinate systems.

*(Dennis et al. 2014)*

***If an LDP or set of LDPs (such as the InGCS) is officially approved and adopted by the proper governing agency (such as INDOT) they may very likely be considered for inclusion in the International Association of Oil & Gas Producer's (IOGP) EPSG Geodetic Parameter Dataset and in future versions of proprietary geospatial software vendors' platforms.***

*With these important milestones, an LDP system is set to be a mechanism for a seamless workflow between users within different geospatial industries.*



# Chapter 5 Emergence of the InGCS

## 5.1 Additional Map Projections in the Hoosier State

With map projections being in practice for centuries, many may wonder why *new* maps projections are being added and what is the "best" number of map projections? The answer? Well, it depends.

If the intent is simple navigation without respect to areas or shapes of large areas, then the single, world-wide Mercator projection as shown in Figure 5.1-1 *may* work best. If areas and shapes of large areas were a desired characteristic, then the Mercator projection would not be the best choice, as distortion increases away from the Equator. A simple example is to compare the portrayed areas of Greenland (G), Mexico (M), and South America (SA) in Figure 5.1-1. The Mercator projection makes it appear that Greenland is larger than South America, when in fact it is much closer to size of Mexico.

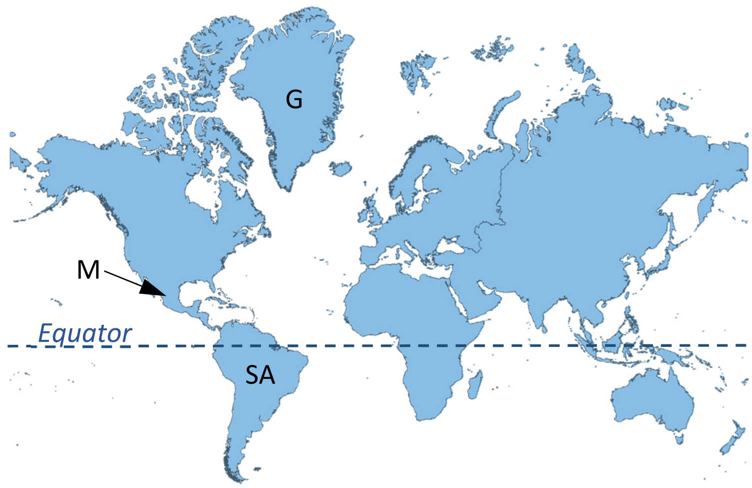



***Figure 5.1-1:*** *Mercator map projection.*

If the intent is to simply show the contiguous United States on a single map, with only minimal or reasonable distortion of areas and shapes, then the U.S.A. Contiguous Lambert conformal conic (LCC)(Figure 5.1-2) will probably work best.

***Figure 5.1-2:*** *USA Contiguous LCC.*

If the intent is to serve GIS applications or statewide orthophotography projects that place more emphasis on the geodata being properly and accurately georeferenced than the selected projection exhibiting the grid vs. ground performance preferred in land surveying and civil engineering projects, then employing a single or minimal number of map projections across an entire state with reasonable linear distortion would suffice.

But if the intent is to utilize a *published* map projection throughout a particular geographical region (such as a county) for land surveying projects ranging from a residential boundary retracement survey to a commercial ALTA survey to an industrial construction project for a new manufacturing facility with prefabricated materials and systems (steel columns, piping systems, assembly lines, etc.) to a Department of Transportation's highway project stretching over several miles of new terrain, then practitioners should strongly consider selecting a conformal map projection that delivers the grid vs. ground performance that satisfies the needs of these projects and others.

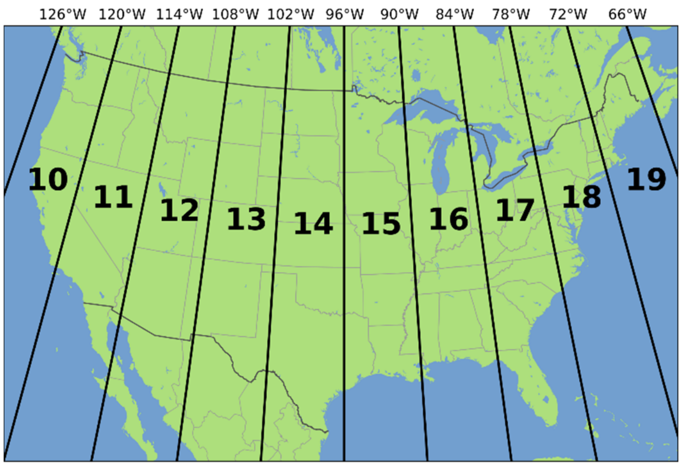



**Figure 5.1-3:** *UTM zones 10-19.*
*(Image courtesy Chrismurf at English Wikipedia.)*

Within Indiana, the Universal transverse Mercator zone 16 (see Figure 5.1-3) provides grid vs. ground differences, on average, of approximately 2.1 feet per mile (±400 ppm), while the East and West zones of the Indiana State Plane Coordinate System (Figure 5.1-4) provide differences, on average, of ±0.25 feet per mile (±50 ppm)(upwards of ±0.4 feet per mile (±76 ppm)). This performance has historically been acceptable for *general* mapping applications, GIS applications, statewide orthophotography projects, etc., but has by and large been deemed undesirable or unacceptable in cases such as the residential boundary surveys, industrial construction projects, and DOT projects listed above. As stated in Chapter 4 (*History of Coordinate Systems at the Indiana DOT)*, INDOT projects have also historically opted to develop alternative, project-based coordinate systems that exhibit grid vs. ground performance exceeding the performance of UTM16 and both Indiana State Plane Coordinate System zones. But without being made easily accessible in geospatial software platforms by the appropriate vendors, these (numerous) systems may never be used beyond the geographical limits of each project site or for no longer a period of time than the life of the particular project.

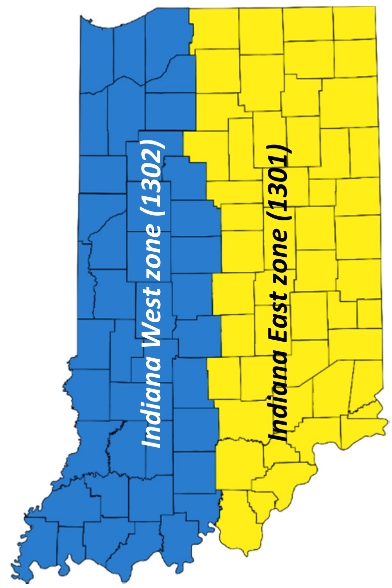



**Figure 5.1-4:** *Indiana SPCS zones.*

As discussed at the end of Chapter 4, LDPs that (1) exhibit the grid vs. ground performance preferred in land surveying and civil engineering projects, (2) have been approved and adopted by the proper governing agency (such as INDOT), and (3) have been included in EPSG's Geodetic Parameter Dataset and in proprietary geospatial software are poised to be successful mechanisms for seamless workflows between users within different geospatial industries.

***The number and size of LDPs neighboring one another in a particular region and the "preferred" grid vs. ground performance are dependent upon the collaborative efforts of a Technical Development Team, an LDP Developer, the LDP Design Criteria, and the actual terrain characteristics of the region.***

## 5.2 Background

While engaged in many different types of surveys (Location Control Route Surveys, boundary surveys, topographic surveys, ALTA surveys, construction staking projects, control surveys, aerial photography projects, etc.) across Indiana for clients in both the public and private sectors, it became apparent to the Lead Author and Bernardin, Lochmueller and Associates, Inc. (now *Lochmueller Group*) that there *should* be a better system to base these types of projects on, rather than nearly always developing an arbitrary or modified (scaled-to-ground) State Plane Coordinate Systems (SPCS) for *each* project to minimize grid vs. ground differences.

Use of arbitrary (e.g., “N 5,000.000 E 5,000.000”) and modified SPCS provided the desired grid vs. ground relationship for survey project requirements, but provided persistent inefficiencies in attempting to drape aerial photography behind the survey data for surveying, civil engineering, and GIS. They also provided difficulties in attempting to share data back and forth between other adjacent projects that were based upon other coordinate systems. Across the board, “*inefficiency*” was the common theme being echoed by geospatial practitioners.

To be *considerably* more effective, the new system would need to (1) retain the grid vs. ground relationship that the arbitrary and modified SPCS offered so as to satisfy project guidelines and/or preferences, (2) retain the direct tie between published grid coordinates and the underlying geometric datum’s values of latitude and longitude that SPCS offered, and (3) create a seamless workflow between land surveying, civil engineering, and GIS using the *project* coordinates used in surveying projects.

Personal research by the Lead Author in 2006 then led to the concept of *Low Distortion Projections (LDPs)* that the states of Minnesota and Wisconsin had already embraced, developed, and put into place for practitioners in those states to utilize in their everyday activities. Further research led to the handout entitled *“Ground Truth – Low-distortion map projections for surveying and GIS”* presented by Michael Dennis of Geodetic Analysis, LLC at the August 2006 ESRI Survey and GIS Summit. After further discussing the concept of LDPs with Mr. Dennis and many others who were experienced in using LDPs in their everyday practice, it was determined to actively pursue bringing LDPs to the Hoosier state.

In 2007, rather than using multiple scaled-to-ground systems for the various Sections and Segments of the I-69 “Evansville to Indianapolis” project, two LDPs were developed by the Lead Author and Lochmueller Group and proven successful for all design-level activities involved in the project.

In 2009, a state-wide, county-based LDP concept was introduced to the (now) IGIC/ISPLS Geodetic Control Workgroup.

Through the support of the IGIC/ISPLS Geodetic Control Workgroup, the Indiana Department of Transportation, and the Federal Highway Administration, Lochmueller Group was awarded the contract in 2014 to develop what is now referred to as the *Indiana Geospatial Coordinate System (InGCS)*.

In July of 2015, the InGCS was approved and adopted by the Indiana Department of Transportation.

In September of 2015, a notice was sent out to many geospatial software vendors informing them of the approval and adoption of the InGCS by INDOT, as well as providing them with the InGCS’ URL (http://in.gov/indot/InGCS.htm) where the files containing the InGCS parameters are located, should they choose to incorporate the InGCS in future versions of their platforms.

## 5.3 Design Criteria for the InGCS

The "Design Criteria" guidelines agreed upon by the InGCS Technical Development Team that led to the resulting successful character of the InGCS are listed as follows:

1. Geometric Datum
    a. Reference all projections "generically" to NAD 83
    b. By default, the reference ellipsoid will be GRS 80
    c. As Indiana State Plane East or West references no realization or datum tag, so no reference system realization or datum tag will be associated in any of the coordinate reference system definitions
2. Linear Units
    a. Actual definition of grid coordinate False Northings and False Eastings will be in meters
    b. "Working" linear units will be the U.S. Survey Foot definition (1 meter = 39.37 inches)
3. Projection Type(s)
    a. As Indiana users have experience with transverse Mercator projections (Indiana State Plane East and West zones and UTM 16), all zones will be based upon this projection type.
4. Linear Distortion Budget
    a. As legacy INDOT project Guidelines for Measurement Techniques and Coordinate Systems were written with the purpose of minimizing linear distortion for *each* project, the attempt will be made to design zones that would preferably not exceed linear distortion in the amount of 5 ppm's at the 95% level and 10 ppm's at the 99% level within each zone.
5. Zone Limits/Boundaries
    a. The smallest zone shall be that of the boundary of a particular Indiana county.
    b. The constraining factor for combining of counties into particular groups will be that of the Linear Distortion Budget (see above).
6. Numerical Definitions of Each Zone
    a. Central Meridian Scale Factor
        i. Set to exactly six decimal places, e.g., "1.123 456"
    b. Central Meridians and Latitudes of Grid Origins:
        i. Round to the nearest three arc-minutes for "clean" decimal conversions, e.g. 86°03'00"=86.05°(exact)
    c. False Northings and Eastings:
        i. All positive values, preferably set to provide adequate working to the south and west of zone boundaries to prevent negative values
        ii. Non-overlapping of northing and easting values within each zone to aid in components not being mistakenly switched
        iii. Values that do not mimic either Indiana State Plane East or West Zone or UTM zone 16.
        iv. When practical and sensible, keep values under 1,000,000 (U.S. Survey Feet) for simplicity in manual calculations, readability, and consumption of space in coordinate tables on published documents, such as survey plats, engineering and construction plans, etc.
    d. For future national geometric datums, it may be best to keep the same numerical definitions for each zone, except for the False Northings and Eastings, and to change

them by values significant enough that most prudent geospatial users will be able to easily distinguish between datums.

## 5.4 Sample Data Source, Spacing, and Quantity

The digital elevation models utilized for this project (including the colorized linear distortion raster images on the InGCS Individual Zone Data Sheets in Appendix C) originated from the United States Geological Survey's National Elevation Dataset (NED) and were reduced to 5 arc-second spacing both in latitude and longitude. In central Indiana, this provided a sample point approximately every 390 feet east/west and 505 feet north/south.

For each county and composite/group of counties analyzed, an offset of approximately 1,000 meters (±3,280 feet) of the corresponding perimeter was generated to create an artificial boundary for trimming excess data. This provided somewhat of a buffer zone, so to speak, of surplus data in each area analyzed when developing the corresponding LDP and for addressing instances of future projects crossing from one InGCS zone to another.

The 5 arc-second spacing and 1,000 meter offset/buffer zone mentioned above lent to an abundance of sample data for each area analyzed. Three examples are provided below for the varying sizes of counties and their corresponding datasets:

1. Ohio County (smallest): +/-17,000 points
2. Marion County (typical): +/-67,000 points
3. Allen County (Largest): +/-106,000 points

## 5.5 Selecting InGCS Zones' Central Meridians and Scale Factors

When utilizing the transverse Mercator projection for a given geographical region, minimized linear distortion occurs when a meridian of longitude and associated scale factor are reckoned that best harmonizes the resulting developable surface with the terrain embraced within the focus region. Given the behavior of linear distortion intrinsic to the transverse Mercator projection, the linear distortion for a given geographical region changes each time a new central meridian is entertained either east or west of the prior meridian attempted bearing the same scale factor. This characteristic is particularly advantageous in regions that have a generally-constant slope in either an east or west direction across the entirety of its terrain, as the developable surface can act more like a best-fit line through the sloping terrain rather than a secant cutting through the curvature of the Earth.

This can *somewhat* be envisioned conceptually in a 2D, latitudinal cross section sense as a fulcrum and lever, with the reference ellipsoid (GRS 80) being the fulcrum and the transverse Mercator's developable surface being the lever. The more the terrain throughout a region slopes downhill in either an east or west direction, the farther towards the downward-sloping direction the central meridian should be placed to act as a counterbalance.

In Figures 5.5-1, 5.5-2, and 5.5-3, the "Ground" represents the general surface terrain slope for the particular terrain region (in the case of the InGCS, these "regions" are counties) and the blue arrows represent the approximate separation from the terrain surface to the projection's developable surface. In general, the smaller the arrows, the less the linear distortion.
In Figure 5.5-1, the central meridian was placed along a meridian of longitude that is near the eastern edge of the region, whereas in Figure 5.5-2, the central meridian was placed near the centroid of the

region, while in Figure 5.5-3, the central meridian was placed near the western edge of the region. As can be seen, the arrows (linear distortion) are the smallest when the central meridian is placed near the western edge of the region and a scale factor is reckoned to best-fit the projection's developable surface to the terrain surface.

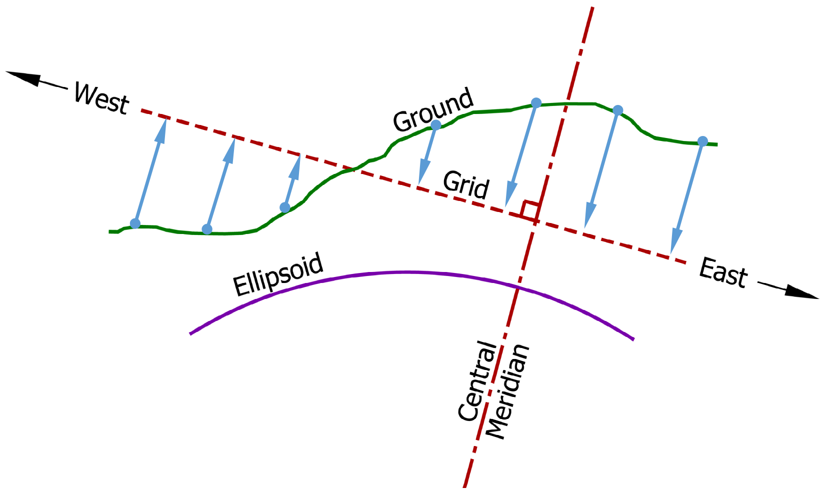



***Figure 5.5-1:*** *Transverse Mercator Latitudinal Cross Section #1.*

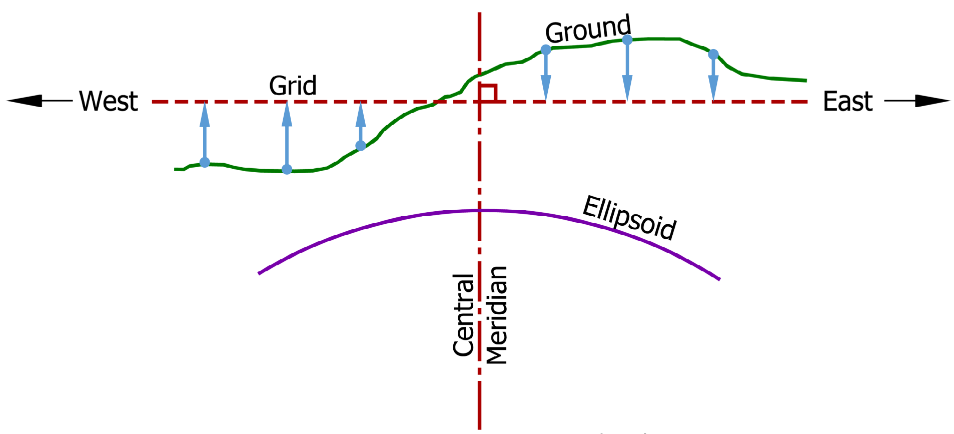



***Figure 5.5-2:*** *Transverse Mercator Latitudinal Cross Section #2.*

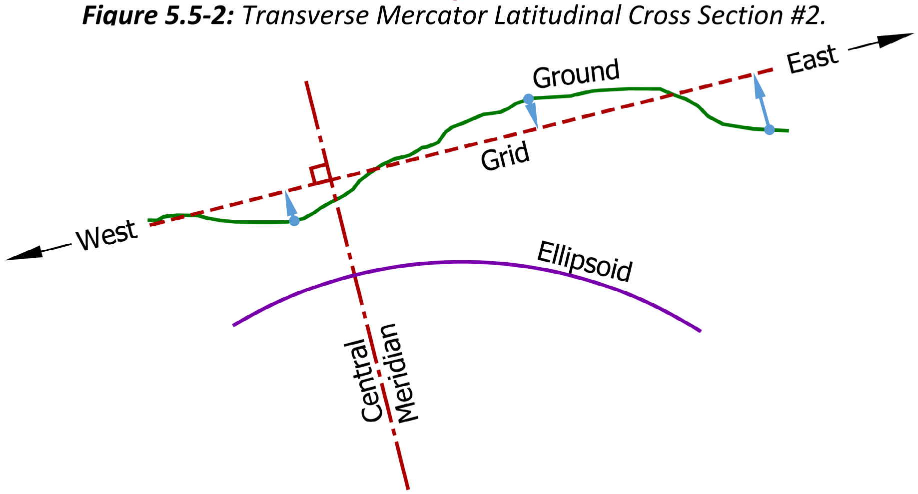



***Figure 5.5-3:*** *Transverse Mercator Latitudinal Cross Section #3.*

In this fashion, the meridians of longitude and respective scale factors that were employed for the InGCS zones were selected as a result of an iterative process to determine where and by what scale would best minimize linear distortion for a given county or group thereof. One of the better examples of this effect can be seen by the placement of the central meridian for the “Decatur” and “Rush” zones (counties).

Figure 5.5-4 is a colorized elevation relief map of these two counties. In an east-west sense, it can be seen that the terrain slopes downward in a westerly direction throughout most of these two counties. Because of this characteristic, the location for the central meridian (and associated scale factor) that minimized linear distortion for these two counties was determined to lie west of the western boundary of Rush County and came somewhat close to approximating the western boundary of Decatur County.

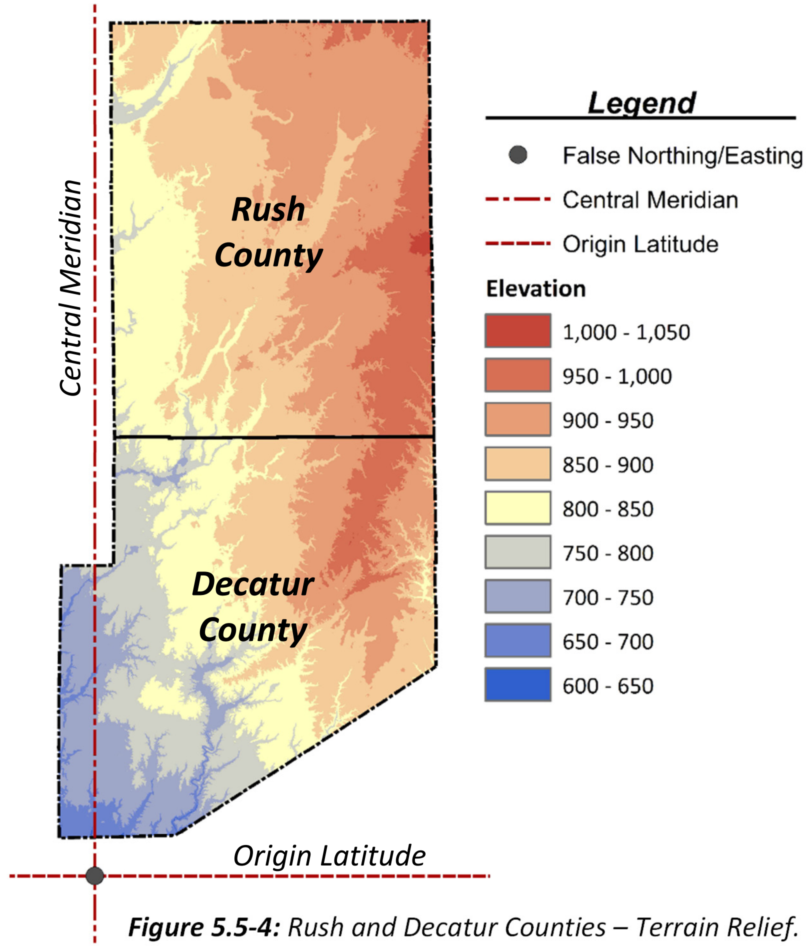



**Figure 5.5-4:** *Rush and Decatur Counties – Terrain Relief.*

Disregarding *local* terrain anomalies as encountered in smaller regions, the ***general*** curvature of the Earth bends *away* from the developable surface of a transverse Mercator projection with increasing east-west departures from the central meridian. It is for this reason that as the east-west span of a particular region increases that a transverse Mercator projection is meant to embrace, the more it becomes apparent that the developable surface should become increasingly more secant to the Earth’s surface rather than ±tangent at the central meridian. This characteristic is a controlled by the designation of the central meridian’s scale factor. A scale factor of “1” drapes the developable surface of the projection onto the ellipsoidal surface along the central meridian. Scale factors greater than “1” raises the developable surface above (and parallel with) the ellipsoidal surface at the central meridian, whereas scale factors less than “1” lowers the developable surface.

Figures 5.5-5 and 5.5-6 provide examples of transverse Mercator LDPs that are approximately tangent to the local terrain surface and that cut through the regional terrain surface. Figure 5.5-5 can somewhat be envisioned as a Site-Specific (Micro) LDP because the geographical extents of a typical project site (e.g., residential subdivision, manufacturing facility, road intersection improvement, airport, etc.) are small enough that, when compared to larger regions (e.g., an entire county, group of counties, state, etc.), the developable surface of the LDP is nearly tangent to the local surface of the Earth. The larger the geographical extents of an LDP becomes (particularly perpendicular to the projection axis), the more the developable surface begins to descend beneath the Earth’s surface.

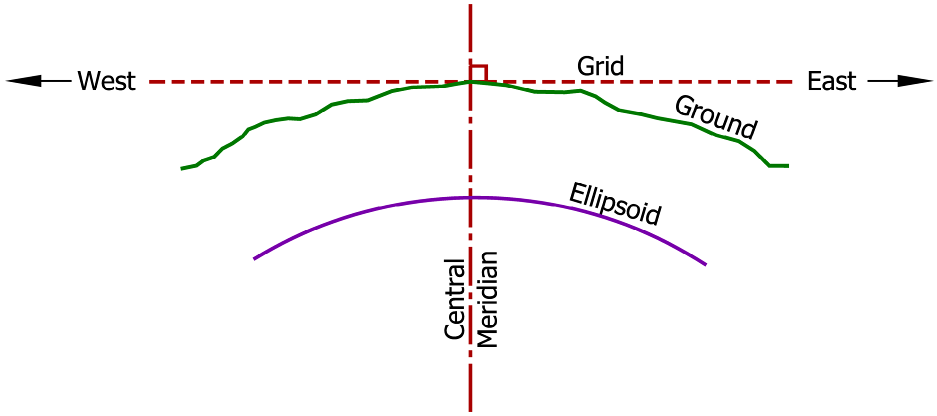



***Figure 5.5-5:*** *Transverse Mercator LDP, ±Tangent to Local Terrain Surface (Latitudinal Cross Section).*

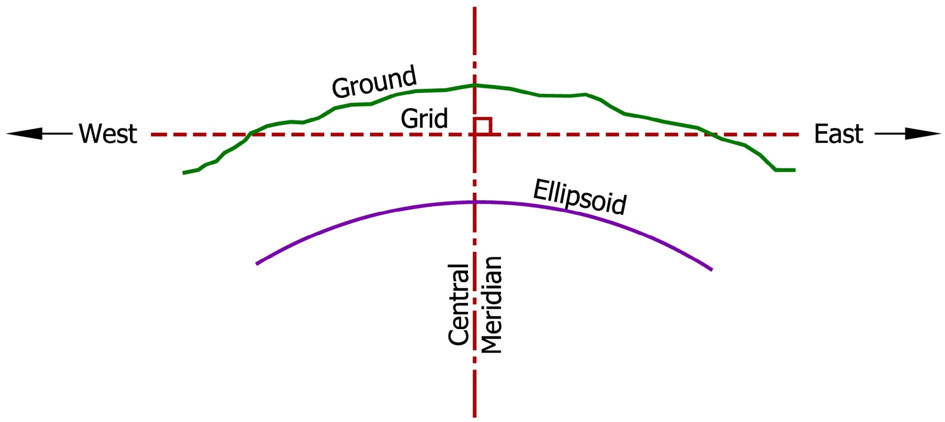



***Figure 5.5-6:*** *Transverse Mercator LDP, Beneath Regional Terrain Surface (Latitudinal Cross Section).*

The behavior of linear distortion along longitudinal cross sections of transverse Mercator projections is quite different than it is along latitudinal cross sections. *Linear distortion values are constant along the central meridian for a given offset of the ellipsoidal surface.* Because global ellipsoids (e.g., the GRS 80 ellipsoid) are developed to approximate the geoid (a model of global mean sea level), the developable surface of a transverse Mercator projection, in turn, bends *with* the general curvature of the Earth along the central meridian. Longitudinal cross sections in close proximity to the central meridian still generally bend with the Earth's curvature, but become increasingly more oblique as east-west departures from the central meridian correspondingly increase. Figure 5.5-7 provides an example longitudinal cross section of a transverse Mercator LDP's developable surface along the central meridian.

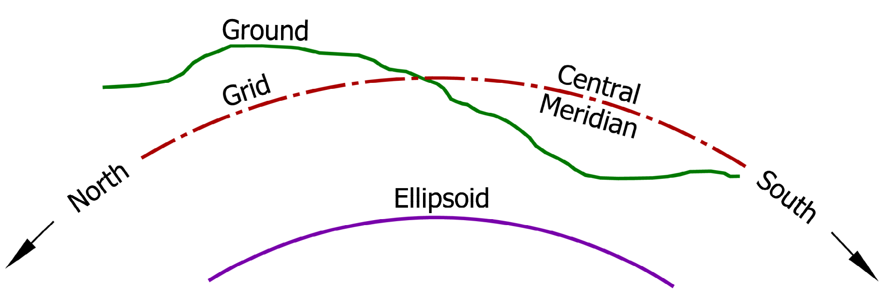



***Figure 5.5-7:*** *Transverse Mercator along Central Meridian (Longitudinal Cross Section).*

## 5.6 InGCS Grid Coordinates ≠ Indiana State Plane or UTM zone 16 Grid Coordinates

Somewhat similar to the efforts made by the National Geodetic Survey when developing the SPCS of 1983 to supersede NAD 27, the origin of each InGCS zone was assigned specific numeric grid values so as to make at least one, but preferably both, of the two coordinate components (Northing and/or Easting) appear *clearly and significantly* different than the NAD 27 or NAD 83 definitions of the East and West zones of the Indiana SPCS, within the nominal limits of each InGCS zone. Additional effort was also made to avoid similarities between the grid coordinates of the InGCS zones and UTM zone 16.

No potential conflicts/grid overlaps were determined between the InGCS and the Indiana SPCS, per NAD 83 or UTM zone 16, per NAD 83.

Although the northing components of Perry County's perimeter as depicted in the InGCS, Perry zone and the Indiana SPCS, West zone (per NAD 27) are within ±8,000 feet of one another, the easting components of its perimeter as depicted between the two zones are separated by ±176,000 feet. Likewise, although the easting components of the perimeters of Dearborn, Ohio, and Switzerland Counties as depicted in the InGCS, Dearborn, Ohio, and Switzerland zones and the Indiana SPCS, East zone (per NAD 27) are within ±68,000 feet of one another, the northing components of their perimeters are separated by ±301,000 feet. No smaller potential grid coordinate conflicts/grid overlaps were discovered between the InGCS and the East and West zones of the Indiana SPCS, per NAD 27.

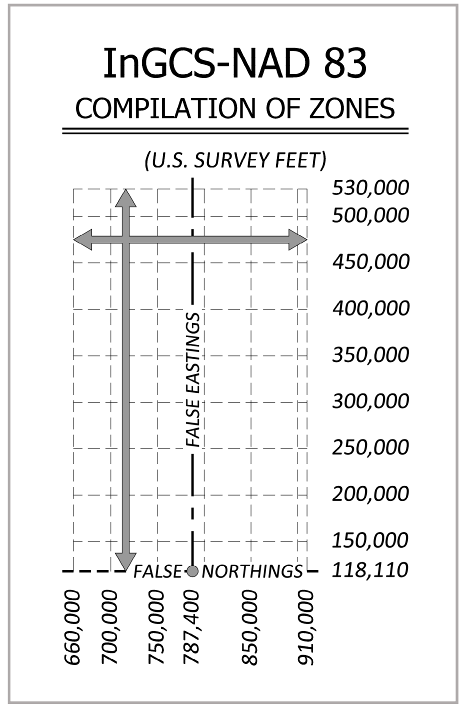



***Figure 5.6-1:*** *InGCS-NAD 83, Consumed Grid Coordinate Range Consumption.*

Refer to Figures 5.6-1 through 5.6-6 for coordinate grid illustrations of (1) the InGCS per NAD 83, (2) the East and West zones of the Indiana SPCS per NAD 27 and NAD 83, and (3) UTM zone 16 per NAD 83.

Figure 5.6-1 illustrates the effective range of grid coordinates (in the northing and easting components) consumed/occupied by county boundaries within the associated InGCS zones (per NAD 83), in U.S. Survey Feet. For example, the largest grid northing value of ±523,000 (rounded up to 530,000 as shown) is consumed/occupied by the northern boundary of Elkhart County of the Elkhart zone. The largest grid easting value of ±906,000 (rounded up to 910,000 as shown) consumed/occupied is consumed/occupied by the eastern boundary of Greene County of the Greene zone; whereas the smallest easting of ±663,000 is consumed by the western boundary of Floyd County/zone. The smallest northing of 118,110 is the value assigned for the False Northing of all InGCS zones.

Figure 5.6-2 illustrates the effective range of grid coordinates consumed/occupied by county boundaries within the associated Indiana SPCS zone, per NAD 27, in U.S. Survey Feet.

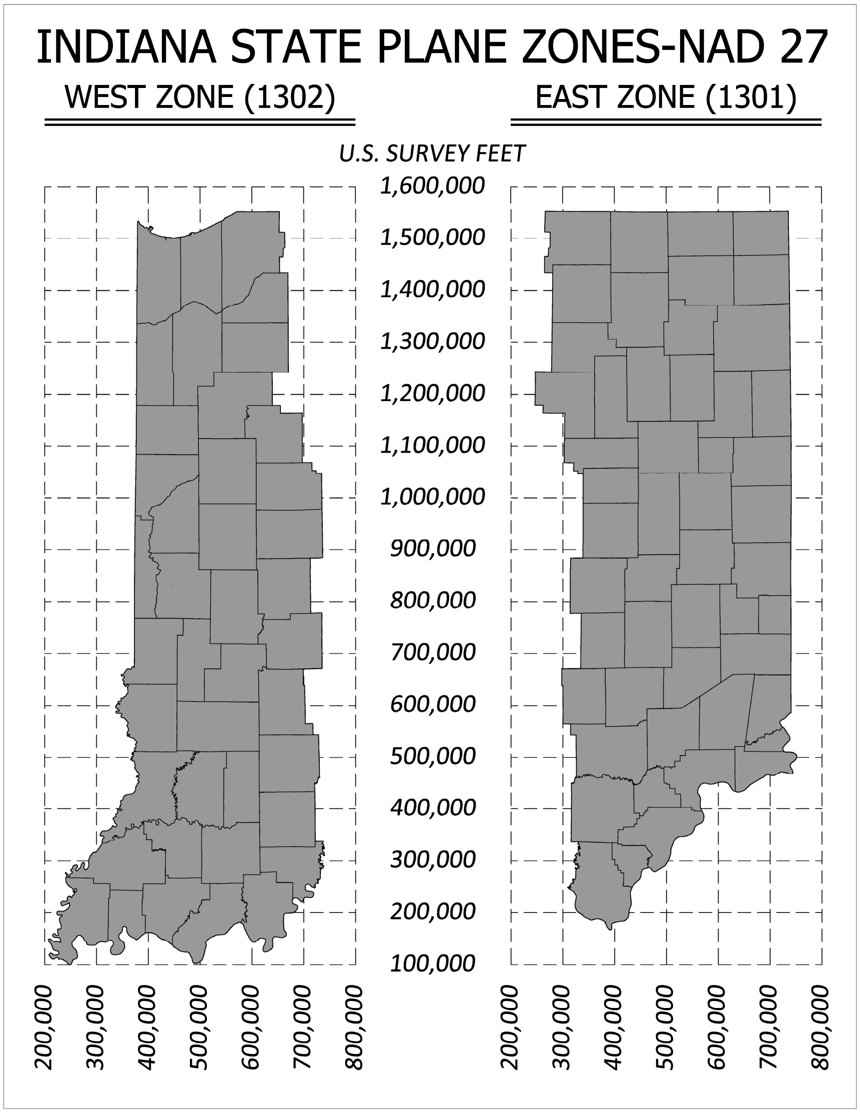



***Figure 5.6-2:*** *Indiana SPCS-NAD 27, Consumed Grid Coordinate Range.*

Figure 5.6-3 illustrates the effective range of grid coordinates consumed/occupied by county boundaries within the associated Indiana SPCS zone, per NAD 83, in U.S. Survey Feet.

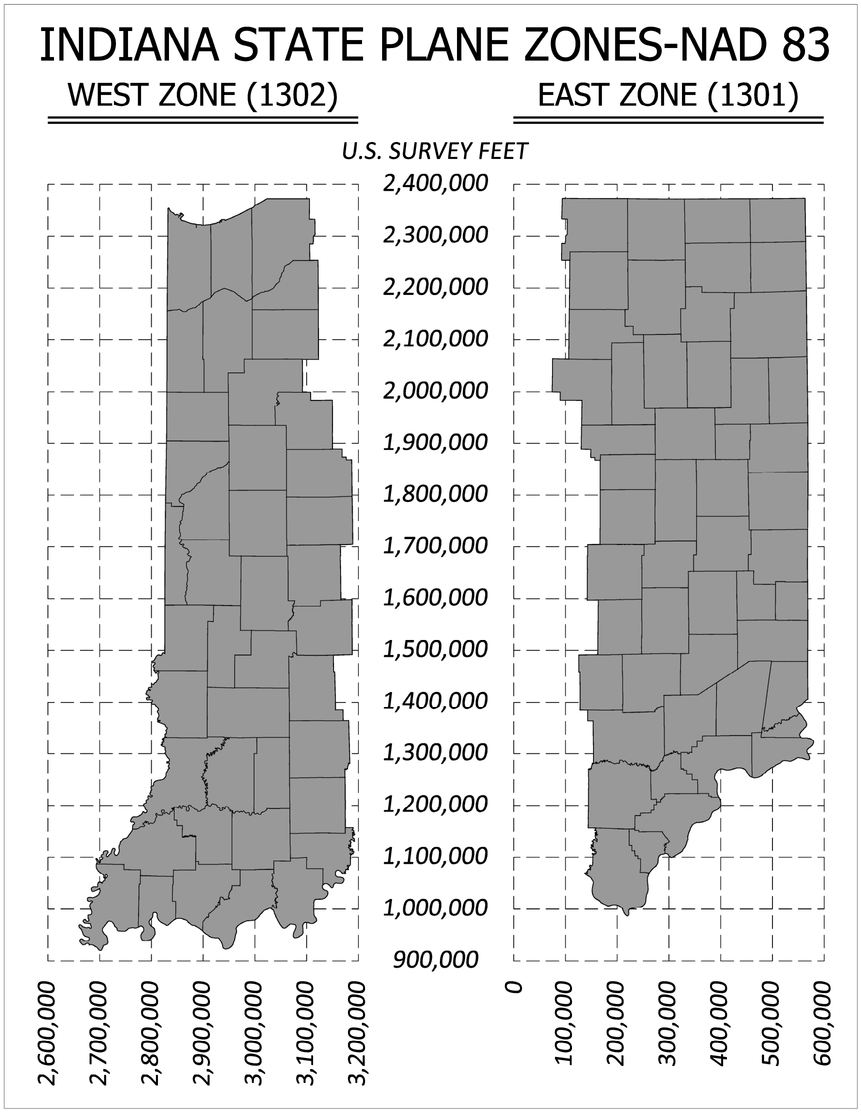



***Figure 5.6-3:*** *Indiana SPCS-NAD 83, Consumed Grid Coordinate Range.*

Figure 5.6-4 illustrates the effective range of grid coordinates consumed/occupied by county boundaries within UTM zone 16, per NAD 83, in U.S. Survey Feet.

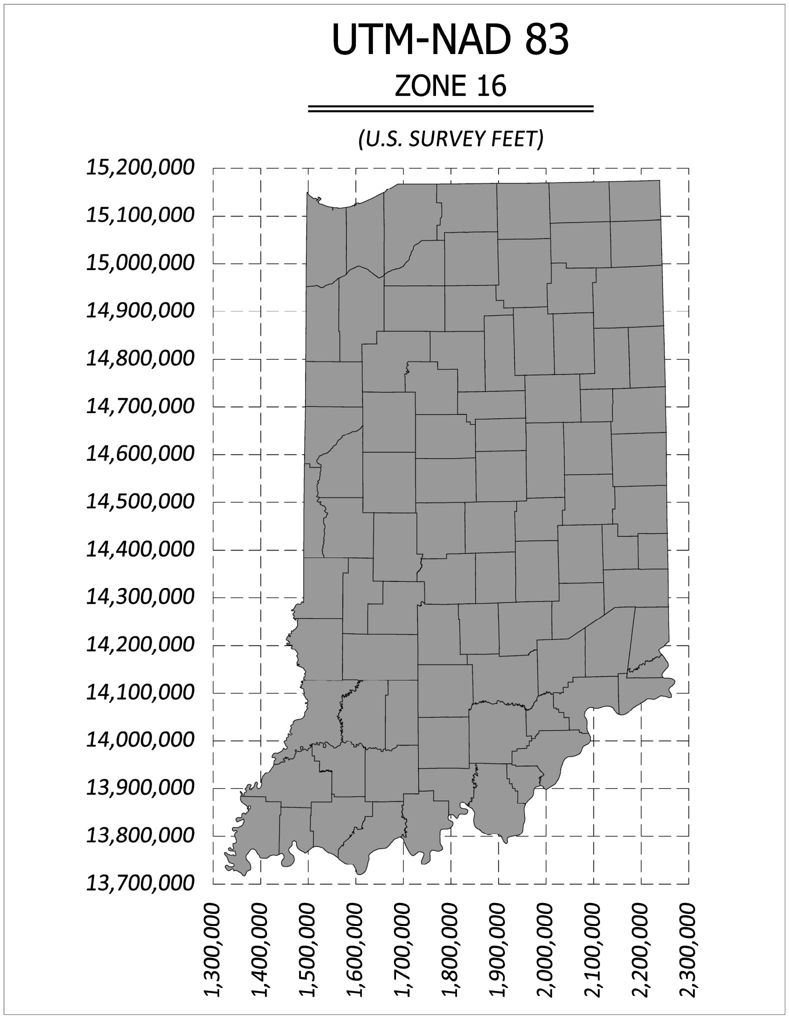



***Figure 5.6-4:*** *UTM zone 16-NAD 83, Consumed Grid Coordinate Range.*

## 5.7 InGCS Design Summary and Performance Statistics

The characteristics and linear distortion performance of the InGCS' zones are summarized below.

Zones Limits/Boundaries

The nominal limits of each zone of the InGCS are the boundaries of Indiana counties. As in the case with State Plane Coordinate Systems, the mathematical projections do not "stop" at the nominal limits of the zones, i.e., office and field software will still compute positions beyond the nominal limits of the zones.

(Note: An exception to this occurs in some software systems when attempting to perform operations outside the software's defined limits of the datum, e.g., determining Indiana State Plane coordinates per NAD 83(2011) epoch 2010.00 at the equator.)

Zones Count

Primarily for intuitive use by the end user community, each county was designated as its own zone. Since Indiana has 92 counties, the InGCS accordingly has 92 zones.

Zone "Groups"

Disregarding the 92 unique zone *names* and then comparing the remaining numerical projection parameters (central meridian, central meridian scale factor, latitude of grid origin, false northing and easting) of adjacent zones, it is apparent that there are but 57 distinct sets/groups of projection parameters, in which each set/group contains identical numerical values.

Zones with Common Basis of Bearings

Of these 57 distinct groups, there are several adjacent groups that share the same central meridians, and thus basis of grid bearings; yet they have different central meridian scale factors and latitudes of grid origins, resulting in different grid coordinates. For a graphical summary of this, please refer to the InGCS Zones Overview Map in Appendix C.

False Northings and Eastings of Zones

As part of the approach detailed in the "Design Criteria for the INGCS" for the design of these zones, all of the false northings and false eastings were defined in meters, while the "working" units (values shown on survey plats, design plans, etc.) are to be in U.S. Survey Feet, as Indiana is legislatively a U.S. Survey Foot state.

So as to further minimize the possibility of *manual* entry errors or rounding errors either by geospatial software vendors or individuals entering the parameters of the InGCS zones into their respective software platforms, all of the false northings and false eastings were set at increments of 1,200 meters *(exact)*. Upon conversion, this results in increments of 3,937 U.S. Survey Feet *(exact)*. All false northings were set at 36,000 meters (118,110 U.S Survey Feet), while all false eastings were set at 240,000 meters (787,400 U.S. Survey Feet). These InGCS zone grid coordinate values do not conflict with State Plane grid coordinate values of either NAD 27 or NAD 83 within the nominal limits of each InGCS zone.

Central Meridian Scale Factors

All central meridian scale factors were set to a precision of "exactly" six decimal places (e.g., 1.123 456) at values that harmonized with the locations of the central meridians so as to minimize the grid vs. ground differences within the corresponding counties or groups thereof.

Central Meridians and Latitudes of Grid Origin

All central meridians were placed at intervals of three arc-minutes (for "clean" decimal conversions, e.g., 86°03'00"=86.05°(exact)) that harmonized with the corresponding central meridian scale factors so as to minimize the grid vs. ground differences within the corresponding counties or groups thereof. The "clean" decimal conversion criteria was set forth in an effort to minimize the possibility of *manual* entry errors or rounding errors either by geospatial software vendors or individuals entering the parameters of the InGCS zones into their respective software platforms.

Linear Distortion Performance

Throughout all 92 zones of the InGCS:

- The average linear distortion is less than 3 ppm (0.016'/mile)
- Approximately 95% of the linear distortion is less than 13 ppm (0.069'/mile)
- Approximately 99% of the linear distortion is less than 18 ppm (0.095'/mile)
- The maximum sampled linear distortion is less than 24 ppm (0.127'/mile)

Statistics and graphical representations of the linear distortion for each zone (county) of the InGCS can be found in Appendix C.

In revisiting the example land surveying projects from Section 5.1 (residential boundary retracement survey, commercial ALTA survey, industrial construction project, DOT project), it is believed that the InGCS provides the preferred grid vs. ground performance for these and nearly all other land surveying and civil engineering projects, while also providing for a seamless workflow between users in different geospatial industries.

## 5.8 InGCS at the "Evansville Calibration Base Line"

Thanks to the volunteer effort of members from the Southwest Chapter of the Indiana Society of Professional Land Surveyors, an EDMI Calibration Base line was constructed in northern Vanderburgh County in 2013, observed by the National Geodetic Survey and members of the SW Chapter in 2015, and published on NGS' CBL web page (http://www.ngs.noaa.gov/CBLINES/calibration.html) later that year. Refer to Figure 5.8-1 for an aerial view of the Evansville CBL and the arrangement of the corresponding survey monuments and Figure 5.8-2 for the List of Adjusted Distances published by NGS, found at http://www.ngs.noaa.gov/CBLINES/BASELINES/in .

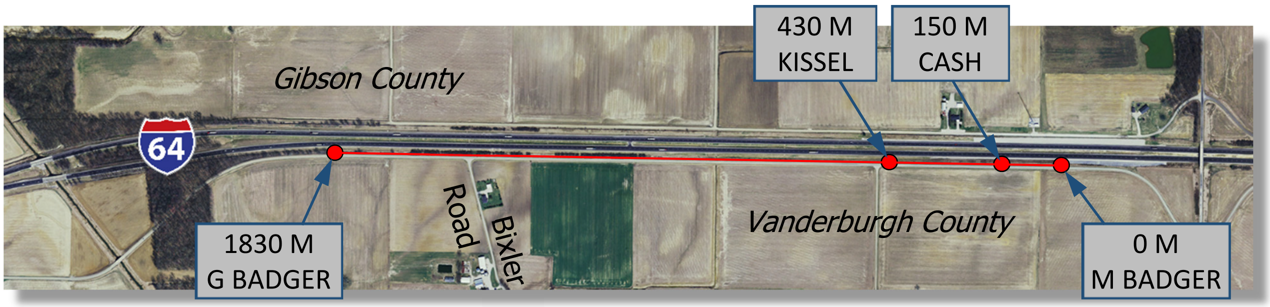



***Figure 5.8-1:*** *Evansville CBL (aerial view).*

US DEPARTMENT OF COMMERCE - NOAA
NOS - NATIONAL GEODETIC SURVEY
SILVER SPRING MD 20910

CALIBRATION BASE LINE DATA
BASE LINE DESIGNATION: EVANSVILLE CBL
PROJECT ACCESSION NUMBER: 15838
NEAREST TOWN: EVANSVILLE

QUAD: N380873
INDIANA
VANDERBURGH COUNTY

LIST OF ADJUSTED DISTANCES ( 5/10/2015)

| FROM STATION | ELEV.(M) | TO STATION | ELEV.(M) | ADJ. DIST.(M) HORIZONTAL | ADJ. DIST.(M) MARK - MARK | STD. ERROR(MM) |
|---|---|---|---|---|---|---|
| 0 | 139.640 | 150 | 137.933 | 149.9993 | 150.0090 | .2 |
| 0 | 139.640 | 430 | 134.227 | 430.0004 | 430.0344 | .3 |
| 0 | 139.640 | 1830 | 128.838 | 1829.9939 | 1830.0257 | .5 |
| 150 | 137.933 | 430 | 134.227 | 280.0011 | 280.0256 | .2 |
| 150 | 137.933 | 1830 | 128.838 | 1679.9944 | 1680.0191 | .3 |
| 430 | 134.227 | 1830 | 128.838 | 1399.9931 | 1400.0035 | .2 |

***Figure 5.8-2:*** *Evansville CBL: List of Adjusted Distances.*

To test the InGCS' "Vanderburgh" zone at the Evansville CBL, a static GNSS survey was performed *(independent of the EDMI observations performed by the NGS)* using NGS' OPUS utility, Trimble Business Center, and MicroSurvey's Star*Net to determine the InGCS "Vanderburgh" zone grid coordinates (per NAD 83(2011) epoch 2010.00) at the 0-Station and the associated grid azimuth to the 1830-Station. Using this grid azimuth (271°01'42.4"), the horizontal distance as listed on the Evansville CBL data sheet from the 0-Station to the 1830-Station (6,003.905 U.S. Feet (1,829.9939m)), and the "elevation" values (approximating NAVD 88 via Geoid12A, as determined by the SW Chapter) listed on the Evansville CBL data sheet, the resulting InGCS "Vanderburgh" zone grid coordinates were then calculated at the 1830-Station. Refer to Table 5.8-1 for the results of this test.

***Table 5.8-1:*** *Independent Surveyed Values of "Evansville CBL" 0-Station and 1830-Station.*

| Independent Surveyed Values of "Evansville CBL" 0-Station and 1830-Station | | | |
|---|---|---|---|
| *1830-Station* | | *0-Station* | |
| Geometric Datum: NAD 83(2011) epoch 2010.00 | | | |
| Latitude | 38°10'02.706277" (N) | Latitude | 38°10'01.70087" (N) |
| Longitude | 87°39'14.288105" (W) | Longitude | 87°37'59.12283" (W) |
| Grid System: Indiana Geospatial Coordinate System (InGCS), Vanderburgh zone (U.S. Feet) | | | |
| Northing | N 251,927.8301 | Northing | N 251,820.0676 |
| Easting | E 757,507.7228 | Easting | E 763,510.6587 |
| Grid Inverse (0-Station to 1830-Station) | | | |
| Azimuth | 271°01'42.4" | Distance | 6,003.903' |

Refer to Table 5.8-2 for a grid vs. ground comparison of the different grid systems noted in Section 5.1 (Additional Map Projections in the Hoosier State) with the NGS' published horizontal distance between the 0-Station and 1830-Station.

***Table 5.8-2:*** *Grid vs. Ground comparisons at the "Evansville CBL."*

| Grid vs. Ground at the "Evansville CBL" | | | |
|---|---|---|---|
| NGS Published Horizontal Distance: 1,829.9939m (6,003.905 U.S. Feet) | | | |
| Grid System | Grid Distance | Grid vs. Ground | PPM |
| World Mercator | 7,626.6' | +1,622.7' | +270k |
| USA Contiguous LCC | 5,971.8' | -32.1' | -5.3k |
| UTM zone 16 | 6,001.642' | -2.26' | -377 |
| Indiana State Plane, West zone | 6,003.786' | -0.12' | -20 |
| InGCS, Vanderburgh zone | 6,003.903' | -0.002' | -0.3 |

# Chapter 6 InGCS in Geospatial Software Programs

## 6.1 Adding InGCS Coordinate Reference System Definitions to Software

To use the InGCS in geospatial software platforms for surveying, engineering, GIS, and other geospatial applications, it must first be defined within the respective platforms. InGCS zone parameters are entered into the appropriate "coordinate system management/definition" module of the software. Because of the number and variability of commercial software packages and the frequency of software updates, this Handbook and User Guide does not give specific instructions for defining the InGCS in vendor software.

Eric Banschbach, PS, Manager of the Land and Aerial Survey Office of the Indiana Department of Transportation *proactively* notified, via email, many geospatial software vendors of INDOT's approval and adoption of the InGCS in 2015. This notification also provided them with the URL of the InGCS' webpage where the zone names, parameters, projection methods, and other specifications could be retrieved. With this information, these vendors can, in turn, include the InGCS in future releases, patches, updates, etc. within their respective platforms.

If your particular software vendor has not already included the InGCS into their platform(s), you are encouraged to contact the vendor and request that the InGCS be included in their future official releases, as well as requesting technical support from them for manually defining the InGCS' parameters until the official release has become available. Otherwise, it is recommended that you consult the "help" documentation and tutorials of the particular vendor software you plan to work with.

Over time, most commercial software manufacturers are likely to add the InGCS to their standard coordinate system libraries. When that occurs, there will be no need to manually enter the zone parameters. But in some cases, it may still be necessary to change the NAD 83 realization in commercial software coordinate system definitions (such as *.prj files) if a dataset is referenced to the wrong realization. This can occur, for example, if a dataset is referenced to "NAD 83" (without any modifier), which is often interpreted by software as original NAD 83(1986). Another example is an existing project referenced to an earlier realization, such as NAD 83(2007), rather than the current 2011 realization. Although changing the NAD 83 realization can be done, such changes should *only* be made after it has been verified that the change is necessary, appropriate, and correct.

*Note regarding the relationship between NAD 83 and WGS 84:* For the purposes of entering the InGCS projection parameters into particular vendor software, the datum should be defined as NAD 83 (which uses the GRS 80 reference ellipsoid for all realizations). Some commercial software implementations assume there is no transformation between WGS 84 and NAD 83 (i.e., all transformation parameters are zero). Other implementations use a non-zero transformation, and in some cases both types are available in a single software package. The type of transformation used will depend on specific circumstances, ***although often the zero transformation <u>is</u> the appropriate choice*** *(even though it is not technically correct)*. Check with software support to ensure the appropriate transformation is being used for your application.

*(Dennis et al. 2014)*

## 6.2 Validating Software Output

To ensure that a certain geospatial software platform has the InGCS zones correctly included into its "coordinate system management/definition" module, users are encouraged to compare the geodetic datum and projection parameters therein against the values published in this Handbook and User Guide, which can also be found on the InGCS webpage, prior to beginning work within a particular zone.

After ensuring that the InGCS zones are correctly included into a particular coordinate system management/definition module, users may wish to confirm that their geospatial software platforms are correctly performing geodetic computations to derive InGCS zone grid coordinates (northings and eastings, in U.S. Survey Feet) from positions of latitude and longitude (or vice-versa).

Once the project file has been configured with the correct preferences and parameters (especially the particular InGCS zone *and linear units set to U.S. Survey Feet)*, this can be accomplished by entering a *known* position of latitude and longitude into the software and comparing the resulting grid coordinates with the corresponding pair of known InGCS grid coordinates.

Since this exercise merely requires the *software* to *mathematically calculate* a pair of grid coordinates from a position of latitude and longitude (or vice versa), there is no need to provide a unique point located within each zone or at a physical survey marker, such as an NGS control mark. Thus, for simplification purposes, a pair of grid coordinates for each InGCS zone was calculated for a single, common position of latitude and longitude of 42° North and 85° West (approximately 19 miles northwest of the northeast corner of Indiana). This position, known as the "Validation Point" (shown in Figure 6.2-1) yields positive grid coordinates for all InGCS zones. The resulting grid coordinates (in meters) for each InGCS zone can be found in the "Validation Point" fields in Appendix A. The values listed were derived using MicroSurvey's Star*Net Version 7.2 and were compared to values determined from Trimble Business Center Version 3.40 and Topcon Magnet Tools Version 1.2.1. The numerical differences in grid coordinates found between these vendors' platforms were approximately 1 millimeter or less.

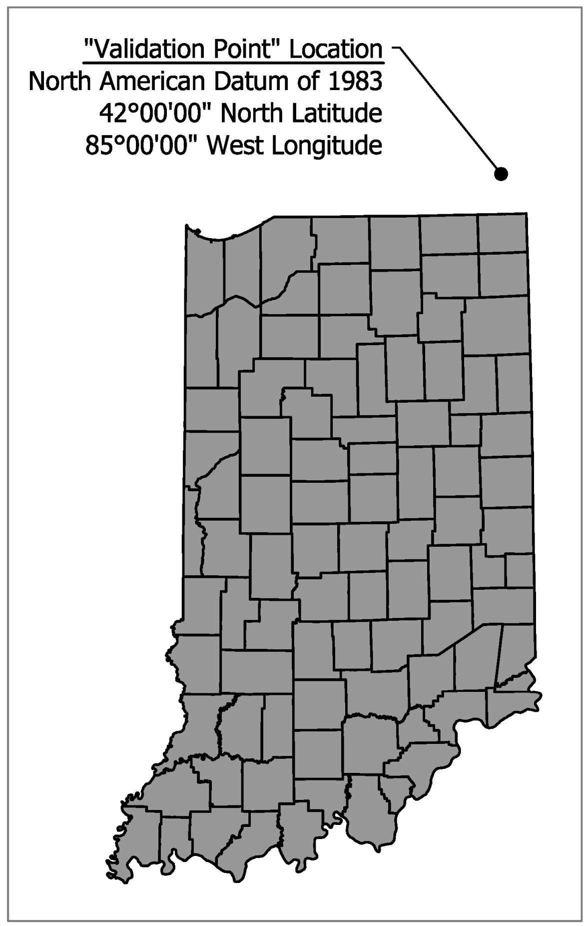



***Figure 6.2-1:*** *Validation Point for Software.*

If InGCS zone definition errors are found within your coordinate system management/definition module or the respective software is not correctly performing geodetic computations between positions of latitude and longitude and grid northings and eastings, users should contact their particular software vendor to report the issue(s).

Users are also encouraged to perform field validations to ensure that their system is performing satisfactorily. Appendix D contains InGCS grid coordinates on available NGS control marks with

*ADJUSTED* NAD 83(2011) epoch 2010.00 for each InGCS zone. Station "GLASGOW RM 2" (PID=JZ1879) was not included as NGS replaced/updated it with "GLASGOW RM 2 DISTURBED" (PID=AH8172). Marks with “NAD 83(2011) NO CHECK” values were not included. Note that the datasheets for these marks were harvested using NGS’ DSWorld program (by Malcom Archer-Shee, LS) Version 3.00.47 on 2015/09/03 and the reported InGCS grid coordinates were generated using Trimble Business Center Version 3.70. Users should double-check these values with their own geospatial software before using them on projects.

In researching NGS’ datasheets for passive marks to include on projects that employ the InGCS for project coordinates, it is important to note that the mere appearance of extended decimal precision for values of latitude and longitude in the “CURRENT SURVEY CONTROL” section for certain marks doesn’t necessarily imply that they were derived from GPS/GNSS static observations, nor does it imply that those values are respective to the “CURRENT” geometric datum’s realization. Figure 6.2-2 is an excerpt from NGS’ datasheet for Station “MT VERNON 3” to serve as an example.

**The NGS Data Sheet**

**See file dsdata.txt for more information about the datasheet.**

```
PROGRAM = datasheet95, VERSION = 8.8
1        National Geodetic Survey,   Retrieval Date = MAY  2, 2016
 HA1083 *********************************************************************
 HA1083  DESIGNATION -  MT VERNON 3
 HA1083  PID         -  HA1083
 HA1083  STATE/COUNTY-  IN/POSEY
 HA1083  COUNTRY     -  US
 HA1083  USGS QUAD   -  MOUNT VERNON (1981)
 HA1083
 HA1083                       *CURRENT SURVEY CONTROL
 HA1083  ______________________________________________________________________
 HA1083* NAD 83(1997) POSITION- 37 56 13.90144(N) 087 53 29.30813(W)   ADJUSTED
 HA1083* NAVD 88 ORTHO HEIGHT -   126.362 (meters)      414.57  (feet) ADJUSTED
 HA1083  ______________________________________________________________________
 HA1083  LAPLACE CORR    -         -2.16  (seconds)                    DEFLEC12B
 HA1083  GEOID HEIGHT    -        -30.585 (meters)                     GEOID12B
 HA1083  DYNAMIC HEIGHT  -        126.276 (meters)      414.29  (feet) COMP
 HA1083  MODELED GRAVITY -    979,947.5   (mgal)                       NAVD 88
 HA1083
 HA1083  HORZ ORDER      -  SECOND
 HA1083  VERT ORDER      -  FIRST     CLASS II
 HA1083
 HA1083.The horizontal coordinates were established by classical geodetic methods
 HA1083.and adjusted by the National Geodetic Survey in May 1999.
```

***Figure 6.2-2:*** *NGS IDB Datasheet for Station “MT VERNON 3” (PID: HA1083).*

The values of latitude and longitude for Station “MT VERNON 3” are shown to 5-decimal places of a second in each component, respective to the NAD 83(1997) realization, rather than the realization current at the original data of this document (i.e., NAD 83(2011) epoch 2010.00). The inclusion of the “HORZ ORDER - SECOND” line along with the note at the bottom of the excerpt, “The horizontal coordinates were established by classical geodetic methods and adjusted by the National Geodetic Survey in May 1999.” informs users that the “horizontal coordinates” were obtained with classical methods (e.g., triangulation, trilateration, baselines, traverses, etc.) rather than GPS observations. Beginning with the 2007 readjustment (NAD 83(NSRS2007)) of all GPS survey control in the United

States by NGS, classical observations have not been included in readjustments; hence, the position of "MT VERNON 3" has not advanced with successive realizations.

Had GPS observations been performed and the Station been elected to include in successive realizations, the datasheet would have included fields for an ellipsoidal height, epoch date, ECEF XYZ coordinates, statement of network and local accuracies, a note similar to "The horizontal coordinates were established by GPS observations and adjusted by the National Geodetic Survey in June 2012." along with other related information, as shown in Figure 6.2-3 for Station HATFIELD.

# The NGS Data Sheet

**See file dsdata.txt for more information about the datasheet.**

```
PROGRAM = datasheet95, VERSION = 8.8
1        National Geodetic Survey,   Retrieval Date = MAY  2, 2016
 HA0727 ***********************************************************************
 HA0727  CBN          -  This is a Cooperative Base Network Control Station.
 HA0727  DESIGNATION -  HATFIELD
 HA0727  PID          -  HA0727
 HA0727  STATE/COUNTY-  IN/SPENCER
 HA0727  COUNTRY      -  US
 HA0727  USGS QUAD    -  RICHLAND CITY (1980)
 HA0727
 HA0727                          *CURRENT SURVEY CONTROL
 HA0727  ______________________________________________________________________
 HA0727* NAD 83(2011) POSITION- 37 54 11.18210(N) 087 14 32.43551(W)   ADJUSTED
 HA0727* NAD 83(2011) ELLIP HT-    86.318 (meters)        (06/27/12)   ADJUSTED
 HA0727* NAD 83(2011) EPOCH   -  2010.00
 HA0727* NAVD 88 ORTHO HEIGHT -   117.379 (meters)      385.10  (feet) ADJUSTED
 HA0727  ______________________________________________________________________
 HA0727  NAD 83(2011) X  -    242,439.774 (meters)                     COMP
 HA0727  NAD 83(2011) Y  - -5,033,276.108 (meters)                     COMP
 HA0727  NAD 83(2011) Z  -  3,897,016.512 (meters)                     COMP
 HA0727  LAPLACE CORR    -         -0.65  (seconds)                    DEFLEC12B
 HA0727  GEOID HEIGHT    -        -31.063 (meters)                     GEOID12B
 HA0727  DYNAMIC HEIGHT  -        117.299 (meters)      384.84  (feet) COMP
 HA0727  MODELED GRAVITY -    979,946.5   (mgal)                       NAVD 88
 HA0727
 HA0727  VERT ORDER      -  FIRST     CLASS II
 HA0727
 HA0727  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 HA0727  Standards:
 HA0727         FGDC (95% conf, cm)      Standard deviation (cm)      CorrNE
 HA0727            Horiz  Ellip            SD_N   SD_E   SD_h      (unitless)
 HA0727  -------------------------------------------------------------------
 HA0727  NETWORK    0.57   1.02            0.26   0.20   0.52     -0.05427504
 HA0727  -------------------------------------------------------------------
 HA0727  Click here for local accuracies and other accuracy information.
 HA0727
 HA0727
 HA0727.The horizontal coordinates were established by GPS observations
 HA0727.and adjusted by the National Geodetic Survey in June 2012.
```

***Figure 6.2-3:*** *NGS IDB Datasheet for Station "HATFIELD" (PID: HA0727).*

An eight-hour GNSS static session was performed on this mark in 2015 and submitted to *OPUS Shared Solutions* to demonstrate the horizontal difference between the OPUS Shared Solution's position relative to NAD 83(2011) epoch 2010.00 and the NAD 83(1997) position listed on the datasheet from

NGS' Integrated Data Base (NGSIDB) as a result of classical geodetic methods. Refer to Figure 6.2-4 for an excerpt of the resulting OPUS Shared Solution. Although results *will* vary between marks of the same Order as well as marks from different Orders, the horizontal difference observed at this particular mark was approximately 0.39 feet, as shown in Table 6.2-1.

***Table 6.2-1:*** *Horizontal difference between geodetic methods at Station "MT VERNON 3."*

| **Horizontal difference between geodetic methods at Station "MT VERNON 3"** | | | |
|---|---|---|---|
| *Geodetic Method: Classical<br>Geometric Datum: NAD 83(1997)* | | *Geodetic Method: GNSS (OPUS Shared Solutions)<br>Geometric Datum: NAD 83(2011) epoch 2010.00* | |
| Latitude | 37°56'13.90144" (N) | Latitude | 37°56'13.89756" (N) |
| Longitude | 87°53'29.30813" (W) | Longitude | 87°53'29.30823" (W) |
| Grid System: Indiana SPCS, West zone (1302) | | | |
| Northing | 298,831.169m | Northing | 298,831.050m |
| Easting | 828,960.268m | Easting | 828,960.265m |
| Grid Inverse | | | |
| Azimuth | 182° | Distance | 0.120 m (0.39') |

*This* difference is significant enough that users who regularly employ sound geodetic positioning techniques and *properly* tie to the NSRS with centimeter-grade accuracy GNSS receivers via OPUS, appropriate NGS passive marks, RTNs, etc. could quickly determine that the NAD 83(1997) position of "MT VERNON 3" does not *accurately* fit with geodetic control that *is* relative to later realizations of NAD 83 (which did *not* include classical observations). These users would most likely either not include the mark in their project network or determine project-based values and use it accordingly.

More information concerning the information found in NGS' Datasheets can be found in their Digital Survey DATA text file (DSDATA.txt) on the following NGS webpage: http://www.ngs.noaa.gov/cgi-bin/ds_lookup.prl?Item=DSDATA.TXT

## Shared Solution

**PID:** HA1083
**Designation:** MT VERNON 3
**Stamping:** MT VERNON 3 1964
**Stability:** May hold commonly subject to ground movement
**Setting:** Set in top of concrete monument
**Mark Condition:** G
**Description:**
**Observed:** 2015-06-02T12:20:00Z See Also 2007-04-10
**Source:** OPUS - page5 1209.04

Close-up View

| REF_FRAME: NAD_83(2011) | EPOCH: 2010.0000 | SOURCE: NAVD88 (Computed using GEOID12B) | UNITS: m | SET PROFILE | DETAILS |
|---|---|---|---|---|---|

| | | | |
|---|---|---|---|
| **LAT:** | 37° 56' 13.89756" | ± 0.014 | m |
| **LON:** | -87° 53' 29.30823" | ± 0.012 | m |
| **ELL HT:** | 95.795 | ± 0.027 | m |
| **X:** | 185315.763 | ± 0.012 | m |
| **Y:** | -5033383.521 | ± 0.029 | m |
| **Z:** | 3900007.105 | ± 0.006 | m |
| **ORTHO HT:** | 126.380 | ± 0.048 | m |

| | UTM 16 | SPC 1302(IN W) |
|---|---|---|
| **NORTHING:** | 4199221.266m | 298831.050m |
| **EASTING:** | 421663.435m | 828960.265m |
| **CONVERGENCE:** | -0.54810399° | -0.49686377° |
| **POINT SCALE:** | 0.99967558 | 1.00002880 |
| **COMBINED FACTOR:** | 0.99966055 | 1.00001377 |

***Figure 6.2-4:*** *NGS OPUS Shared Solution for Station "MT VERNON 3" (PID: HA1083).*

<u>*Note concerning the InGCS and U.S. Survey Feet*</u>*:* As stated elsewhere in this document, the InGCS' ***working*** *linear units* are **U.S. Survey Feet**. The definitions for the U.S. Survey Foot and International Foot were provided in the "Unit of Measurement" Section in Chapter 1, but are provided here as well for further discussion.

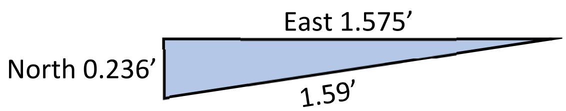
- *U.S. Survey Foot*: One meter = 39.37 inches "exact"
  - Stated differently: 1,200 meters = 3,937 U.S. Survey Feet "exact"
- *International Foot:* One foot = 0.3048 meters "exact"
  - Stated differently: One inch = 2.54 centimeters "exact"

These two definitions provide the following approximate results (to seven decimal places):

- *U.S. Survey Foot:* One meter ≈ 3.280 833 3 feet
- *International Foot:* One meter ≈ 3.280 839 9 feet

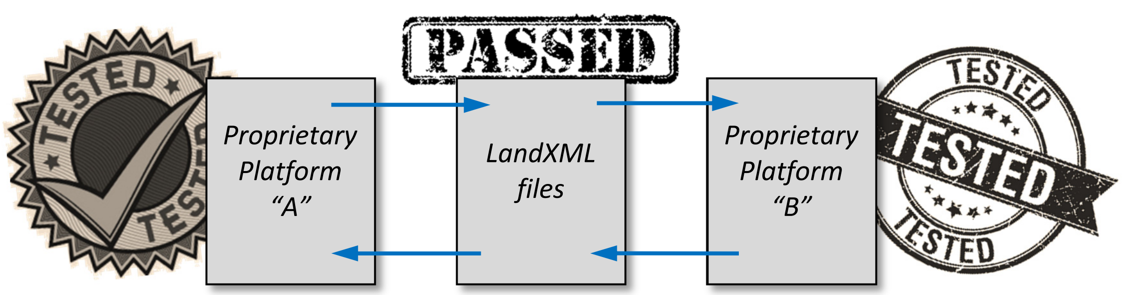
At face value, the 2 ppm difference between these two definitions may *seem* negligible, but because grid coordinate system (such as the InGCS, SPCS, UTM, etc.) typically use large values, it is significant. For example, the False Northings and False Eastings of each InGCS zone are defined as 36,000 meters and 240,000 meters, respectively. Using the two different definitions of the foot leads to the following values and resulting differences:

- *U.S. Survey Foot:* N 118,110 (exact) E 787,400 (exact)
- *International Foot:* N 118,110.236 E 787,401.575 (to three decimal places)
- *Differences:*




Selecting the incorrect foot definition could lead to positioning errors of similar magnitude in software, on plats, plans, in the field, etc. depending upon coordinate values. *Certain geospatial software platforms may have the <u>International Foot</u> set as the <u>default</u> linear units*. Great care should be exercised to ensure that the linear units within and throughout all geospatial software platforms have been set to U.S. Survey Feet when working on projects based upon the InGCS. Not only is this critical for users performing work within their own organization, it is also critical that users in collaborating organizations select the correct foot definition so all data shared back and forth will not be *unintentionally* converted to the *incorrect* definition. *Users are encouraged to contact their software vendors to determine if templates can be prepared that use the correct foot definition in all applicable option fields for particular projects.*

*LandXML Files Sharing:* The sharing of LandXML files between organizations has dramatically increased as new proprietary geospatial software platforms enter the marketplace and as more users become proficient in working with LandXML files. Though a non-proprietary data standard, LandXML files should ***still*** be reviewed before importing them into a user’s platform or sharing them with others. *Some proprietary platforms may not issue warnings when conversions (such as between International Feet and U.S. Survey Feet) are performed upon importing LandXML files.*




Before importing or exporting LandXML files, users should verify that all *units* (area, linear, volume, temperature, pressure, diameter, angular, direction, etc.) *and their respective precisions* have been set correctly and that the correct “Coordinate System” and associated meters, U.S. Foot, or International Foot definition has been selected. While some proprietary platforms may allow users to adjust the precision of units, others may not. For platforms that *do* allow users to adjust the precision of units, users should set the respective precisions small enough so as to not lose precision (due to double-precision rounding) with round trip exchanges of LandXML files between various platforms before or after the course of a project.

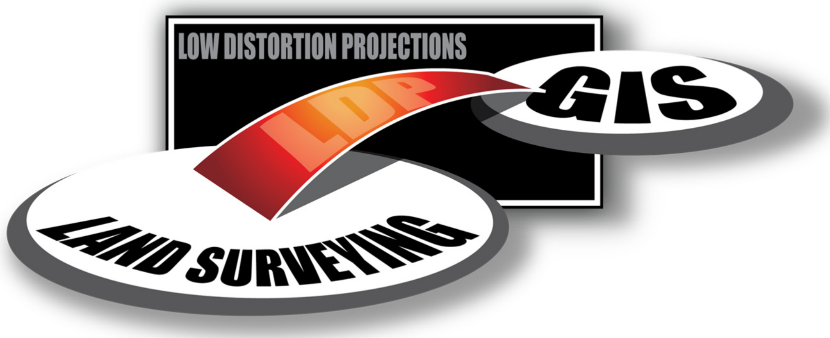
After importing/exporting a LandXML file into/from a certain proprietary platform, checking a "sufficient" number of grid coordinates and elevations of individual data points as well as the vertices of alignments, surface models, etc. in both the LandXML file and the proprietary platform's file is a step in the right direction towards validating that the corresponding settings are correct and that no *unintentional* conversions have been performed. Refer to www.landxml.org for more information regarding LandXML files.

### 6.3 Low Distortion Projects in GIS

Modern GIS software incorporates on-the-fly reprojections. This allows users to simultaneously display data from differing coordinate systems in a common coordinate system on the computer screen. Low distortion projection systems can thus be easily and seamlessly incorporated for display of GIS databases. An advantage to LDPs is the fact that the historical data need not be modified. Past data can still reside in its original coordinate system and merely be reprojected in real time into the new coordinate system for use with new LDP data. Thus, as future LDPs are developed, multiple round-off error will not propagate with each time a new projection is applied. ***This will allow cities and counties to adopt the new LDPs while still using their original data without modification.*** New data can be acquired in the best LDP for the area and still be used with the historical data or other data collected by other agencies in different coordinate systems with minimal effort by the user.

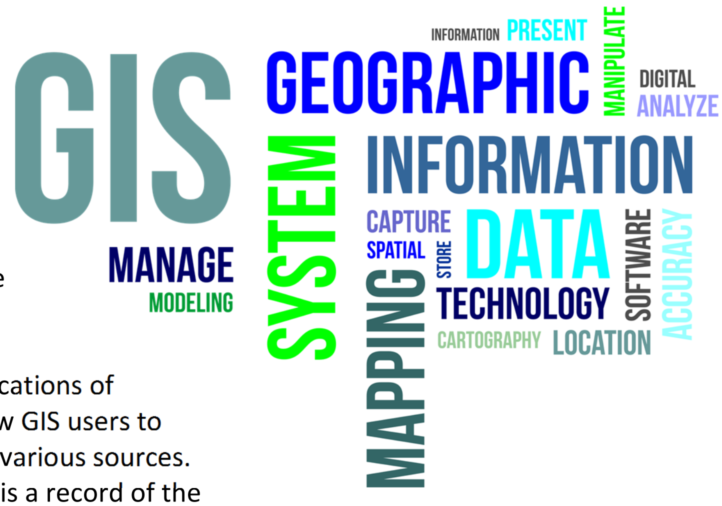
Many cities and counties in Indiana use GIS data to manage their resources. Because the InGCS zones are defined by county boundaries, the InGCS will usually provide excellent coverage for the entire service area of an agency.

GIS calculations of route distances, cut/fill volumes, etc. will be more accurate with use of LDPs because of the minimized distortion. Existing coordinate systems may be adequate for large, statewide analyses where data resolution is low (e.g. large grids cell sizes > 30m). The development of LDPs allows for new high resolution data (e.g. small grid cell sizes 0.1m to 2m) and digital terrain models (DTM) from LIDAR and other new technologies to be analyzed with minimal distortion in GIS environments when studies are performed on a localized county or city areas. Existing coordinate systems would provide a substantial amount of distortion when analyzing these DTMs. Hence, LDPs will allow for the development of more accurate GIS databases and help bridge the gap between GIS and Surveying for mapping.




*(Dennis et al. 2014)*

## 6.4 Managing GIS Data




Geographic Information System managers administer data. Data includes spatial and attribute information that is provided from many sources. The spatial data locates features across the landscape while the attributes provide characteristics of the features. GIS managers use the same reference frameworks as surveyors to define positions in space.

Nearly all GIS operations require accurate locations of geographic features. Accurate locations allow GIS users to integrate and/or combine information from various sources. Critical to the accurate locations of features is a record of the coordinate system and associated projection parameters. GIS managers often incorporate surveyed data into geographic databases. Conversion of coordinate information into a different map projection system from which it was collected is usually necessary. *Critical to this process is a well-defined set of existing and desired map projection parameters.*

The newly defined InGCS low distortion projections provide another reference system in which data will be collected. By having detailed descriptions of properties of the map projection, GIS software can re-project and transform the geographic locations of dataset elements into any appropriate coordinate system. This allows the integration of multiple GIS layers, a fundamental GIS capability.

A GIS or mapping project based on one of the new low distortion coordinate systems has significant advantages. The design of the coordinate system allows field based measurements (data collection) to be directly utilized in the GIS without translation, saving time and reducing error. The size, position and orientation of features in the system can match ground conditions, increasing confidence and reducing the need for repetitive observation.

*(Dennis et al. 2014)*

# Chapter 7 InGCS in Practice

### 7.1 General Use

Before users or organizations elect to utilize the InGCS for a particular project or establish its use as standard practice for all projects that emanate from them, they should first verify that it satisfies the requirements of their projects.

As stated throughout this document, each zone of the InGCS was designed to minimize the differences in distances between pairs of projected coordinates when compared to the ground-measured horizontal distances *within a specific county or group of counties*, while simultaneously maintaining a direct tie between project coordinates and the underlying values of latitude and longitude of the controlling geometric datum. By including the InGCS into commercial software, users across various industries have the ability to seamlessly share data that may be referenced to a different projected coordinate system, such as a State Plane system. This system's grid vs. ground performance and seamless workflow is anticipated to satisfy the requirements in the vast majority of land surveying and civil engineering projects.


However, if a user's project *does* require greater grid vs. ground performance than achieved by the InGCS zone embracing the project site and the user therefore resolves to modify that zone's parameters (as is the case in "modified State Plane systems"), the intended seamless workflow of the InGCS would, by definition, be broken as all subsequent users of data within that project would need the modification parameters to reproduce the results. ***It is for this reason that the InGCS be used in practice strictly on an "as-is" basis, i.e., do not modify the InGCS zones' parameters.*** Rather than modifying the InGCS zone's parameters, the user should alternatively consider developing a site-specific LDP.

But before proceeding with the development of a site-specific LDP, the user is encouraged to ***first*** reconsider using the appropriate InGCS zone by quantifying and analyzing its grid vs. ground performance across the project site and gauge that against the project's requirements, particularly the stated precision of the local, ground-measured horizontal spatial correlations between various specific features. In other words, how precisely are certain features actually needed to physically fit together, be set apart from one another, or their existing horizontal spatial relationships reported? Example data collection and lay out features include:


- Survey boundary, control, alignment, right-of-way, etc. monuments/markers
- Plotting and compiling deeds along linear routes
- Fire hydrants
- Area drains
- Curb and gutter inlets
- Curb lines
- Manholes
- Utility lines and poles
- Auger cast piles
- Building footer and foundation corners or center lines
- Column lines and anchor bolts
- Wall lines
- Control lines for production/assembly lines
- Bridge piers and beams
- Rail lines
- Building Information Modeling features
- FAA Runway lengths

While approximately 99% of the sampled linear distortion throughout all InGCS zones is less than 18 ppm (0.095'/mile), the average grid vs. ground difference is less than 3 ppm (0.016'/mile), which rivals the stated accuracies of many (survey-grade) total stations' EDMs. With LDPs exhibiting both positive and negative linear distortion across their design regions, terrain conditions on project sites can frequently exhibit opposing distortion values nearly balance/cancel out.

***Second***, the user should compare the grid vs. ground performance of the InGCS zone across the project site against that of a site-specific LDP. Depending upon terrain characteristics, the magnitude of the difference in grid vs. ground performance between the site-specific LDP and the appropriate InGCS zone may not be significant enough to warrant the use of a site-specific LDP, or justify the time (already) involved in developing the LDP, along with the additional time for field and office testing, reporting, coordination, and dissemination of the parameters to all parties involved.

## 7.2 Positioning Projects Relative to the NSRS

The InGCS was developed with the focus of serving land surveying and civil engineering projects and being able to be seamlessly share them with other geospatial industries, such as GIS, construction, etc. By definition, the InGCS is referenced to the National Spatial Reference System (NSRS), which is currently defined geometrically as NAD 83 (based on the GRS 80 ellipsoid); therefore, surveying and civil engineering projects that are based upon the InGCS should be properly referenced to the NSRS. When the InGCS was approved and adopted by the Indiana Department of Transportation in 2015, the most current realization of NAD 83 at that time was NAD 83(2011) epoch 2010.00. Regardless of the realization "current" at the date of work performed on a particular project, the burden of identifying the datum tag (realization) in metadata for such project will be upon the practitioner.

### 7.2.1 GNSS Observations

*NGS CORS and Passive Marks:* Since the National Geodetic Survey's active network of Continuously Operating Reference Stations (CORS) is the foundation of the NSRS, it should be considered as the top of the chain of command in the hierarchy of control relative to the NSRS, especially so for positions of latitude, longitude and ellipsoidal height. All other mechanisms used for tying projects to the NSRS for positions of latitude, longitude, and ellipsoidal heights, such as NGS passive control marks with "ADJUSTED" positional values of NAD 83(2011) epoch 2010.00 (or later) or proprietary Real-Time (GNSS) Networks (RTN), can be considered junior to the NGS CORS as they themselves derive their 3D positions (either wholly or in part) from the CORS. For positioning the orthometric heights of projects in Indiana relative to the North American Vertical Datum of 1988 (NAVD 88), the inclusion of undisturbed NGS bench marks yielding such "ADJUSTED" heights remains as the recommended procedure at the initial public release date of this Handbook and User Guide.

The NGS' CORS are considered "active" because the NGS has the ability to monitor their positions in 4D from GNSS data being collected from each CORS site and streamed to the NGS via the internet in regular increments (hourly, daily, etc., depending upon each site's availability). The NGS' "passive" marks are considered so because they are not being "actively" monitored as the CORS. From the moment which ends the last observation session for a particular passive mark that will eventually be included in the NGS Integrated Database (IDB) with "ADJUSTED" positional values of the then-current realization, the values associated with that mark starts to become "stale" as it is not being "actively" monitored. The region within which the mark resides may experience subsidence, uplift, or other geological events or the mark itself may be disturbed, either slightly or greatly, due to construction or other events caused by man. Many of these instances may not be perceptible upon visual inspection of the area surrounding the mark, leaving the user to believe the mark is otherwise undisturbed. Of the styles of passive marks constructed by the NGS, those with a stability rating of "A" (such as a disk set in bedrock or 3D monument driven to refusal) are the *least* likely to be disturbed as a result of subsidence or uplift. Unlike many "C" stability monuments (such as a disk set in a concrete cylinder projecting several inches above grade), these are typically set flush with the surrounding grade and are less susceptible of being struck from mowing operations or other activities.

<u>*Real Time Networks (RTNs):*</u> Utilization of RTNs requires the user to have internet access at their GNSS rovers so as to contact the RTN provider's server. While in some cases an RTN user can access the internet from a local Wi-Fi source, the majority of RTN users rely on cellular networks to access the internet to receive corrections from their RTN provider(s). This limits RTN use to geographical regions that have "adequate" cellular coverage. In regions that that have adequate cellular coverage, users are encouraged to perform validations that the RTN(s) they are using provides positions that are within acceptable tolerances when compared to positions provided by use of NGS' CORS.


Be aware that field personnel should exercise particular caution when working with RTNs. The following excerpt is from "*The Ever Moving Datum, Ever Changing Earth Conundrum*" article written by Michael McInnis, System Dividends, LLC concerning this topic:

"Being "star" based, one of the many things GPS has reinforced is the fact that the physical Earth is a dynamic structure, continually changing shape and dimension over time. This means of course that any given measurements of the Earth must be considered not in three dimensions (XYZ) but in four (XYZ and Time). Since the satellites in the GPS system are not conditional on the local movement of the Earth, that presents surveyors with a relatively new set of problems when using established coordinate system s such as State Plane and UTM or even user defined systems based on "accurate" global values (latitude, longitude and ellipsoid height). As more and more spatial information is integrated into our daily lives (GIS, location based services, etc.) the disparities between a "fixed" measuring platform and a constantly changing target become more acute. This document will be confined in a general way to the two most basic Earth changes (the movement of the center of mass of the Earth and shifts in the "local" Earth surface) and specifically how this movement is realized and dealt with in the ***Trimble Business Center (TBC)*** software.

To begin, in the context of this document the word *accuracy* is meant to describe how well a position on the Earth is known and can be repeated (global coordinates like latitude/longitude/height) and the word *precision* is meant to describe how well the relationships between several points on the Earth are known and can be repeated within themselves (delta XYZ). At the end of the day, a boundary surveyor is more concerned with property corners relative to the Section or legal monuments that control the survey (*precision*) as opposed to their global accuracy. However, if the surveyor publishes a boundary survey purported to be on an accurate basis (required for State Plane/UTM) or wants to make the survey portable across a multitude of coordinate systems (**highly recommended**), then both *accuracy* and *precision* are in play.

The datum discussed here will be generally the basic WGS84 which is the foundation of the GPS system and GRS 80 which is the basis for NAD83....in the *original* realization of the NAD83 datum, both NAD83 and WGS84 shared the same physical center of mass of the Earth which is why when using the ***NAD83 (Conus)*** datum in ***TBC*** the ***Local*** and ***Global*** lat/longs/hts will be identical (the ***Molodensky*** transformation values are set to zero). Over time however, the center of the WGS84 ellipsoid shifts with the current dynamic center of mass of the Earth which means that the WGS84 and NAD83 lat/long/hts are no longer the same. To account for the differences there have been new realizations of NAD83. This is evidenced by using the ***NAD83 CORS96*** and ***NAD83 2011*** datum transformation in ***TBC*** wherein a seven parameter transformation performs the shift between the two datum (NAD83 and WGS84) and the ***Local*** and ***Global*** lat/long/ht values are not the same. Since its inception, the NGS OPUS utility has been based on the NAD83 CORS 96 *2002.00* realization but on July 15th, 2012 that changed to NAD83 2011 *2010.00* (the last number in the name, *2002.00* and *2010.00* refers to the epoch date in time). The new realization of NAD83 also includes adjustment of the CORS stations themselves...

...As of ***Survey Controller Version 12.49*** and ***Access Ver 2012.20*** – when using a VRS system the Trimble data collectors ASSUME that the broadcast position is WGS84. If that is **NOT** the case (many VRS systems are now broadcasting a NAD83 2011 position) **AND** the controller coordinate system/datum transformation is using the seven parameter transformation (as referenced above in the NAD83 COR96 and NAD83 2011 systems), **ALL VALUES WILL BE WRONG!!!!!!!** For example, if the VRS is in fact broadcasting NAD83 2011 and Colorado State Plane NAD83 2011 is used as the coordinate system, the Trimble data collector will interpret the broadcast lat/long/height as WGS84 (which is incorrect) and the transformed **Local** value and projected **Grid** coordinates will also be incorrect.

The work around is to use the original NAD83 (Conus) coordinate systems in the controllers and then transform the values using HTDP as necessary."

The complete article by Mr. McInnis can be found at on-line at the following URL: http://www.neigps.com/wp-content/uploads/2014/03/NAD83-CORS96-vs-NAD83-2011.pdf .

The following Figures help illustrate this issue. Figures 7.2.1-1 and 7.2.1-2 were adapted from the *Upcoming Changes to the National Spatial Reference System – The Upcoming Changes in National Datums* – presentation given by Dave Minkel (former NGS Geodetic Advisor to Arizona), at the 2011 ACSM Survey Summit.

Figure 7.2.1-1 illustrates a basic geodetic reference frame that uses the GRS 80 ellipsoid. Here, the position of point “A” can be expressed in terms of Earth-Centered, Earth-Fixed (ECEF) XYZ values or by values of latitude, longitude, and ellipsoidal height *relative to the Earth Mass Center of **this** reference frame*.

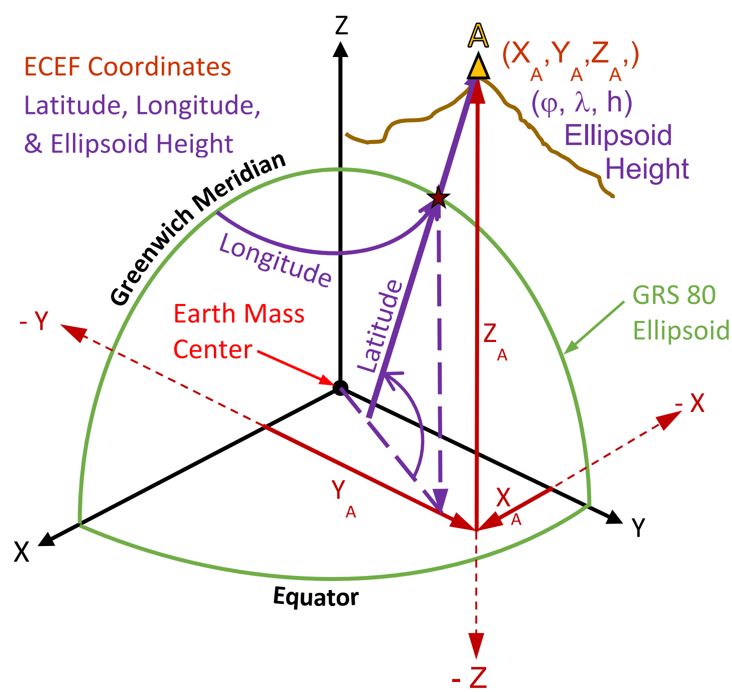



***Figure 7.2.1-1:*** *Geodetic Reference Frame.*

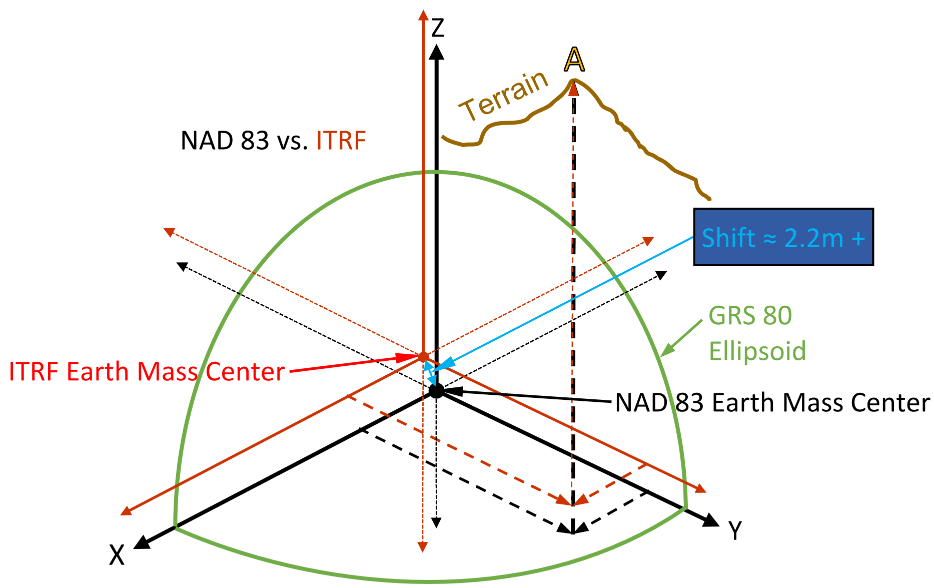



Figure 7.2.1-2 illustrates the approximate shift between the Earth Mass Centers of NAD 83 and ITRF and the corresponding effect on ECEF XYZ coordinates.

***Figure 7.2.1-2:*** *NAD 83 vs. ITRF XYZ.*

Figure 7.2.1-3 illustrates the approximate shift between the Earth Mass Centers of NAD 83 and ITRF and the corresponding effect on ellipsoidal heights.

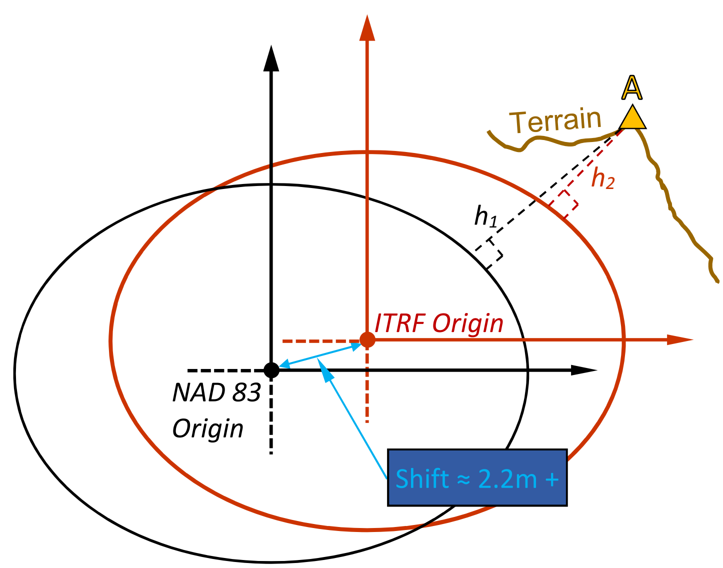



***Figure 7.2.1-3:*** *NAD 83 vs. ITRF Ellipsoidal Heights.*

*Example Exercise #1:* The following example exercise describes and illustrates (see Figure 7.2.1-4) the potential horizontal error associated when an RTN user's field software transforms coordinates received from an RTN that were already in the correct geometric reference frame.


***Figure 7.2.1-4:*** *Horizontal difference of potential correction errors with RTNs.*

The two physical survey marks in this example are known as “DR.JEKYLL” and “MR.HYDE.” The static GPS files, photographs, descriptions, and other pertinent data for these stations were submitted to NGS' OPUS-DB (Shared Solutions) and are archived with the Designations “DR.JEKYLL” (PID: BBDX25) and “MR.HYDE” (PID: BBDX24). Refer to Table 7.2.1-1. for the corresponding results.

***Table 7.2.1-1:*** *Horizontal difference of potential correction errors with RTNs.*

| OPUS-DB (Shared Solutions) Values of Stations “DR.JEKYLL” and “MR.HYDE” | | | |
|---|---|---|---|
| *Station Designation: DR.JEKYLL PID: BBDX25* | | *Station Designation: Mr.Hyde PID: BBDX24* | |
| Geometric Datum: NAD 83(2011) epoch 2010.00 | | | |
| Latitude | 37°57'38.67220"(N) ±0.014m | Latitude | 37°57'38.69839"(N) ±0.004m |
| Longitude | 87°40'41.49061"(W) ±0.017m | Longitude | 87°40'41.50968"(W) ±0.024m |
| Grid System: Indiana SPCS, West zone (1302) | | | |
| Northing | 301,303.642m | Northing | 301,304.452m |
| Easting | 847,725.785m | Easting | 847,725.325m |
| Static GPS Schedule | | | |
| Start | 2015/07/16 10:37:30 (UTC) | Start | 2015/07/16 10:37:30 (UTC) |
| Stop | 2015/07/16 21:10:45 (UTC) | Stop | 2015/07/16 21:10:45 (UTC) |
| Duration | 10:33:15 | Duration | 10:33:15 |
| Grid Inverse | | | |
| Azimuth | 330°24' | Distance | 0.932m (3.06') |

If a user were to (1) set up a daily job file in their field software with a NAD 83 datum bearing a seven parameter transformation (such as "United States/ITRF to NAD83"), (2) input the Indiana SPCS, West zone grid coordinates listed above for station DR.JEKYLL, (3) select either INDOT's InCORS, Trimble's VRS Now, or Topcon's TopNET Live RTN (all of which broadcast relative to NAD 83(2011) epoch 2010.00), and (4) stake out the grid coordinates of DR.JEKYLL listed in Table 7.2.1-1, the user would be incorrectly directed to the MR.HYDE mark, falling ±3' northwest of the DR.JEKYLL mark.

None of this implies that users should avoid using NGS passive marks, Real-Time Networks, other mechanisms to tie their projects to the NSRS, or to avoid using them as a means for QA/QC. *On the contrary,* proper combinations of these mechanisms will provide increased confidence to the user that their project(s) have been sufficiently tied to the NSRS. It may also help isolate possible inconsistencies, such as a passive mark having subsided, the user selecting the incorrect antenna type or submitting the incorrect measurement to the Antenna Reference Point (ARP) when submitting solutions to the NGS' Online Positioning User Service (OPUS), or positional differences lying outside of project-specific tolerances between an RTN and the NGS' CORS.

Users should always exercise sound judgement in deciding when to use which mechanism (or a combination thereof) to achieve the optimal results necessary to satisfy the specific requirements of each project while meeting or exceeding the minimum standards for competent practice of land surveying set forth by the appropriate governing body. In Indiana, these *minimum standards* are established in Title 865 of the Indiana Administrative Code, Article 1, Rule 12. Should a particular project or client require standards higher than those outlined in Rule 12's minimum standards, those higher standards should be followed.

*Geospatial Field Software Quality Control:* A series of RTN field observations were collected on two separate days on Station "PERCH" with some of the proprietary field software platforms more widely-utilized in Indiana as a limited means of ensuring that they were positioning correctly relative to NAD 83(2011) epoch 2010.00 and to compare the average RTN values of each platform with the position derived for Station "PERCH" using NGS' OPUS utility. Refer to Appendix E for more information on Station "PERCH" and the results of the RTN observations.

*GPS+Space-Based Augmentation Systems (SBAS):* Nearly the opposite effect of the potential correction errors associated when using RTNs is encountered when using GPS+SBAS (Wide Area Augmentation System (WAAS) within the U.S.) and selecting a NAD 83 datum with a zero transformation in the user's field software. Refer to Figures 7.2.1-5. and 7.2.1-6 for graphics of this example. This problem is even more acute with more accurate SBAS solutions, such as Trimble's CenterPoint RTX (< 4 cm accuracy).

<u>*Example Exercise #2:*</u> In this exercise, Station “PERCH” was occupied on 2015/12/14 with a Trimble R8 Model 3 GNSS unit. In the field data collector’s (Trimble TSC3) software (Access version 2015.22 (9930)), “NAD 1983 (Conus)(Mol)” and “Indiana West 1302” were selected for the geometric datum and SPCS zone. An “RT differential” with “SBAS” broadcast format survey was then allowed to continuously record positions at 1-second intervals for 24-hours. The results are shown in Figure 7.2.1-5.

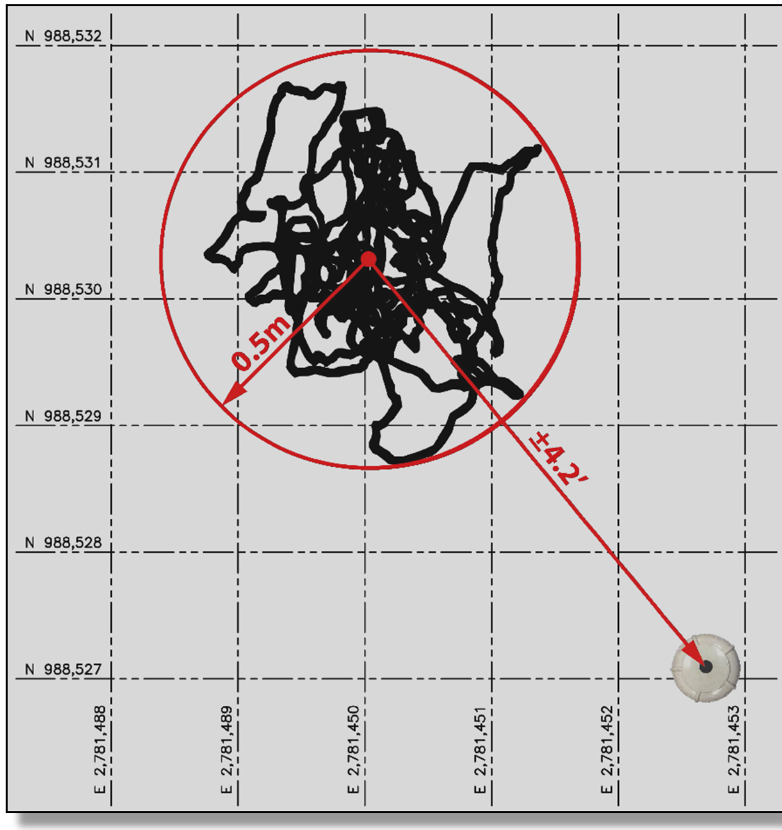



***Figure 7.2.1-5:*** *GPS+SBAS positioning.*

The grid lines shown in Figure 7.2.1-5 are respective to NAD 83(2011) epoch 2010.00, Indiana SPCS, West zone (1302), in U.S. Survey Feet. The Trimble R8 Model 3 is positioned at the grid coordinates of Station “PERCH” as determined from the mean of five, 24-hour static GPS sessions submitted to OPUS after the corresponding precise ephemerides were available. Each of these sessions were collected using a different Trimble GNSS unit in unique GPS weeks. The 0.5-meter radius circle with scatterplot of GPS+SBAS data inside illustrates where the positions were recorded, while the center of the circle represents the mean position of the GPS+SBAS data.


*Station PERCH (top view)*

Note (1) the offset from the mean position of the GPS+SBAS data to the NAD 83(2011) epoch 2010.00 position of “PERCH” and (2) that none of the data overlaps “PERCH’s” physical location. As a result of selecting a NAD 83 datum with a zero transformation (and given the accuracy of the GPS+SBAS positions, epoch differences, etc.), the center of the circle more closely represents the coordinates “PERCH” <u>*would have*</u> *on a grid system based upon the same numerical map projection parameters as Indiana West 1302, but relative to the (then) current realization of WGS 84,* rather than NAD 83.

_Example Exercise #3:_ In this exercise, Station "PERCH" was occupied on 2016/04/20 with a Trimble R8 Model 2 GNSS unit. In the same field data collector, the "Indiana West 1302" was again selected as the SPCS zone, but the "ITRF to NAD 1983 (2011)(7P)" was selected for the geometric datum. An "RT differential" with "SBAS" broadcast format survey was then allowed to continuously record positions at 3-second intervals for 24-hours. The results are shown in Figure 7.2.1-6.

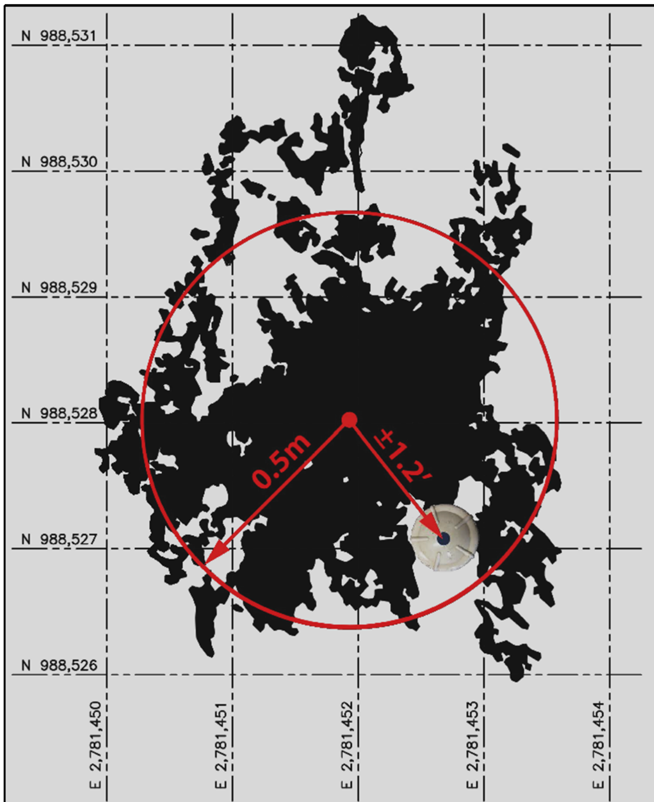



***Figure 7.2.1-6:*** *GPS+SBAS positioning.*

The grid lines shown in Figure 7.2.1-6 are again respective to NAD 83(2011) epoch 2010.00, Indiana SPCS, West zone (1302), in U.S. Survey Feet. The Trimble R8 Model 2 GNSS unit is positioned at the same values of "PERCH" from Example Exercise #2. The scatterplot of data illustrates where the positions were recorded, while the center of the 0.5m circle represents the mean position of the data.

*Station PERCH (side view)*

Note (1) the *lesser* offset from the mean position of the GPS+SBAS data to the NAD 83(2011) epoch 2010.00 position of "PERCH" and (2) that *some* of the data overlaps "PERCH's" physical location. As a result of selecting a NAD 83 datum with the aforementioned seven parameter transformation (and given the accuracy of the GPS+SBAS positions, epoch differences, etc.), the center of the circle is much closer to the coordinates of Station "PERCH" mentioned in Example Exercise #2.

*<u>(Summary) Example Exercise #4:</u>* This example exercise brings the potential positioning errors associated with RTNs and GPS+SBAS from Example Exercises #1 - #3 as well as the "U.S. Survey Feet vs. International Feet" difference from Chapter 6 together for an all-inclusive summary.

Note: All Stations shown in the photograph below and their geographic values of latitude and longitude are the resultant locations of different GNSS users marking what they thought were the correct locations for *NAD 83, Indiana SPCS West zone, grid coordinate values of*
***N 998,305 E 2,838,803*** *(in "feet")*
on the ground, using different project settings in their respective field software (geometric datum, transformation, foot definition, etc.) and global positioning techniques.

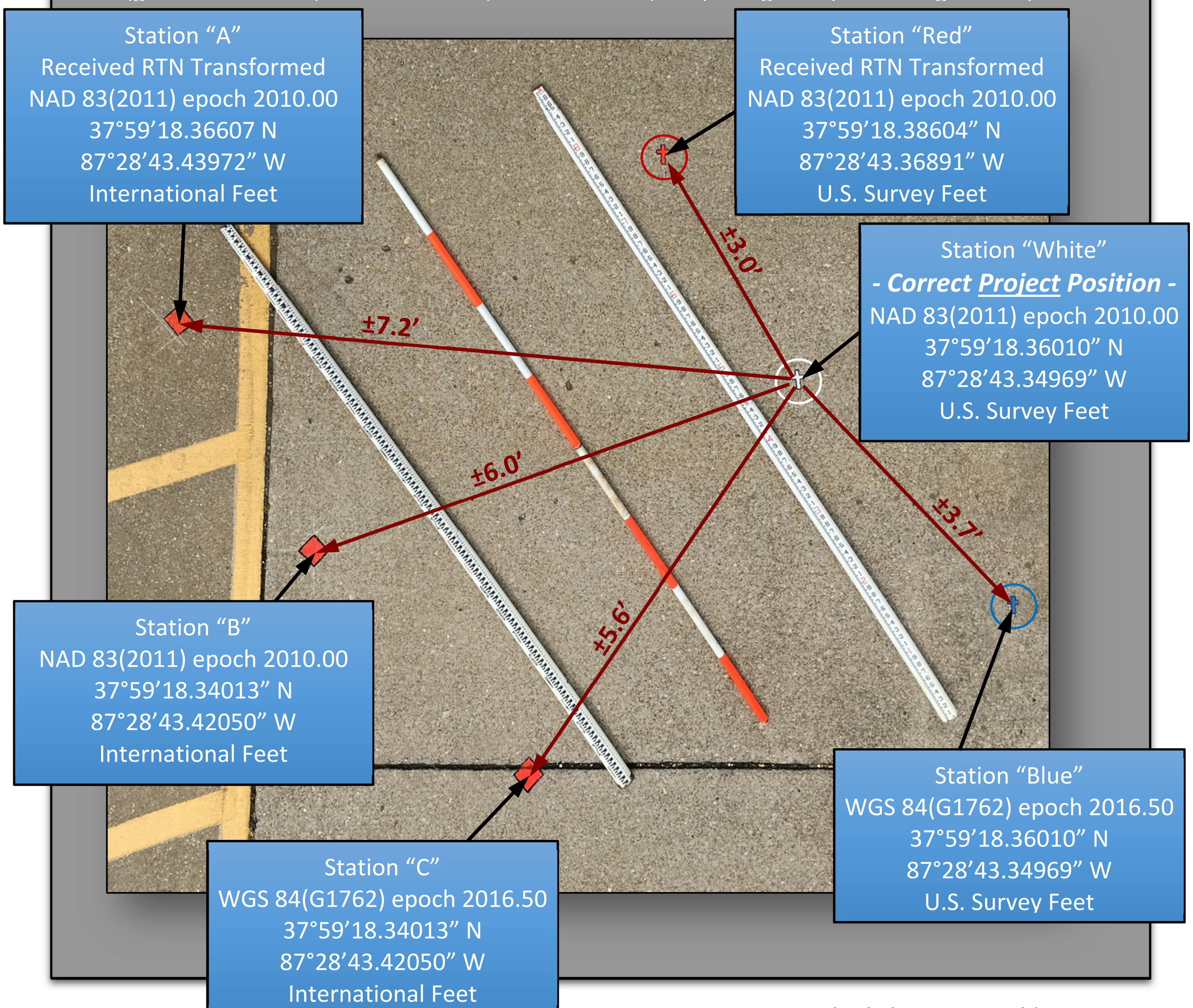



***Figure 7.2.1-7:*** *Multiple locations yielding identical grid coordinate values.*

***Referring to Figure 7.2.1-7…***

Station “Red”: This *incorrect* location was marked as a result of the RTN user selecting a NAD 83 datum in their field software that is associated with a 7-parameter transformation, while receiving real-time corrections from an RTN provider that were already in the correct geometric reference frame. The NAD 83(2011) epoch 2010.00 values of Station “Red” were presented merely as information to indicate the location of Station Red’s location, relative to NAD 83(2011) epoch 2010.00.

Station “White”: This is the ***correct*** location (correctly using OPUS, NGS passive marks, RTNs) for the depicted “Indiana West 1302” grid coordinates of ***N 998,305 E 2,838,803*** per NAD 83(2011) epoch 2010.00, in U.S. Survey Feet. Its correct orthometric height is 383.9.

Station “Blue”: This *incorrect* location was marked as a result of the user selecting a NAD 83 datum in the field software associated with a “zero” transformation while receiving SBAS (WAAS) corrections, a more accurate SBAS, ***or*** of mistakenly selecting the IGS08 positional values (latitude, longitude, and ellipsoid height) reported on an OPUS submission from an observation on the selected epoch date (2016.50) on a project control point (rather than the NAD 83(2011) epoch 2010.00 values) for a local RTK base and staking Station “Blue” using the local RTK corrections accordingly. The WGS 84(G1762) epoch 2016.50 values were shown at Station “Blue” to indicate that, *at that epoch*, the numerical values of latitude and longitude *at this location* were the same as the NAD 83(2011) epoch 2010.00 values for Station “White,” but will change over time.

Stations “A,” “B,” and “C”: All *incorrect* locations, all the results of the user *incorrectly* selecting the *International Foot*, rather than the U.S. Survey Foot, for the same techniques used to derive the locations of Stations “Red,” “White,” and “Blue,” respectively.

- Like Station “Red,” the NAD 83(2011) epoch 2010.00 values of Station “A” were presented merely as information to indicate the location of Station A’s location, relative to NAD 83(2011) epoch 2010.00.
- Like Station “Blue,” the WGS 84(G1762) epoch 2016.50 values were shown at Station “C” to indicate that, *at that epoch*, the numerical values *at this location* were the same as the NAD 83(2011) epoch 2010.00 values for Station “B,” but will change over time.

There are, of course, other scenarios that would *incorrectly* mark the desired location of ***N 998,305 E 2,838,803*** on the ground. For example, using Trimble’s CenterPoint RTX (SBAS) along with a mixture of selecting a NAD 83 datum with the zero or 7-parameter transformations and U.S. Survey Feet or International Feet to stake out the example grid coordinates will result in four different locations than shown in Figure 7.2.1-7. The bottom line of this example is that field users need to be well aware of how the project settings in their field software can impact the 3D locations of collected data and points marked in the field, but more importantly, how to correctly configure the project settings and employ varied positioning techniques (OPUS, RTN, local base RTK, SBAS (WAAS, Trimble CenterPoint RTX, etc.), etc.). Users are thus encouraged to *field test* Example #4 in their local area so as to see firsthand how their field software performs and how to avoid making these types of positioning mistakes.

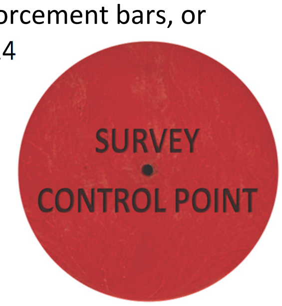
***This example also underpins the importance of including physical monuments (chiefly, survey control points, but also includes other similar types of points, such as boundary, alignment, etc.) inside of or within close proximity to project limits and providing their associated metadata relative to the project and its pertinent features in the course of a surveying and mapping project. This is true <u>regardless</u> if the project features were surveyed or mapped with total stations, local RTK base stations, RTN networks, high-accuracy SBASs, LIDAR (airborne and/or terrestrial), survey-controlled orthophotography (classical or UAS), or other industry-acceptable methods for topographic mapping.***

*Should* a mistake be unknowingly made in the project settings or elsewhere in the process of completing a surveying and/or mapping project which causes a *consistent* error in reporting the correct project coordinates and/or values of latitude and longitude, the act of including physical monuments and their associated metadata on survey plats and design plans provides subsequent users a means by which to *either* follow in the digital and physical footsteps of that survey so all future project-related features yet to be surveyed/mapped for that project remain relative to that system *or* engage in the process of correcting that survey and associated data. This is especially important in construction projects. If no physical monuments were noted on the plat of survey or design plans and subsequent users merely *assume* that the project coordinates were determined correctly, and they then determine their own coordinate values from their project settings and positioning source, the improvements to the project *may* be built in error, by whatever magnitude the original survey and subsequent surveys or construction activities differ from one another. Such an error may not be realized on a construction project until the time comes for the designed features to tie/match into existing features, which may not occur until late in the civil infrastructure staging process. *As the saying goes, "The proof of the position is in the testing." Therefore, practitioners should always perform field tests to verify that they are in sync with the project's horizontal (and vertical) basis prior to commencing any field activities.*

Survey control monuments are not to be confused with *centerline* control monuments, such as those found in location control route surveys. Survey control monuments are typically set in user-selected locations that facilitate total station or GNSS base station setups or for photo-identifiable targets in orthophotography projects. For example, an area may be selected for a survey control point that is safe, easily accessible 24/7, is free of or has minimal sky obstructions for GNSS base station locations or for aerial photo targets, etc., but is not strictly based upon the calculated geometry of an existing or future route's centerline.

The distribution and amount of survey control monuments justified for a project will vary from site to site, depending upon the size, shape, and character of the site itself. In the most general sense, their distribution should be as reasonably uniform as site conditions permit, with emphasis being placed along the exterior limits of the site or strategically beyond the anticipated construction limits, rather than most or all of the reported project control points being grouped together towards the center of the project (where they will most likely be destroyed during construction). This provides both for potentially strong survey network geometry as well as the perpetuation of a project's control basis. Title 865 of the Indiana Administrative code states that (centerline) control points in route surveys are to be monumented at each angle point and at intervals that typically do not exceed 1/4 mile. This may prove to be a good *minimum* standard for survey control monument distribution. For project sites that generally span less than a quarter mile in radius, diligent effort should be made to provide a preferred minimum of four survey control monuments distributed as previously described.

Example characteristics of acceptable *physical* monuments for perpetuating the horizontal positions of survey control points include 5/8 inch diameter or larger iron or steel rods, reinforcement bars, or galvanized pipes weighing a minimum of one pound per foot and being at least 24 inches long with a substantial, center-punched plastic or metal tag or cap permanently affixed. Other preferred monuments include those made of material of similar or greater durability, size, character, and can be found by a device capable of detecting ferrous or magnetic objects, such as a two inch or longer, 1/4 inch or larger diameter, magnetic concrete nail, or similar magnetic monument. When those types of monuments cannot be set, other suitable monuments include drill holes, cut crosses, notches, or other similar mark.



<u>*Measuring GNSS Antenna Heights:*</u> Although projected coordinate systems such as the UTM, SPCS, and InGCS are regarded primarily as horizontal/2D systems, positioning with GNSS also includes the vertical component, which elevates it to a 3D system, while plate tectonics, deformation studies, etc. moves it into a 4-D (time variable) system.

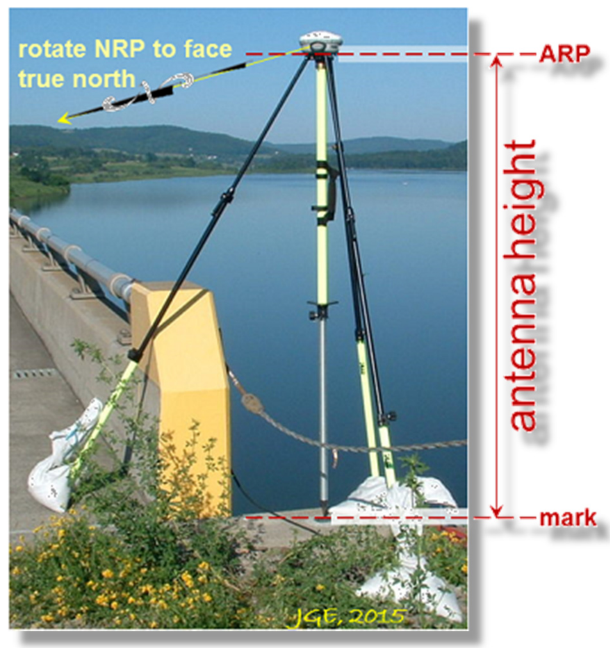
Equally important to *accurately* measuring GNSS antenna heights is correctly reporting ***which*** antenna was used and ***where*** on the physical antenna assembly the accurate measurements were respective to ***when using a given software platform***. Incorrect selection of the GNSS antenna used and/or incorrect GNSS antenna heights not only impact orthometric and ellipsoidal heights, but they also impact ECEF XYZ coordinates and *can* impact latitude, longitude and corresponding projected grid coordinates. The following image and two paragraphs are excerpts from NGS' "About OPUS" page (http://www.ngs.noaa.gov/OPUS/about.jsp) concerning submitting GNSS static files to OPUS:

**Antenna**

Selecting your antenna will engage the appropriate antenna calibration model, to counter the unique measurement biases inherent in each antenna's design. Take care! Choosing an incorrect antenna may result in a height error as large as 80 cm vertical, 1 cm horizontal. Tip: Browse antenna calibrations to find an exact match.

**Antenna Height**

Enter the vertical height in meters of your Antenna Reference Point (ARP) above the mark you are positioning, as shown in the image at right. The ARP for your antenna, usually the center of the base or tripod mount, is illustrated within antenna calibration drawings, along with the North Reference Point (NRP), which should be oriented to true north during your observation.




*(Image courtesy of NOAA's National Geodetic Survey.)*

***While OPUS uses the Antenna Reference Point (ARP) as the physical location on GNSS antennas as the antenna height, this is not necessarily the same <u>location</u> or <u>value</u> that is entered in the field to begin the GNSS static session within all vendor platforms.*** When starting GNSS static sessions, users *might* select the option in their field software to vertically measure to the ARP, but their particular field software may also offer alternative locations to measure to, either vertically or along a slant from the survey mark being occupied, that may be a more sensible option for their particular workflow.

For example, the Trimble R10 GNSS receiver shown in Figure 7.2.1-8 has a 5-centimeter "quick release adapter" that attaches to the center of the base. Users are unable to attach the R10 to a rod, tripod, etc. via a standard 5/8-11 without this quick release adapter, so it becomes an integral part of everyday field activities that includes the R10. Since many GNSS rover rods and fixed-height tripods are manufactured so that the height graduations marked on the rod are respective to the distance measured from the bottom tip of the rod to the center of the surface plane/base of the 5/8-11 thread near the top of the rod, the more functional approach for recoding GNSS antenna measurements with this receiver might be to reference the bottom of the quick release, rather than other locations on the antenna. Since

Trimble, along with other proprietary geospatial software platforms, program their respective software to correct *from* the entered antenna heights and entered reference marks *to* the location where geodetic calculations are performed (many times the antenna phase center), there's not usually any problems associated with software-dependent calculations and antenna heights.

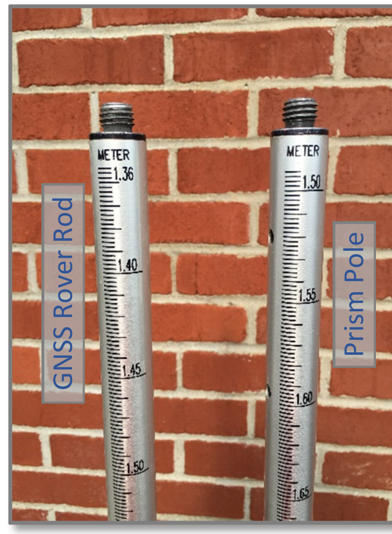
The rub occurs if users *mistakenly* enter the *same* numerical values into OPUS' input field for "meters above your mark" that represents the "antenna height of your *antenna's reference point*" they did in their field software to start the GNSS static session, rather than entering the actual ARP height above the mark. In the Trimble R10 example, if the user were to have a 2-meter fixed-height tripod to set up over a mark and select the "Bottom of quick release" option, the height entered in the field software would then be 2-meters (provided the tripod and tip are in good condition). Should users enter the same value of "2-meters" in the appropriate OPUS input field that they entered in their field software without regard to where the measurement was respective to, they have done so in error. Any solutions returned by OPUS to the users would be suspect to error of at least the difference between the correct and incorrect antenna heights.

Some proprietary geospatial software platforms may offer an upload service that users can employ to submit GNSS static files to OPUS. This service may automatically detect which height measurement was entered for their antenna, correct it to the ARP if needed, and then submit it to OPUS for processing.
If R10 users with 2-meter fixed-height tripods were to instead select the "Bottom of antenna mount" option to start their GNSS surveys, the height entered in the field software would then be 2.050-meters. This would also be the correct value to enter in OPUS' input field for "meters above your mark" that represents the "antenna height of your *antenna's reference point*" for this particular integrated antenna/receiver. ***Users are strongly encouraged to browse NGS' "Antenna Calibrations" webpage (http://www.ngs.noaa.gov/ANTCAL/) to find the exact match of the particular antenna used during an observation and determine the location of the ARP that OPUS references for that antenna.*** The Antenna Calibration page also contains (amongst other items) a column entitled "Images" that typically contains a drawing from the antenna manufacturer on which NGS adds a leader arrow and note entitled "Reference Surface For NGS Offset Measurements," "Reference surface for NGS vertical offset measurements," "Point used for IGS vertical offset measurements," etc. Should a user's particular antenna or associated "Drawing" not be included on NGS' Antenna Calibration webpage, they are encouraged to contact their vendor and request that it be provided to NGS for inclusion on that page in the future.


***Figure 7.2.1-8:*** *Trimble R10 GNSS Receiver.*

*Performing GNSS Observations:* Because project goals, schedules, specifications, characteristics, etc. vary so widely, it is well beyond the scope of this document to thoroughly outline recommended guidelines for GNSS observation procedures that might otherwise be misconstrued as trying to pigeonhole users into conducting ALL field surveys in the same manner, regardless of task or required accuracy. However, the following *condensed* list is provided as food for thought or general "tips and tricks" for routine field operations.

- Check all equipment for wear and tear and repair and/or replace as necessary.
  - Tripods (fixed height and slip leg), rods, tribrachs, bipods, etc. that are damaged, warped, worn out, etc. provide poor foundations from which GNSS units are attached (or supported) and all subsequent measurements are conducted.
  - Rod tips wear down as a result of general use. The greater the wear, the greater the potential resulting height discrepancies of all measurements.
- Validate fixed height tripod and rod height graduations.
  - The simple fact that a particular survey rod/pole/staff is graduated in feet and/or meters doesn't necessarily mean that it was marked so for a specific GNSS antenna, much less a GNSS antenna at all. Some survey rods that were manufactured for GNSS antennas and were graduated relative to the antenna reference point (ARP) ***look*** very similar to rods that were manufactured so as to be used with retro reflective prisms and total stations and are graduated relative to the center of the prism, which may ***NOT*** be the same height as GNSS unit's ARP. Using the incorrect rod/pole/staff in this case will result in incorrect GNSS-based height measurements.




*Example GNSS Rover Rod & Prism Pole*

- Check tribrach and rod bubbles for level.
  - Tribrach and rod bubbles can come out of adjustment through normal everyday use, sometimes quicker than others, even if proper care is taken. In the case of real-time observations of survey markers (control points, boundary corner monuments, alignments points, etc.), it is recommended to perform a series (discussed later) of observations for each point, rotating the tribrach or rod 180° between each observation and averaging the results. If the tribrach or rod has unknowingly came out of adjustment during the course of a work day, the horizontal residuals between the first and second observation *may* be significant enough to be detected by trained personnel. Depending upon the accuracy requirements of the project and the rank of the point(s) themselves, rotating the tribrach or rod 180° between observations *may* tolerably cancel out the horizontal errors caused from not being plumb


*Rotate Rod 180°*

over the point(s). It is recommended to discuss this procedure within an organization prior to its execution in the field.

- Check optical plummets of tribrachs (for tribrachs without rotating optical plummets).
  - Optical plummets can also come out of adjustment in the same manner as bullseye bubbles. Implementing the same “rotate 180°” procedure suggested for bullseye bubbles *may* tolerably cancel out the horizontal errors caused from not being centered over the point(s). It is likewise recommended to discuss this procedure within an organization prior to executing it in the field.
- Strive for clear views of the sky.
  - The less sky obstructions and multipath present, the better the chances of having minimal multipath in GNSS observations. The more sky obstructions and multipath, the more apt the GNSS observations will be wrought with multipath and the more probable the solutions will be degraded. These statements should be in the forefront of all GNSS users’ minds when performing field operations. They should echo loudest when users attempt to push the limits of GNSS units and dive deeper and deeper in “challenging” environments, such as within heavy tree canopy or close to metal buildings or structures.
- Operate in low-latency cellular network environments when working with RTNs.
  - As stated in NGS’ “Guidelines for Real Time GNSS Networks,” “For the RTN software to successfully synchronize the epochs of data from multiple stations a latency in transmission from a station to the CPC (Central Processing Centers) of under 1 second is desired; with an upper, highly undesirable limit of 2.5 seconds” (Henning et al., “Guidelines for Real Time GNSS Networks” 25).
- Collect more than one real-time epoch, reinitialize, restart, rotate, reobserve, average, return on another day (or later in the same day), and repeat (continued from “series of observations” discussed above).
  - The “series of observations” mentioned above emphasizes the importance of collecting more than just a single epoch for survey markers (control points, boundary corner monuments, alignments points, etc.) that will either be used for subsequent survey observations (e.g., beginning or ending 3D traverses, additional RTK base stations, boundary control monuments, etc.) or reported on survey plats with quantified positional uncertainties.
  - Collecting a mere single real-time epoch on a point provides the user with little more confidence in the position returned than the statistics returned by the software for that singular observation. Collecting multiple epochs, say 60 (for a 1-minute real-time observation), while under one initialization will provide the user with a bit more comfort with the position returned; but if the rod’s bullseye bubble had come out of adjustment during the course of the day, this single observation set would only return results for somewhere else than over the mark itself.
  - If the GNSS software had incorrectly solved for integer ambiguities, the horizontal position returned could be in error by several feet. Reinitializing (preferably by temporarily clearing/restarting all satellite vehicles tracking) allows the field software the opportunity to solve for integer ambiguities again and obtain a new fix/lock/solution.

*Cellular Network*

- Rotating the tribrach or rod 180° *may* tolerably cancel out plumb and centering errors for the point(s) being occupied.
- Restarting and/or rebooting the GNSS receiver and field software's real-time survey routine typically clears the last stored ephemerides and, in the case of real-time networks, typically restarts the network connection altogether, which allows for a new network solution altogether. The short time typically involved in this step also allows for the geometrical arrangement of satellite vehicles (SVs)  in view to change slightly enough to provide additional confidence in solving for integer ambiguities.
- Depending upon the field software, averaging the resulting positions allows field personnel to review the residuals between all observed series. Returning to the point(s) either later in the day (±4 hours) or on another day (and time) allows for the geometrical arrangement of the SVs in view to be dramatically different and for different SVs to be available (see Figure 7.2.1-16, courtesy of Hiroaki Yamada, from the *GPS Plan* app, Version 2.5.0.0). Users may not see a dramatic difference in observation performance when occupying marks having a wide-open view of the sky (i.e., optimum SV visibility), but may notice so when occupying marks in "challenging environments," e.g., a mark very near a woods line that blocks a clear view of the sky in that quadrant (i.e., poor SV visibility). For static GNSS work, reoccupying marks on another GPS week allows for different IGS Final Orbits to be used in post-processing.

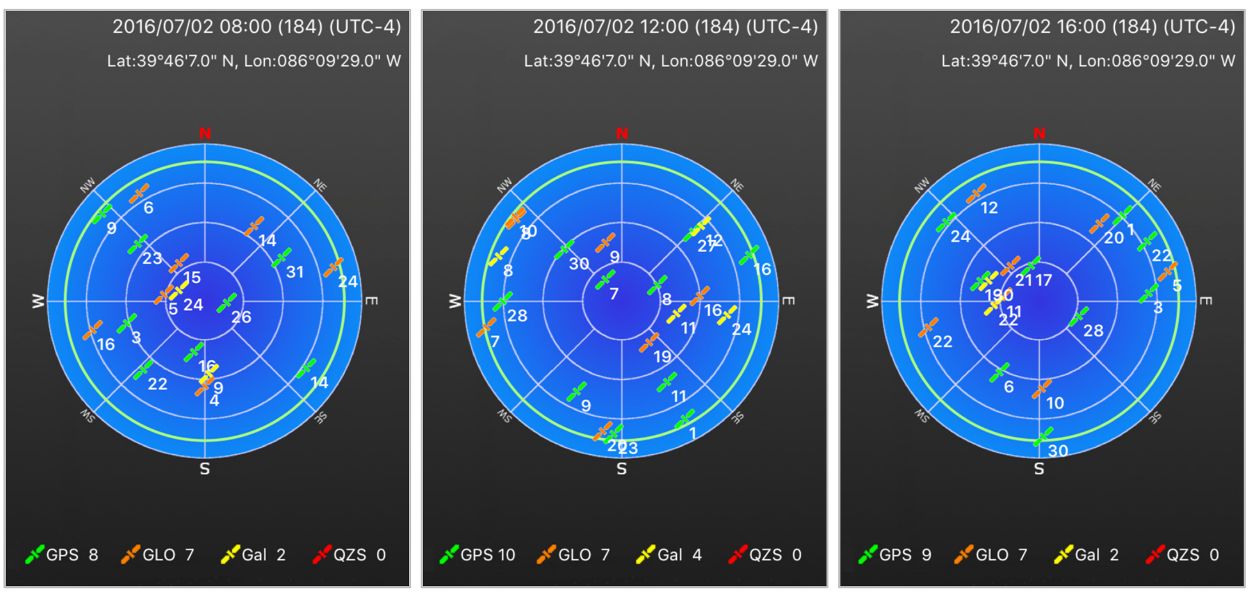


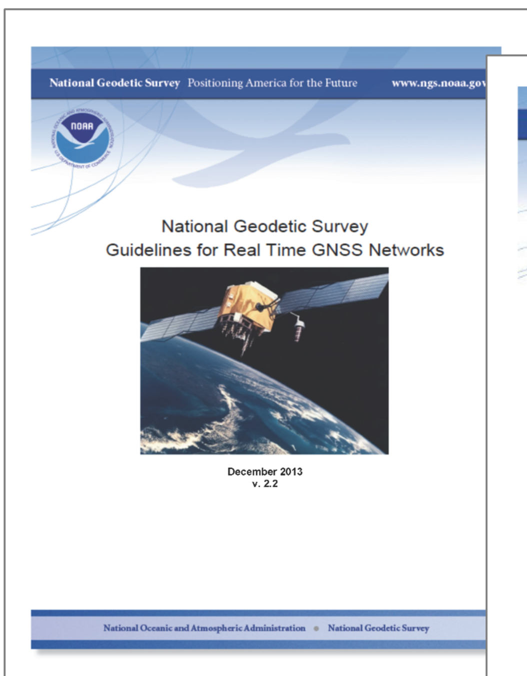

***Figure 7.2.1-16:*** *GNSS Planning Application.*

- Change setup heights between observations.
  - If a fixed height tripod or rod is not used for GNSS observations, changing setup heights between observations may help isolate height measurement reading or software entry errors.
- Minimize local RTK base station setups.
  - When working close to a projection zone boundary that segregates a project into two zones, users *may* be able to use a single, local RTK base station to work/rover in both zones, rather than change setups or have bases setup simultaneously in both zones. Like RTNs, local RTK base stations do not transmit "Northing, Easting, and Orthometric Height" corrections to the rover units; thus, like RTNs, the corrections sent by the reference station is not impacted by which projection zone it is located within. A

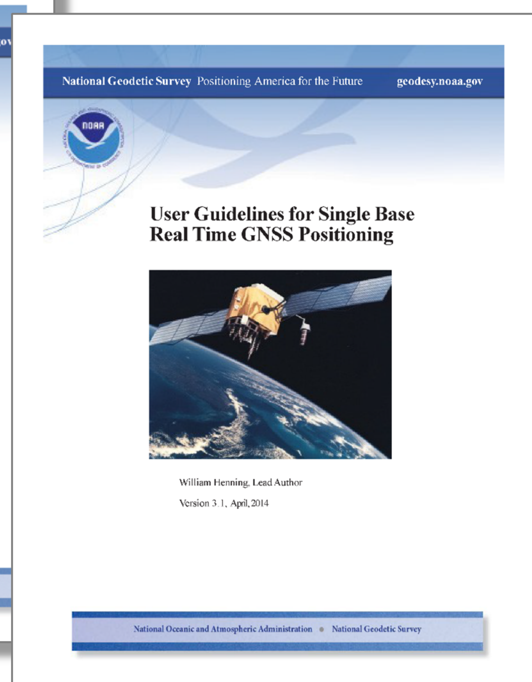
primary concern in using a single, local RTK base station to work in multiple zones is that the project was based upon the same network adjustment and parameters, i.e., the underlying values of latitude, longitude, and ellipsoid height used for the control marks are identical for both zones. If this is indeed the case, the user *should* be able to start the local RTK base station respective to Zone "A" or "B" (regardless whether or not the base station is physically located within the selected Zone) and then work within either Zone from the corrections received from the base. It is recommended to first discuss this procedure *in detail* within an organization prior to its execution in the field. Field personnel are then strongly encouraged to perform thorough check measurements to ensure that the field software is yielding satisfactory results before proceeding with related work.

Users are encouraged to visit NGS' website for further information relating to GNSS positioning.

- Pages focusing on "*Publications on Global Positioning Systems: Technology, CORS/OPUS and Orbits*" can be found at http://www.ngs.noaa.gov/PUBS_LIB/pub_GPS.shtml
  - Guidelines for Real Time GNSS Networks (PDF): http://www.ngs.noaa.gov/PUBS_LIB/NGSGuidelinesForRealTimeGNSSNetworks.pdf
  - User Guidelines for Single Base Real Time GNSS positioning (PDF): http://www.ngs.noaa.gov/PUBS_LIB/UserGuidelinesForSingleBaseRealTimeGNSSPositioningv.3.1APR2014-1.pdf




*NGS Guidelines-RTNs*




*NGS Guidelines-Single Base RTK*

### 7.2.2 Total Station Observations

*Leica Robotic Total Station (Image courtesy of Leica Geosystems.)*

Amongst other features, total stations measure slope distances as well as horizontal and vertical or zenith angles. The slope distances on most (if not all) platforms are internally measured in meters, which can then be converted and displayed to the user in a chosen format, such as U.S. Survey Feet or International Feet. Horizontal distances are then computed as a result of measured slope distances, vertical angles, user-defined atmospheric corrections (temperature, barometric pressure, curvature, and refraction) and prism (target, reflector, etc.) offsets/constants (if any). To field verify that a total station's EDM is performing up to the specifications reported by the manufacturer, it is recommended that the user visit one of NGS' Electronic Distance Measurement Instrument (EDMI) Calibration Base Lines (CBL), make the necessary measurements in accordance with NOAA Technical Memorandum NOS NGS-10, "Use of Calibration Base Line," input their observations into NGS' "CALIBRAT" program and calculate their total station's scale and constant corrections. NGS CBLs available in each state can be found at http://www.ngs.noaa.gov/CBLINES/calibration.html .

The measurements made by a total station are independent of a project being based upon a projected coordinate system, e.g., InGCS, State Plane, UTM, etc. In other words, these observations are ground-based and have not yet been reduced to a projected grid coordinate system. If a project is indeed based upon a projected coordinate system, these ground-based observations will need to be reduced to the appropriate grid system to properly calculate the resultant grid coordinates. Most total station manufacturers have either on-board data collection systems, external data collectors, or offer their software to be included in other physical devices, e.g., laptops, toughbooks, tablets, etc., all of which typically includes their proprietary software platform that will perform the necessary geodetic calculations to reduce the ground-based observations to projected grid coordinates.

Once the InGCS has been properly embedded in a user's field software platform, it *should* be able to perform the necessary geodetic calculations for the user to perform field operations on-the-fly. Users should contact their geospatial equipment provider for technical assistance should they experience troubles with their platform in carrying out field operations.

## 7.3 Checking Distortion Using Computed Distances (Grid vs. Ground)

Once again, each InGCS zone was developed so that grid and ground distances match very closely **(less than 3 ppm on average).** If you are working near the fringe of a zone, or at elevations significantly (more than about a hundred feet) above or below the elevation limits of the zone's low distortion area, then you may want to check the ppm result between control points in your project. The following tests can be performed to calculate distortion.

*Test #1:* Pick the two farthest points in your project that you can directly measure between with a total station's EDM. With the total station occupying a mark with known InGCS zone grid coordinates, properly orient/sight the total station along a known InGCS zone grid bearing toward a target, measure the *horizontal* ground distance between the points and record it with a compatible data collector with software capable of performing the necessary geodetic calculations and determine the resultant InGCS zone grid coordinates for the other point. Then inverse between the determined *grid coordinates* of these points to determine the InGCS grid (map) distance. Subtract the grid distance from the ground distance, divide this difference by the ground distance, and multiply it by 1 million to determine the distortion in parts per million. For example:

1. Horizontal ground distance (from EDM) = 1,776.704 sft
2. Inversed InGCS grid distance (computed) = 1,776.717 sft
3. Inversed minus measured distance = +0.013 ft
4. (+0.013 / 1,776.704) × 1,000,000 = 7.3 parts per million (ppm)

*Test #2:* This Test is similar to Test #1, but is performed using GNSS data. A simple but reasonably accurate way to do this is to use a delta XYZ GNSS vector to estimate the horizontal ground distance between points. Neglecting curvature, this can be computed as:

$$H = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2 - \Delta h^2}$$

Where: *ΔX, ΔY, ΔZ* are the GPS vector components (as ECEF Cartesian coordinate deltas)
*Δh* = change in ellipsoid height between vector end points

Accounting for curvature increases this horizontal ground distance, but for distances of less than 20 miles (about 30 km), the increase is less than 1 ppm (i.e., less than 3 cm).

The curvature correction factor can be approximated as:

$$C = (2R \sin^{-1}(H \div 2R)) \div H$$

where *R* is the Earth radius. A value of 20,914,000 feet (6,374,600 m) works well for Indiana. The (straight) horizontal distance is multiplied by the correction factor to get the curved horizontal ground distance. Note that there is no need to account for refraction, because the GPS vector is computed, not observed.

A more rigorous method for computing the ground distance is to first accurately compute the ellipsoid distance, and then scale it by the ellipsoid height of the endpoints to determine the ground distance.

**Step 1. Ellipsoid Distance.** The Vincenty method can be used for computing an accurate ellipsoid distance. This computation is beyond the scope of this document, but it can be done using the NGS Geodetic Toolkit at www.ngs.noaa.gov/TOOLS/Inv_Fwd/Inv_Fwd.html.

In addition, many surveying and mapping software programs can perform this calculation (although it is recommended that commercial software be checked against the NGS version).

**Step 2. Ground Distance** = *$(((h_1+h_2)/2) + R_G)/ R_G$ x [Vincenty ellipsoid distance from step 1]*
Where:

$h_1$ & $h_2$ are the ellipsoid heights of the endpoints.

$R_G$ is the geometric mean ellipsoid radius of curvature: $R_G = \frac{a\sqrt{1-e^2}}{1-e^2 \sin^2 \varphi}$

$a$ = semi-major axis = 6,378,137 m (exact) (≈ 20,925,604.474 sft)
$e^2$ = first eccentricity squared = $2f - f^2$
$f$ = geometric flattening = 1 / 298.257222101

*(Dennis et al. 2014)*

## 7.4 Projects Spanning Multiple Zones

### 7.4.1 Historical Examples

The concept of a project spanning multiple coordinate reference system zones or of changing the basis of spatial calculations somewhere within a project is not new to geospatial practitioners. Take the following Interstate 64 (southern Indiana) design plan sheet from 1967 as an example.

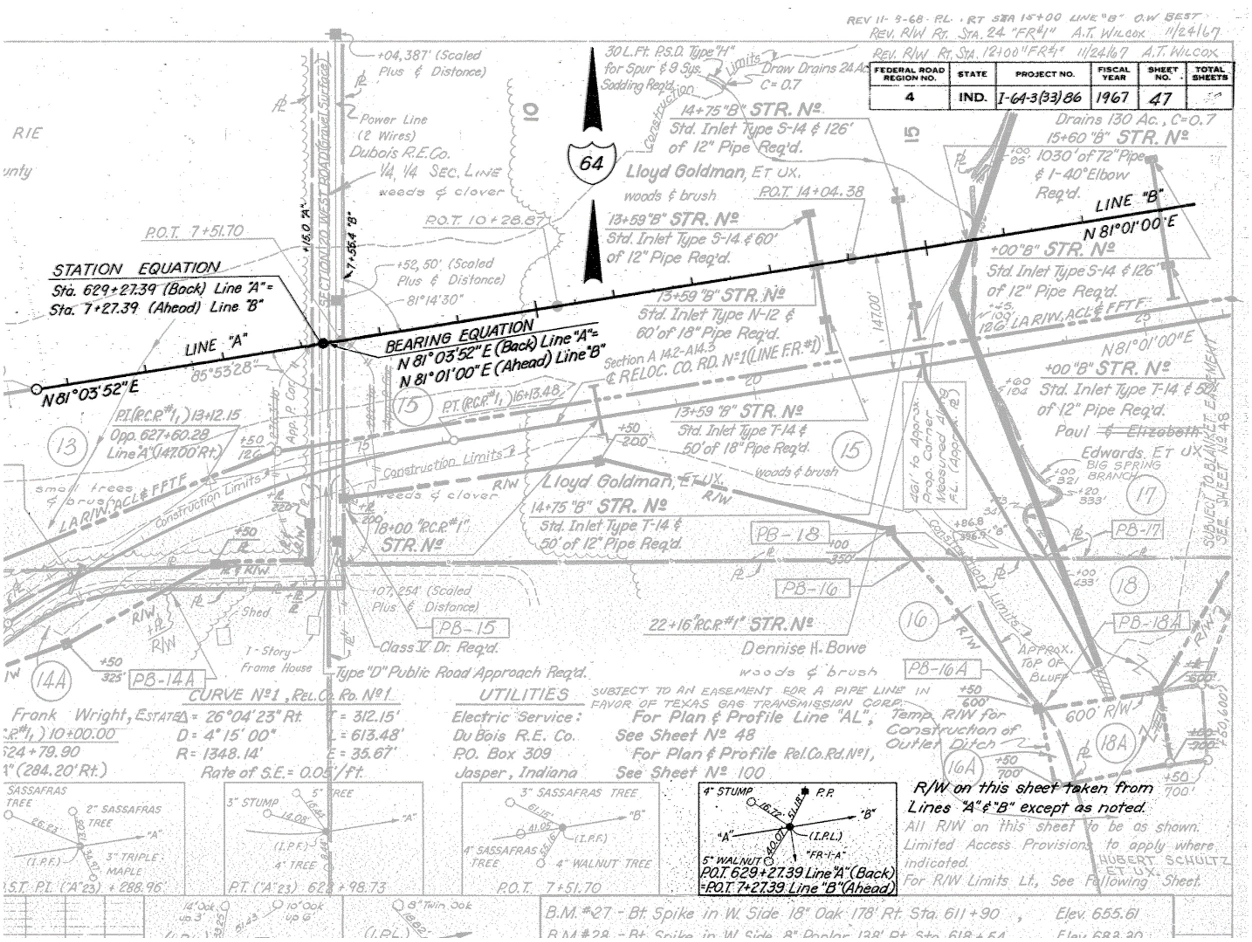



*Figure 7.4.1-1:* *Interstate 64 Design Plan Sheet.*

As discussed in Chapter 4, projects such as this were prepared using 2D (horizontal) alignments based upon arbitrary directions or directions based upon north (from magnetic, solar, or Polaris observations). There was no real geographic (either latitudes and longitudes or northings and eastings with respect to a projected coordinate reference system) basis to this system. In this example, both the basis of bearings and stationing was changed via a “BEARING EQUATION” and “STATION EQUATION” (see **bold** text and graphics in Figure 7.4.1-1), which effectively changed the project’s “coordinate system” at that location in the project.

Other, more recent examples may include projects that span SPCS zones, state lines, or local projects that either neighbor or overlap one another occurring either simultaneously or sequentially by different surveyors.

### 7.4.2 General Recommendations and Considerations

The *General Recommendations* listed in this Section and shown graphically in Figures 7.4.2-1 through 7.4.2-7 were adapted from the Wisconsin Department of Transportation's WisDOT Facilities Development Manual (FDM), FDM 9-20-27 (2009/07/22), and also appear in similar form within the INDOT Design Manual for INDOT projects. They are likewise presented in this Handbook and User Guide for consistency with other agencies, organizations, and industries that may or may not reference the INDOT Design Manual.

As projects have historically risen that span state lines or SPCS zone lines, the same will be true for projects that span InGCS zone lines. Likewise, as it has been more practical to utilize a single SPCS zone for projects that cross into another zone by *reasonably* small distances, the same will most likely prove true for projects that will also cross into another InGCS zone by reasonably small distances. Therefore, it is believed most practitioners would likely agree that unless it is *clearly* obvious that a project *would in fact* benefit from being based upon more than one zone, the more common sense approach would be to only segregate the project into multiple zones if the project is to advance in stages. In this case, the geographical extents of each stage could be strategically positioned to align with the appropriate zone boundaries or other sensible ownership lines.

When a project does arise that spans multiple InGCS zones with different grid coordinates and the decision is made to base the project on more than one of the underlying zones, the following General Recommendations are offered to provide guidance to determine which InGCS zone(s) will be used and where to make the change from one zone to another. As there are a seemingly infinite number of different scenarios for projects crossing zone lines, along with the varying complexity of projects, these General Recommendations are *not* meant to be strict rules to unnecessarily burden projects. They are only meant to act as guidelines. Instances will, with little doubt, arise where more logical solutions could be determined that may contradict these guidelines.

When using the InGCS for a project in multiple InGCS zones, it is important to consider linear distortion and legal requirements as data are acquired near or across an InGCS zone or county line. Usually, increase in linear distortion will not be critical unless there is a great difference in elevation between the InGCS zones. Legally, there may be a requirement to file documents using the zone of the resident county. Specific requirements should be checked for each project.

<u>*General Recommendations:*</u>

1. For projects that are continuous throughout more than one InGCS zone, the InGCS zone used should change at the zone line, as InGCS zones are nominally bounded by county lines. Design plans and survey plats should be completed in the respective InGCS zone/county.
2. Projects that extend more than roughly 1-mile into the next zone should follow the guidance in the previous paragraph.
3. For projects that extend into an adjacent InGCS zone approximately 1-mile or less, the InGCS zone used should remain that of the primary zone.
4. For projects that tend to lie within roughly 1-mile of a zone line, the InGCS zone used should be the zone for County "A" (which will usually be the county with the majority of the project). Examples include, but are not limited to, (a) bridge or small structure projects straddling county lines, road rehabilitation projects running along a zone line, (b) interchange projects at the intersection of multiple zones, or (c) projects that zigzag a zone line. The InGCS zone for County "A" may be used on the plat to be recorded in County "B" zone. It is crucial to document the

InGCS zone used and to clearly label the InGCS zone on plans, plats, computer files, and all other documentation.

5. For projects that would *otherwise* seemingly satisfy the criteria of one of these "General Recommendations," but because of specific design considerations, modifications as to where in those projects changing to the neighboring zone would make much more *functional* sense, it is recommended to consult with the appropriate project manager and seek the ***most practical*** solution aligned with the spirit of these "General Recommendations."

   Take for example a project that is continuous throughout two neighboring zones but has a massive bridge structure straddling the zone/county line (refer to Figure 7.4.2-1, noting that the project limits are depicted by the red polygon). General Recommendation #1 would normally call for this project to change zones at the zone/county line, but it may not be practical to design, prepare design plans, or stage construction for such a structure in two zones.

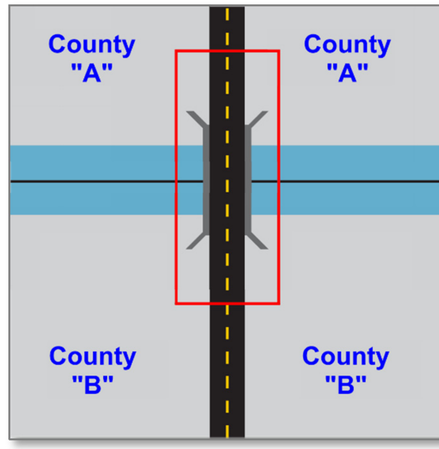



***Figure 7.4.2-1:*** *Project divide-GR#5.*

   In this scenario, it would make more functional and practical sense to make the change from one zone to another at a different location, such as beyond the limits of structure-related features and at a sensible ownership line (PLSS, Grant, Donation, Location, etc.). Project-related land descriptions (particularly for INDOT Parcel Descriptions (Exhibit "A") and accompanying Parcel Plats (Exhibit "B")) could then ***call to*** such ownership line, rather than project coordinates or project-related station and offset geometry.

6. When other instances arise that are more complex than those listed in this "General Recommendations" Section for selection of InGCS zones for projects, it is *again* recommended to consult with the appropriate project manager and seek the ***most practical*** solution aligned with the spirit of these "General Recommendations."

The following graphics illustrate these General Recommendations. Note again that project limits are depicted by the red polygons.

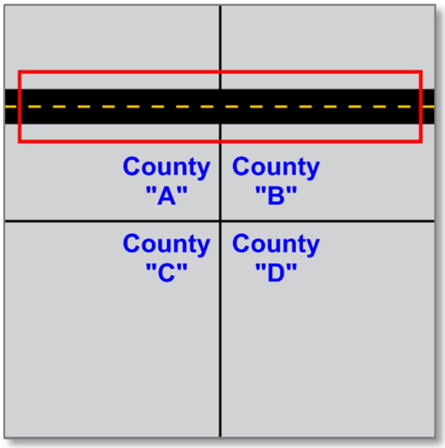



***Figure 7.4.2-2:*** *Project divide-GR#1.*

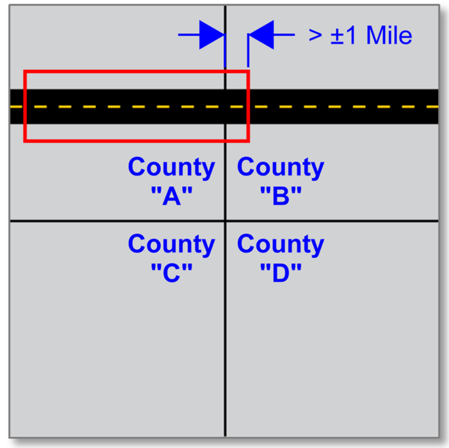



***Figure 7.4.2-3:*** *Project divide-GR#2.*

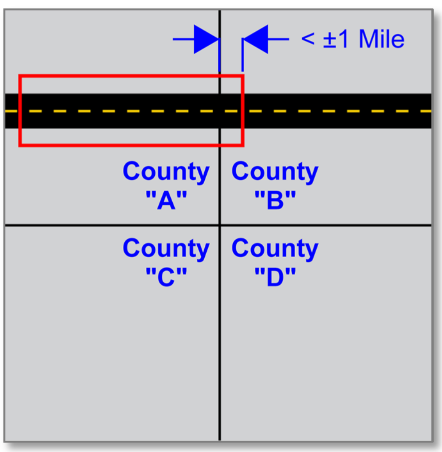



***Figure 7.4.2-4:*** *Project divide-GR#3.*

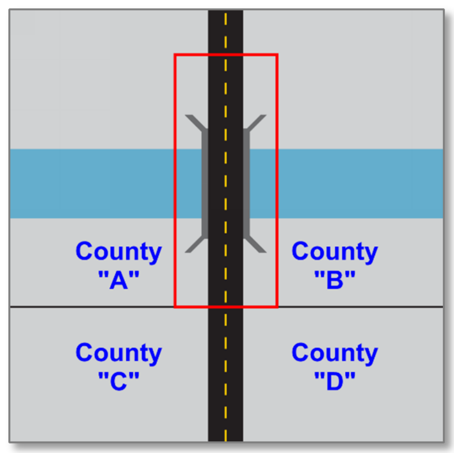



***Figure 7.4.2-5:*** *Project divide-GR#4a.*

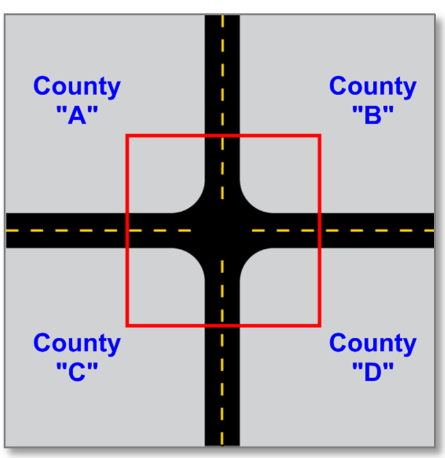



***Figure 7.4.2-6****: Project divide-GR#4b.*

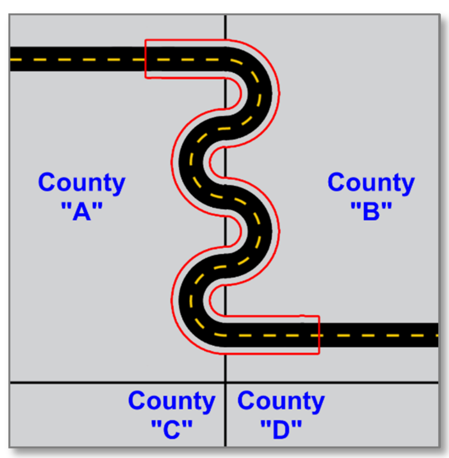



***Figure 7.4.2-7:*** *Project divide-GR#4c.*

_General Considerations:_ Along with the *General Recommendations* listed above for dividing a project between zones in respect to a zone/county line or other type of on ownership line, these *General Considerations* are geared more towards linear/route projects and dividing them with respect to their horizontal geometry.

It is important to mention that when working on linear/route projects in Indiana, a Location Control Route Survey (LCRS) (or simply “Route Survey”) plat *that is filed in the appropriate County Recorder’s Offices* serves as a *publically-available document* that provides (amongst other items) detailed graphical depictions, 2D (horizontal) geometry, and tabular listings of survey control point metadata relative to physically-monumented horizontal alignments. In tandem with publishing the project coordinates and geometric dimensions of the alignments on the LCRS plat, the act of setting physical survey markers at the corresponding points shown on the plat, in essence, officially affixes the plat and the associated alignments to the respective locations on the Earth. Once the plat has been recorded, a monumented alignment can then serve as the mathematical backbone from which *right-of-way* can be calculated, described, and shown in project-related land descriptions and plats for *acquisition purposes*. This right-of-way, in turn, provides a geographical corridor from which future design and associated construction activities are limited to.

Though it *may* be advantageous to synchronize the location and stationing of alignments shown on the LCRS plat with the alignments created during the design phase of a project, they by no means *have to be* coincident with one another. Many times, the alignments shown on LCRS plats are derived from preliminary design calculations and are merely meant to represent the *best estimate* of where the center of the route’s final footprint *might* be. When the locations of the final design alignments differ from the locations of the LCRS plat alignments, the associated design plans should then include adequate information to correctly relate them to one another.

Accordingly, should it be determined that a project is to be divided into multiple InGCS zones, the locations where the project is segregated on the LCRS plat(s) doesn’t *necessarily* mean that they *must* be in concert with where it is segregated on the design plans. For LCRS plats, right-of-way plans, parcel plats, parcel descriptions, etc., sensible locations may include zone/county lines or other ownership lines, without regards to any design-related features (such as bridge structures, circular curves, etc.); whereas designers may elect to choose locations that are sensible to design features, without regards to ownership lines.

To try and simplify reprojections of horizontal geometry typically encountered in a linear/route surveying and civil engineering project and minimize possible confusion, a preferred location for project segregation would likely occur (1) absent from structure-related features (such as a bridge, railroad crossing, culverts, etc.), (2) along a tangent section, (3) at a typical cross section, (4) at a full-foot station (and preferably where it would be included in future cross-section sheets, e.g., 316+00, 316+50, etc.)*, and (5) along a straight vertical** grade.

Segregating a project within an area containing structure-related features, in a superelevation, elsewhere along a circular curve, in a transition section, at an odd station, in a vertical** curve, etc. would potentially lead to increased considerations on how to properly reproject the appropriate horizontal elements.

* Note: It *may* prove to be advantageous to assign a beginning stationing value in the subsequent zone that does *not* match the stationing in the prior zone, so as to make it *even more obvious* to practitioners that a geometric change in the project occurred at this location. For example, if the ending (“Back”) stationing west of the segregation line was 316+00.00, the beginning (“Ahead”) stationing east of the segregation line could be assigned either a value that is somewhat similar, such as 16+00, 416+00, etc., or is very dissimilar, such as 100+00.

** Note: Reprojections of horizontal geometry does not impact the vertical component of associated project data. The comments of “straight vertical grade” and “vertical curve” only relate to concerns of mistakenly associating the incorrect stationing from reprojected horizontal alignments with vertical alignment calculations.

*<u>Vendor Software:</u>* As user interfaces and internal programming differs greatly between proprietary geospatial software platforms, users are encouraged to contact their vendor(s) for technical advice on the proper procedure(s) for correctly reprojecting both vector and raster data associated with their projects.

### 7.4.3 Zone-to-Zone Considerations

#### 7.4.3.1 Zones with Identical Projection Parameters

When a project spans multiple InGCS zones, it does not necessarily mean that the underlying grid coordinates change when crossing the zone boundary. When cases arise where the different zones have identical projection parameters (which includes grid coordinates), such as Marion and Johnson zones, the “changing” of zones is in name alone. Refer to the InGCS Zones Overview Map and the individual zone data sheets in Appendix C for graphical references as to which InGCS zones have identical or different projection parameters.

#### 7.4.3.2 Zones with Different Projection Parameters

When it is deemed necessary to segregate a project into InGCS zones bearing different projection parameters, careful judgement should be made on how to properly convert the appropriate data, *as is the case for projects that span state plane systems*. Basic characteristics of zone-to-zone conversions are listed below. In these examples, zones “A” and “B” have different projection parameters.

**<u>Field-Observed Data Points</u>**

*<u>Example #1:</u> In this example, zones “A” and “B” have different grid coordinates and basis of bearings (i.e., their central meridians lie at different longitudes).*

When individual data points in zone “A” are observed in the field and zone “A” coordinates are computed, these points can then be properly reprojected to zone “B” without the loss of positional accuracy, i.e., their locations on the Earth.

The grid distances between reprojected data points will vary between zones.

As grid distances change, computed areas will change accordingly.

The grid bearings between data points will vary between zones since the zones have different basis of grid bearings.

**Calculated Data Points**

*<u>Example #2a:</u> In this example, zone "A" is the Indiana State Plane Coordinate System, West zone, while zone "B" is the Indiana State Plane Coordinate System, East zone.*

Bearing-Bearing Intersections: Consider sample data Points #1 through #4 in zone "A" lying grid north-south and east-west of one another in a "+" configuration and being separated by multiple counties, with Point #5 being *calculated* at the bearing-bearing intersection of the first four Points. Refer to Figure 7.4.3.2-1 for a graphical view of these Points and their positions relative to the counties that are designated for use with the Indiana SPCS, West zone. Refer to Table 7.4.3.2-1 for the grid coordinate values of these Points.

After reprojecting Points #1 through #5 from zone "A" to their zone "B" equivalents (Points #1-RP through #5-RP) and calculating a new bearing-bearing intersection between Points #1-RP through #4-RP (at Point #5-RC), it is obvious that Point #5-RC is *not* coincident with Point #5-RP. Point #5-RP lies ±114.5' ***westerly*** of Point #5-RC. Refer to Table 7.4.3.2-1 for the grid coordinate values of Points #1-RP through #5-RP and #5-RC and Figure 7.4.3.2-2 for a detailed graphical view of these six points.

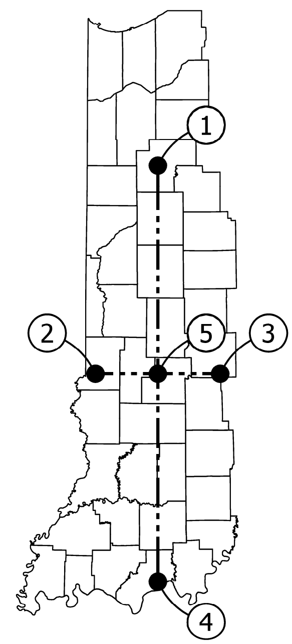


***Figure 7.4.3.2-1:*** *Indiana SPCS Regional Reprojection Example.*

***Table 7.4.3.2-1:*** *Indiana SPCS Regional Reprojection Example.*

| Indiana SPCS Regional Reprojection Example | | | | | |
|---|---|---|---|---|---|
| **Zone "A" (Original Zone)** *West Zone (1302), U.S. Survey Feet* | | | **Zone "B" (Reprojected "RP" or Recalculated "RC" Data)** *East Zone (1301), U.S. Survey Feet* | | |
| Point # | Northing | Easting | Point # | Northing | Easting |
| **1** | 2,000,000 | 3,000,000 | **1-RP** | 2,002,405.1223 | -17,243.0034 |
| **2** | 1,500,000 | 2,850,000 | **2-RP** | 1,504,753.1343 | -175,212.4547 |
| **3** | 1,500,000 | 3,150,000 | **3-RP** | 1,500,047.3677 | 124,792.6911 |
| **4** | 1,000,000 | 3,000,000 | **4-RP** | 1,002,387.9890 | -32,927.2343 |
| **5** | 1,500,000 | 3,000,000 | **5-RP** | 1,502,399.9459 | -25,199.5798 |
| | | | **5-RC** | 1,502,398.2936 | -25,085.0916 |

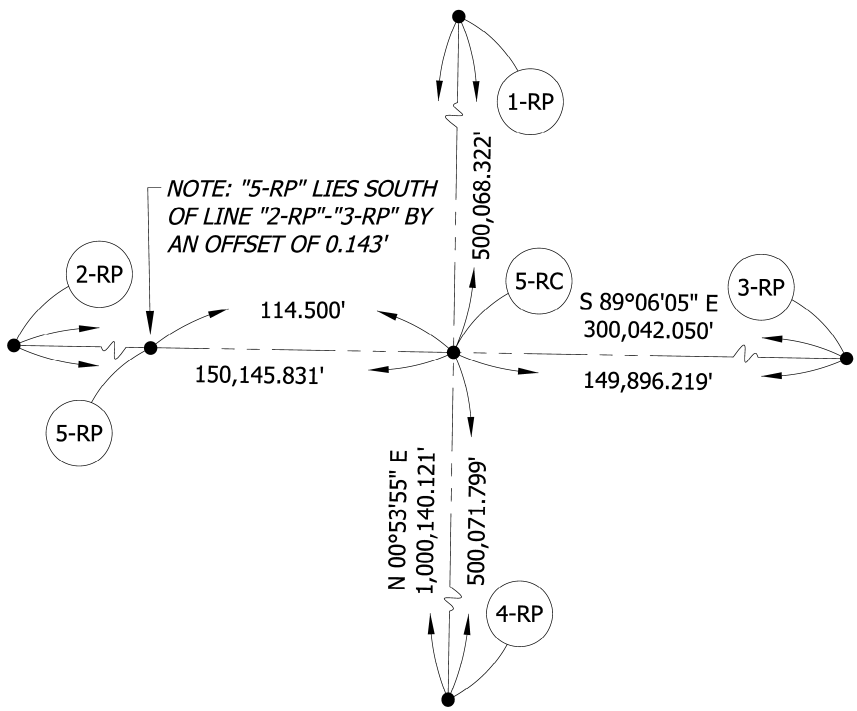



***Figure 7.4.3.2-2:*** *Indiana SPCS Regional Reprojection vs. Bearing-Bearing Recalculation Example.*

<u>*Example #2b:*</u> *Similar to example #2a, zone "A" is the Indiana State Plane Coordinate System, West zone, while zone "B" is the Indiana State Plane Coordinate System, East zone.*

Bearing-Bearing Intersections: Rather than the four points used for a bearing-bearing intersection lying multiple counties apart, Point pairs #6/#9 and #7/#8 in zone "A" in this example lie but one mile apart and, again, at cardinal directions in a "+" configuration. Point #10 is calculated at the bearing-bearing intersection of the other Points. Refer to Figure 7.4.3.2-3 for a general location view, Figure 7.4.3.2-4 for a project limits view relative to zone "A," and Table 7.4.3.2-2 for the grid coordinate values of these Points.

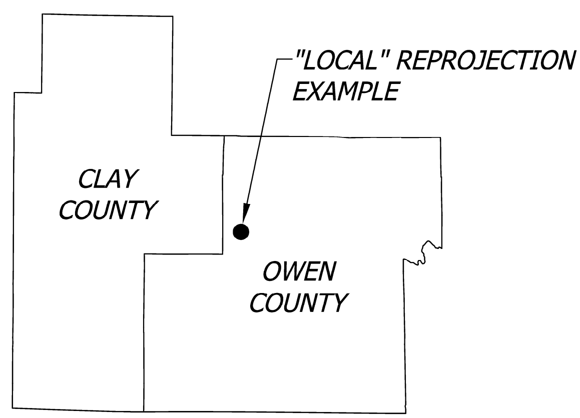



***Figure 7.4.3.2-3:*** *Indiana SPCS Local Reprojection Example.*

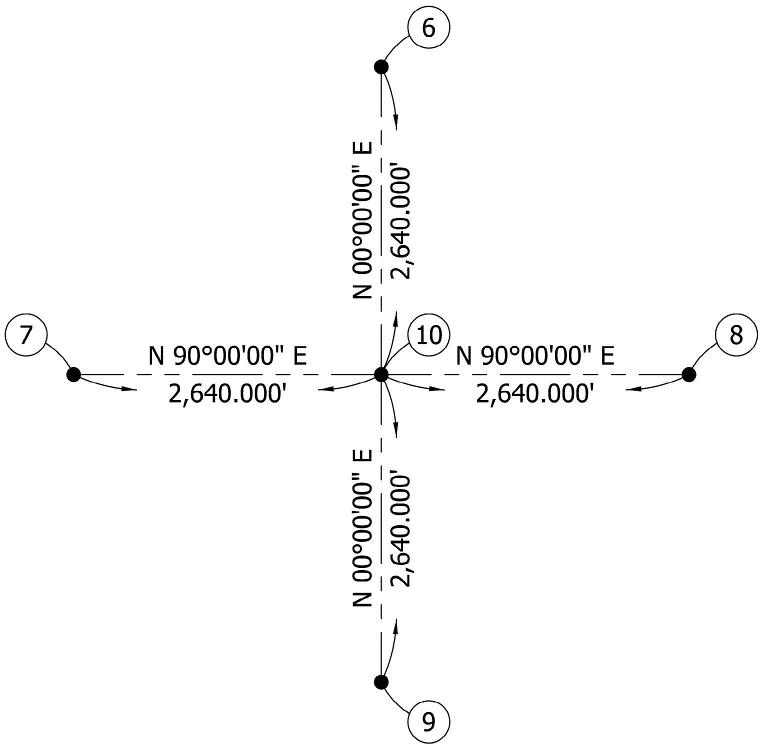



***Figure 7.4.3.2-4:*** *Indiana SPCS Local Reprojection Example.*

After reprojecting Points #6 through #9 from zone "A" to their zone "B" equivalents (Points #6-RP through #9-RP) and calculating a new bearing-bearing intersection from Points #6-RP through #9-RP at Point #10-RC, it can be determined (though not as readily apparent as in Example #2a) that Point #10-RC is not coincident with Point #10-RP. Points #10-RC and #10-RP are separated by ±0.003'. Refer to Table 7.4.3.2-2 for the grid coordinate values of Points #6-RP through #10-RP and #10-RC and Figure 7.4.3.2-5 for a detailed graphical view of these six points.

***Table 7.4.3.2-2:*** *Indiana SPCS Local Reprojection Example.*

| **Indiana SPCS Local Reprojection Example** | | | | | |
|---|---|---|---|---|---|
| **Zone "A" (Original Zone)** *West Zone (1302), U.S. Survey Feet* | | | **Zone "B" (Reprojected "RP" or Recalculated "RC" Data)** *East Zone (1301), U.S. Survey Feet* | | |
| Point # | Northing | Easting | Point # | Northing | Easting |
| **6** | 1,502,640 | 3,000,000 | **6-RP** | 1,505,039.9910 | -25,158.1662 |
| **7** | 1,500,000 | 2,997,360 | **7-RP** | 1,502,441.3563 | -27,839.6282 |
| **8** | 1,500,000 | 3,002,640 | **8-RP** | 1,502,358.5356 | -22,559.5377 |
| **9** | 1,497,360 | 3,000,000 | **9-RP** | 1,499,759.9005 | -25,240.9869 |
| **10** | 1,500,000 | 3,000,000 | **10-RP** | 1,502,399.9459 | -25,199.5798 |
| | | | **10-RC** | 1,502,399.9459 | -25,199.5766 |

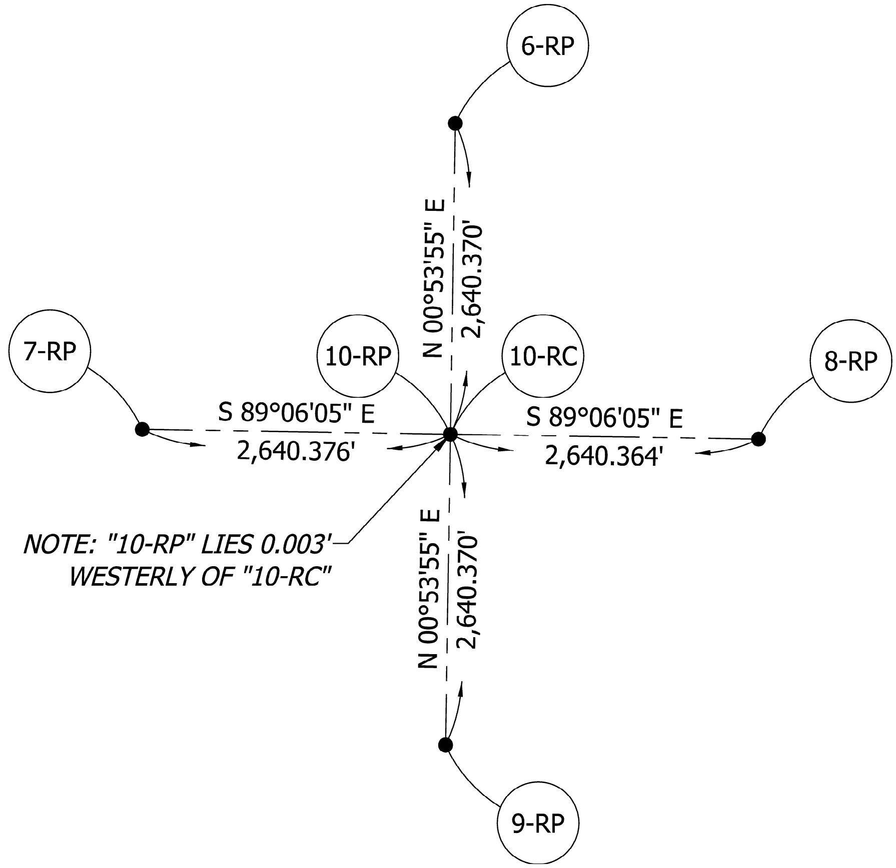



***Figure 7.4.3.2-5:*** *Indiana SPCS Local Reprojection vs. Bearing-Bearing Recalculation Example.*

<u>*Example #2c:*</u> *In this example, zone "A" is the Indiana Geospatial Coordinate System, Owen zone, while zone "B" is the Indiana Geospatial Coordinate System, Clay zone.*

Bearing-Bearing Intersections: Similar to example #2b, Point pairs #11/#14 and #12/#13 from zone "A" in this example lie but one mile apart and, again, at cardinal directions in a "+" configuration. Point #15 is calculated at the bearing-bearing intersection of the other Points. Refer to Figure 7.4.3.2-6 for a general location view (same as Example 2b), Figure 7.4.3.2-7 for a project limits view relative to zone "A," and Table 7.4.3.2-3 for the grid coordinate values of these Points.

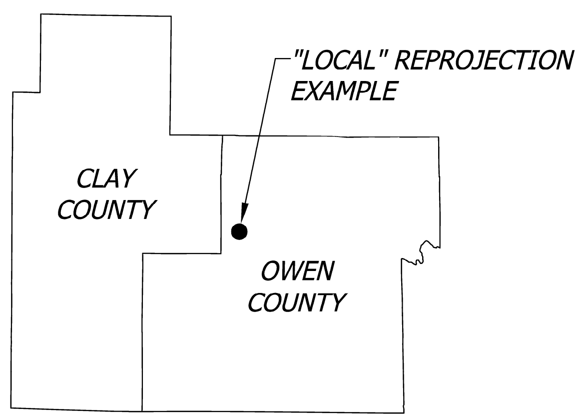



***Figure 7.4.3.2-6:*** *InGCS Local Reprojection Example.*

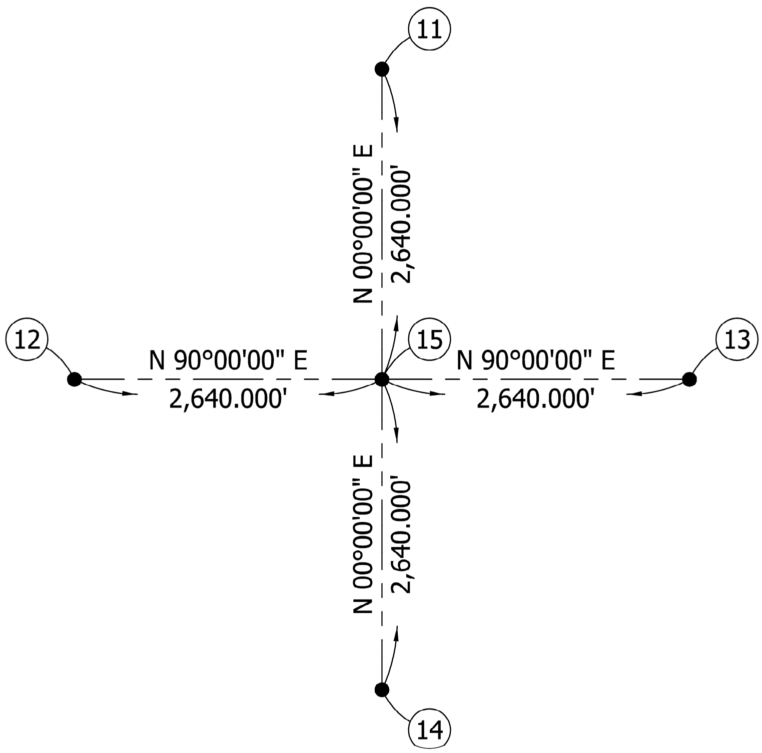



***Figure 7.4.3.2-7**: InGCS Local Reprojection Example.*

After reprojecting Points #11 through #14 from zone "A" to their zone "B" equivalents (Points #11-RP through #14-RP) and calculating a new bearing-bearing intersection from Points #11-RP through #14-RP (at Point #15-RC), it can be determined (though not as readily apparent as in Example #2a) that Point #15-RC is not coincident with Point #15-RP. Points #15-RC and #15-RP are separated by ±0.001'. Refer to Table 7.4.3.2-3 for the grid coordinate values of Points #11-RP through #15-RP and #15-RC and Figure 7.4.3.2-8 for a detailed graphical view of these six points.

***Table 7.4.3.2-3:** InGCS Local Reprojection Example.*

| Indiana Geospatial Coordinate System Local Reprojection Example | | | | | |
|---|---|---|---|---|---|
| **Zone "A" (Original Zone)** *Owen zone, U.S. Survey Feet* | | | **Zone "B" (Reprojected "RP" or Recalculated "RC" Data)** *Clay zone, U.S. Survey Feet* | | |
| Point # | Northing | Easting | Point # | Northing | Easting |
| **11** | 199,624.0869 | 782,816.7620 | **11-RP** | 199,709.0560 | 853,494.8523 |
| **12** | 196,984.0869 | 780,176.7620 | **12-RP** | 197,061.7518 | 850,862.1621 |
| **13** | 196,984.0869 | 785,456.7620 | **13-RP** | 197,076.3646 | 856,142.1576 |
| **14** | 194,344.0869 | 782,816.7620 | **14-RP** | 194,429.0605 | 853,509.4651 |
| **15** | 196,984.0869 | 782,816.7620 | **15-RP** | 197,069.0582 | 853,502.1593 |
| | | | **15-RC** | 197,069.0582 | 853,502.1587 |

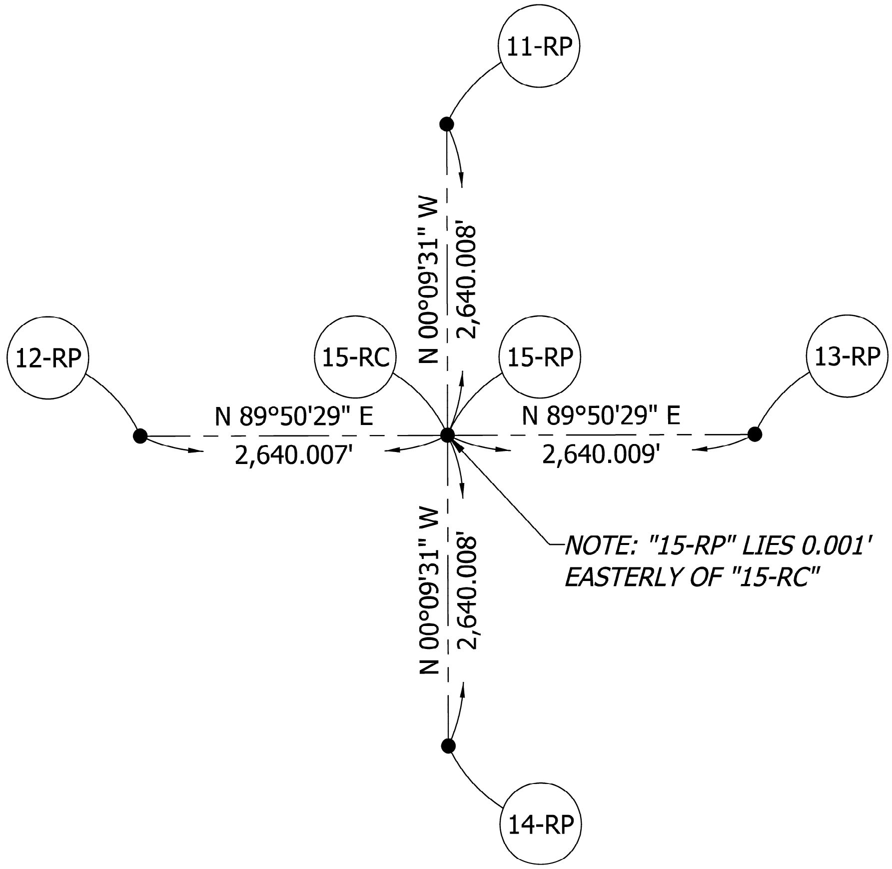



***Figure 7.4.3.2-8:*** *InGCS Local Reprojection vs.*
*Bearing-Bearing Recalculation Example.*

<u>*Summary of Examples #2a-#2c:*</u> The magnitude of positional variances between reprojections and 2D (horizontal) recalculations (such as bearing-bearing intersections) of data in transverse Mercator projections (such as the Indiana SPCS East and West zones and all zones within the InGCS) depends primarily upon the distribution of the appropriate data points and the difference in longitude of the central meridians of the underlying zones. Examples #2a-#2c included zones with central meridians ranging from 0°15’ in longitude apart (InGCS Clay and Owen zones) to 1°25’ in longitude apart (IN SPCS East and West zones) and sample data points ranging from one mile apart to ±189 miles apart, resulting in positional variances ranging from ±0.001’ to ±114.5’. As the separation of the central meridians and distances between sample points increases, so the corresponding positional variances between reprojections and 2D recalculations will increase.

In revisiting Example #2a, reprojected Point #5-RP fell ±114.5’ ***westerly*** of Point #5-RC as a result of zone “B” (Indiana SPCS East zone) being *east* of the original zone “A” (Indiana SPCS West zone). But if the Illinois SPCS East zone (1201), being *west* of the original zone “A”, was chosen as zone “B” rather than the Indiana SPCS East zone, Point #5-RP (as reprojected to Illinois SPCS East zone) would fall ±101.0’ ***easterly*** of Point #5-RC. The reason for this can be *conceptually* thought of as changing the perspective *from* the source projection (zone) selected for performing the original bearing-bearing intersection *to* the destination projection where the subsequent reprojections and recalculations can be performed. Refer to Figure 7.4.3.2-9 for a general location view and Table 7.4.3.2-4 for the grid coordinate values of the appropriate Points.

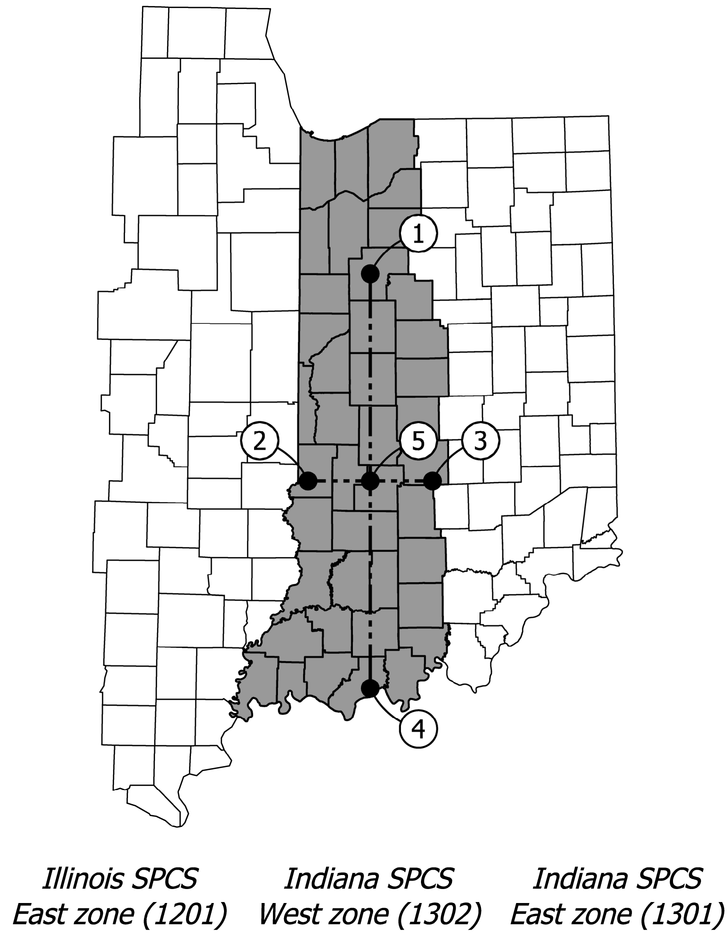


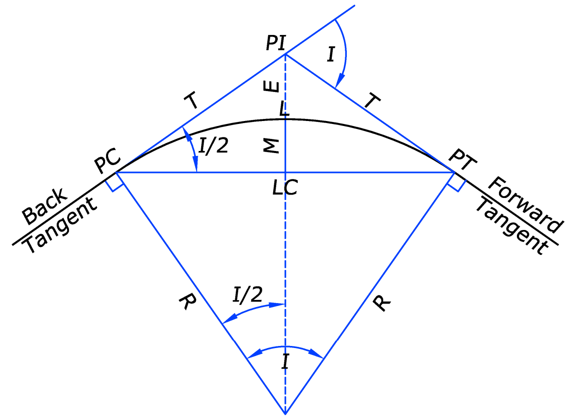

***Figure 7.4.3.2-9:*** *Indiana & Illinois SPCS Regional Reprojection Example.*

***Table 7.4.3.2-4:*** *Indiana and Illinois SPCS Regional Reprojection Example.*

| Indiana and Illinois SPCS Regional Reprojection Example | | | | | |
|---|---|---|---|---|---|
| **Zone “A” (Original Zone)** *IN West Zone (1302), U.S. Survey Feet* | | | **Zone “B” (Reprojected “RP” or Recalculated “RC” Data)** *IL East Zone (1201), U.S. Survey Feet* | | |
| Point # | Northing | Easting | Point # | Northing | Easting |
| **1** | 2,000,000 | 3,000,000 | **1-RP** | 1,486,353.2319 | 1,377,896.5965 |
| **2** | 1,500,000 | 2,850,000 | **2-RP** | 984,233.4203 | 1,234,912.9552 |
| **3** | 1,500,000 | 3,150,000 | **3-RP** | 988,386.0369 | 1,534,941.0243 |
| **4** | 1,000,000 | 3,000,000 | **4-RP** | 486,259.6908 | 1,391,737.1887 |
| **5** | 1,500,000 | 3,000,000 | **5-RP** | 986,309.4588 | 1,384,917.8987 |
| | | | **5-RC** | 986,308.2044 | 1,384,816.8685 |

*<u>Example #3:</u> In this example, zones "A" and "B" again have different grid coordinates and basis of grid bearings.*

Circular Curve Geometry: The same concept of 2D (horizontal) geometric dependency not only applies to bearing-bearing intersections, but also to circular curve elements in highway alignments, particularly for Points of Curvature (P.C.) and Tangency (P.T.). A circular curve is the by-product of the two tangent lines that form its Point of Intersection (P.I.)(and thus its delta angle) and whichever other appropriate curve element the practitioner elects to use to determine the curve's geometry.




*Circular Curve Geometry*

For INDOT projects, this second element is *typically* the radius, particularly in the design of new alignments. However, in *reestablishing* existing alignments on Location Control Route Surveys (LCRSs) at P.I.s with deflection angles approaching zero, many have found that honoring the record Tangent length tends to match constructed pavement centerlines much closer than the record radius values (primarily because, prior to radial traversing and layout with total stations and EDMs or the advent and widespread use of real-time GNSS positioning, the tangents were historically measured in the field), particularly as the *reestablished* deflection angle increases in variance from the record value.

CAD systems can easily detect *extremely* small inconsistencies in reprojected geometry. For example, if a curve's P.C. and P.T. were originally calculated relative to zone "A" and then reprojected to zone "B," these reprojected points (P.C. and P.T.) may not lie *exactly* on the tangent lines as determined from reprojections of the corresponding P.I.s. Therefore, a best practice approach for users to recalculate the curve and associated elements in zone "B" may be to use the reprojected tangent lines (P.I. to P.I. to P.I., see Figure 7.4.3.2-10), using the *exact same* value of the second curve element chosen (e.g., radius, tangent length, arc length, etc.) when calculating the curve in zone "A."

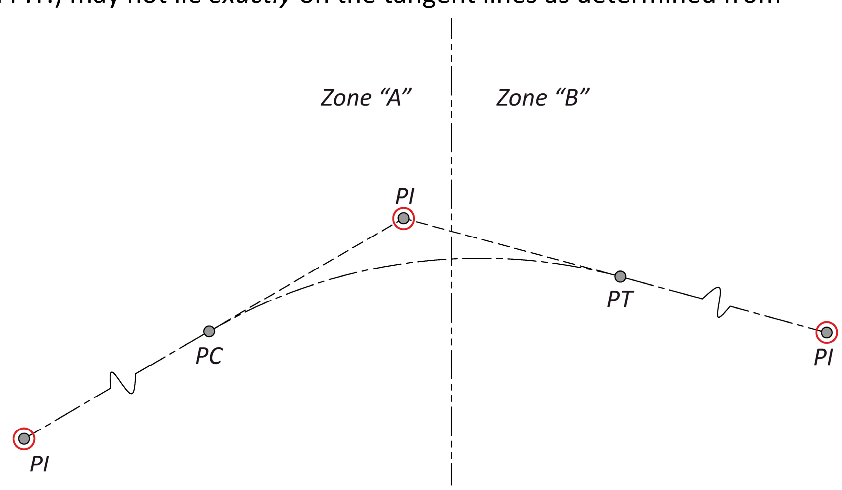



***Figure 7.4.3.2-10:*** *Circular Curve Reprojection.*

For instance, if a radius of (exactly) 3,000 feet was used in zone "A" to calculate the appropriate curve, this same (exact) value of 3,000 feet should be used in zone "B." This will *harmonize* values shown on LCRS plats, R/W Parcel Plats, design plans, etc. produced in both zones; otherwise, instances might arise where a survey plat or set of design plans prepared respective to zone "A" would depict a curve having a radius of 3,000.00' and another survey plat or set of design plans prepared respective to zone "B" would depict the recalculated curve in zone "B" having a radius of 2,999.99' or some other value very close to the original curve designed in zone "A."

<u>Reprojection Mechanics:</u> *Figures 7.4.3.2-11 through 7.4.3.2-14 graphically illustrate the mechanics of this zone-to-zone reprojection and 2D (horizontal) geometric relationship concept. Refer to Section 7.5.3 (Conversion Mechanics) for further discussion on this topic.*

In Figure 7.4.3.2-11, the triangles represent the data points as observed on the terrain surface, the dots represent the respective positions of the triangles as projected to the Indiana State Plane, West zone (1302) grid, while the circles represent the positions of the triangles as projected to the East zone (1301) grid. This *exaggerated* graphic makes it visually apparent that the projected grid distances between the three data points on 1302's grid are *not* equal to the distances as projected to 1301's grid.

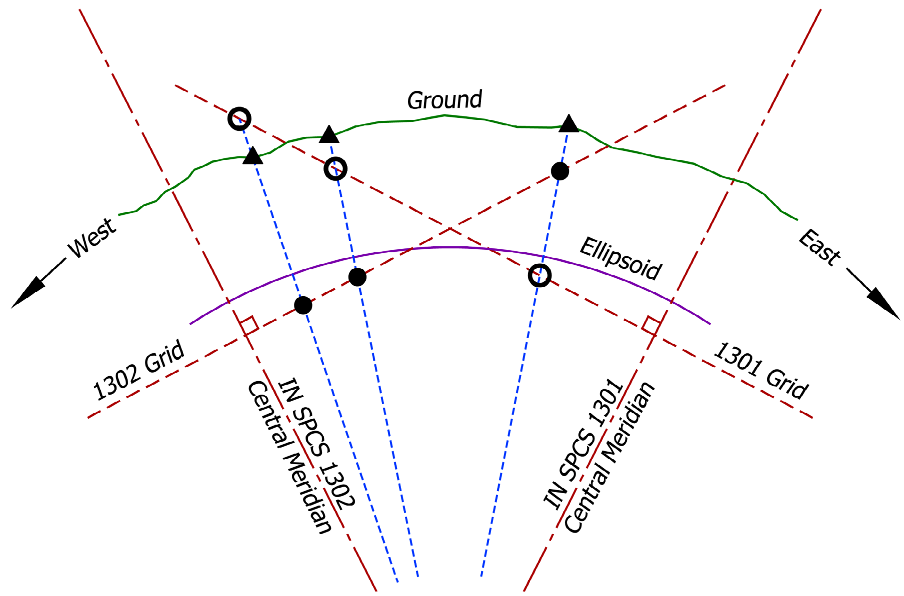
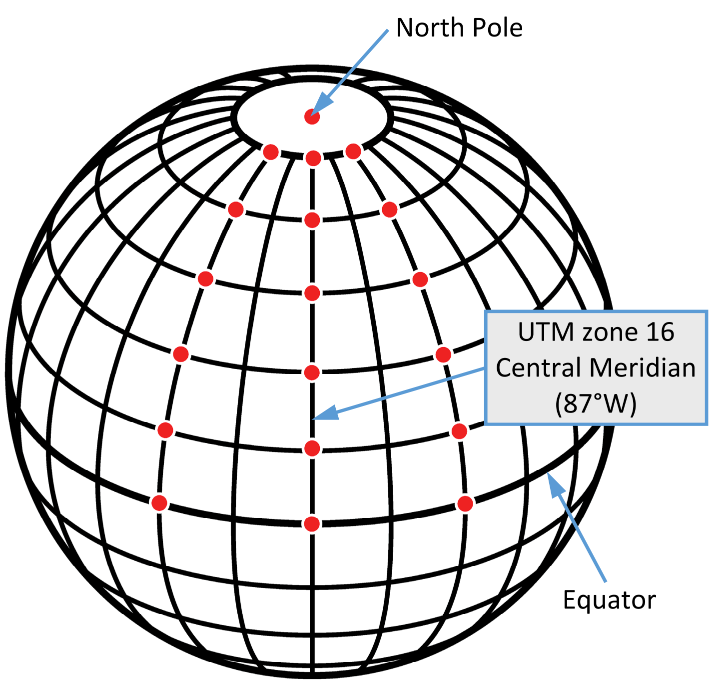



***Figure 7.4.3.2-11**: Reprojection from Indiana SPCS zone 1302 to 1301.*




In Figure 7.4.2-12, the red dots are placed along 15° parallels of latitude, beginning south at the Equator and ending north at the North Pole, and spans 60° in longitude, centered on 87° west longitude. This line of longitude is the central meridian (and projection axis) of UTM zone 16.

***Figure 7.4.3.2-12:** 15° Graticules of Latitude and Longitude.*

In Figure 7.4.2-13, the red dots from Figure 7.4.2-12 have been projected to the UTM zone 16 grid. *(Note that the sample points in this example extend from UTM zone 11 to zone 21.)* By definition, all points along the central meridian of a transverse Mercator projection (87°West in this instance) not only have the same values of longitude, but also the same values of grid Eastings (X). When projected to the grid, all points along similar lines of longitude lying east or west of the central meridian concave towards the central meridian, while all points along similar parallels of latitude concave towards the North Pole (in the northern hemisphere), except at the Equator, where they have the same grid northings (Y).

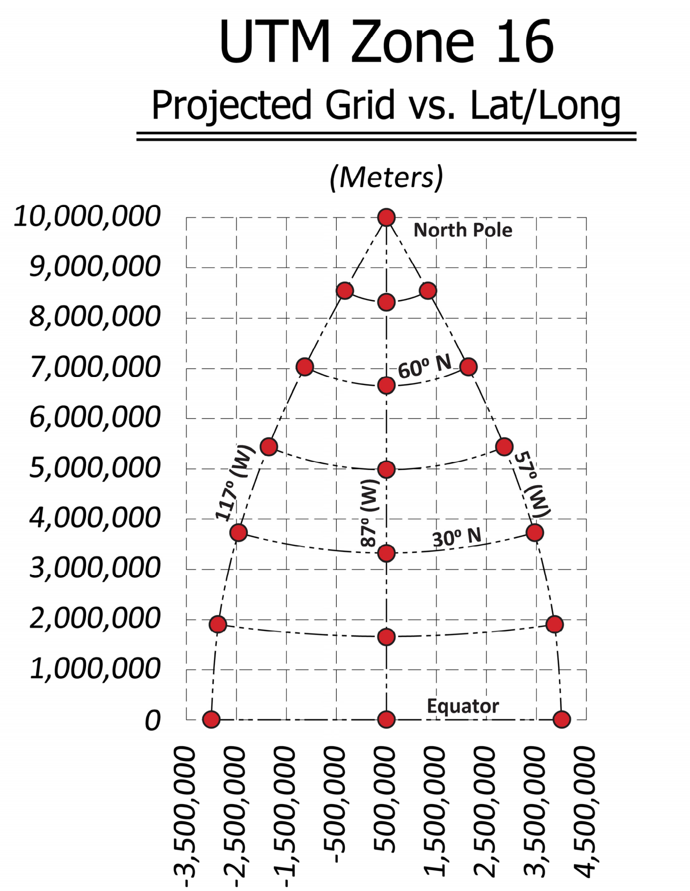



***Figure 7.4.3.2-13:*** *UTM zone 16-Projected Grid vs. Lat/Long.*

The red dots from Figure 7.4.3.2-13 in UTM zone 16 have been reprojected to UTM zones 11 and 21 as shown in Figure 7.4.3.2-14. UTM zone 11 and 21's central meridians are 117° and 57° west longitude, respectively. Note that, when projected to the appropriate zone, the points along that zone's central meridian have the same grid eastings, and all other points that lie along similar lines of longitude concave towards the central meridian. Though on a much larger scale than the previous examples of the Illinois East zone along with the Indiana State Plane West and East zones, the general mechanics of reprojection from one zone to another is the same.

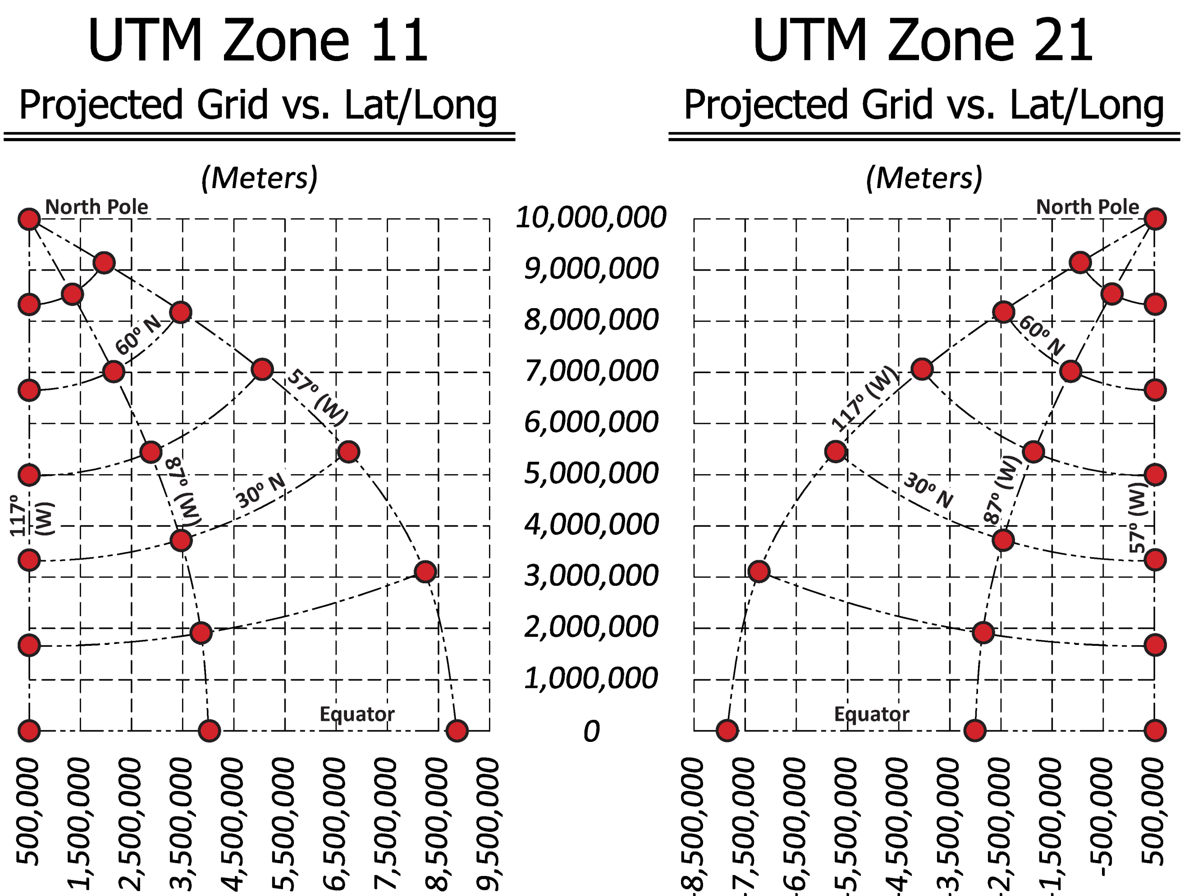



***Figure 7.4.3.2-14:*** *UTM zones 11 and 21-Projected Grid vs. Lat/Long.*

Reprojection Summary: The geographically-vast examples in Figures 7.4.3.2-13 and 7.4.3.2-14 depict how horizontal relationships between points are distorted in reprojections. Essentially, the larger the region being reprojected and the farther apart the projection axes are from one another, the greater the distortion. Conversely, the smaller the region being reprojected and the less the source projections are different, the less the distortion.

These examples, along with all the other examples in this Section (*7.4.3 Zone-to-Zone Considerations*), were provided to bring to the attention of geospatial practitioners that (1) reprojections do *not* ***exactly*** preserve the 2D (horizontal) geometrical relationships of data points, lines, arcs, etc. from one map projection zone to another, but they *do* retain the spatial positions of *individual* ***points***,
(2) horizontally-recalculated positions in a destination system yield different spatial positions than reprojections of individual points do, and (3) minuscule differences detected between reprojected and horizontally-recalculated positions of data points in *small* areas (such as in Examples #2b and #2c) are (most likely) *not* the result of errors in geospatial software, but simply the nature of reprojecting data from one map projection zone to another.

Depending upon positional accuracy goals, horizontal geometric dependency, project scope, etc., the decision to either simply reproject the positions of all data points from a source grid system to a destination system, or to recalculate new positions in the destination system so as to retain certain horizontally geometric-dependent components (e.g., bearing-bearing intersections, circular curves, parallel offsets, etc.), should either be based upon project-specific standards or left up to professional judgement on a project-to-project or case-by-case basis. Whatever the case may be, practitioners should report the method selected in each instance.

### 7.5 Coordinate Conversions and Transformations

#### 7.5.1 Introduction

The need to integrate, analyze and visualize geographically-referenced information in a common coordinate reference system is often necessary. Converting or transforming data from disparate sources into a common system for analysis is a frequent requirement.

Most current mapping and survey computer programs allow for fast and easy transformation of data between rectangular coordinate systems and geographic (latitude/longitude) systems, though end users may not be aware of the subtleties involved in the storage, manipulation, and presentation of the integrated data. Converting and integrating data has also become more complicated due to an increasing number of geodetic datums, adjustments, and coordinate systems in use. This reality requires the need for a basic understanding of data conversion and transformation principles, in addition to the need for quality data documentation to make the most effective use of geographically-referenced information.

*(Wisconsin SCO 2015)*

**7.5.2 Geographic Data Conversion and Transformation**

In the truest sense of the word, conversion refers to an exact process of moving data from one mathematical system into another (in a reproducible fashion), while transformation is used to refer to modeled or "best fit" data.

Geographic coordinates of latitude and longitude can be precisely *converted* into a rectangular coordinate system. Geodetic datum transformations, however, generally use interpolative models that apply approximations to the transformation. Many of these models have been encoded in standard software libraries (e.g. NADCON) and re-used in various GIS software applications.

Increasingly, positional differences between successive datum adjustments (e.g., NAD 83 (1997) and NAD 83 (2011) epoch 2010.00) may be smaller than the accuracy of the underlying transformation models. If so, these data cannot be accurately converted except by using field survey information. Also, the positional differences may be unimportant if within the accuracy requirement of a particular mapping application.

When data requires transformation to another spatial referencing system, consideration should be given to the future use or applications of the transformed data, including accuracy and quality requirements, and the limitations of the source data and the transformation methods. This requires close attention to significant digits, units of measurement, and perhaps most importantly, the details of the coordinate reference system of the source information. These and other details of data transformation should be captured and encoded in a metadata record for reference in the future.

*(Wisconsin SCO 2015)*

## 7.5.3 Conversion Mechanics

### 7.5.3.1 Two-Dimensional Conversions

As depicted in Figure 7.4.3.2-11 (Reprojection from Indiana SPCS zone 1302 to 1301), the developable surfaces (grids) of the Indiana SPCS West (1302) and East (1301) zones are neither coplanar nor parallel with one another. Because of this geometry, attempts to "convert" between these or other similar zones, systems, etc. via a simple two-point, 2D (horizontal/planar) similarity transformation or a more involved multi-point (three or more), 2D similarity transformation (best-fit by scale, rotation and translation in North (Y) and East (X)) approach will almost exclusively result in approximations, and is why its practice is generally discouraged.

The magnitude of these approximations vary depending upon many factors. These factors include, but are not limited to, the following:

- (Horizontal) size of the geographical region
- Distribution of the data
- Similar or different map projection types
- Proximity of the map projections' projection axes

Tables 7.5.3.1-1 lists the residuals of a two-point, 2D similarity transformation and 7.5.3.1-2 lists the residuals of a five-point, 2D similarity transformation, both of which use data from the Indiana SPCS Regional Reprojection Example from Table 7.4.3.2-1.

In Table 7.5.3.1-1, Points #1 through #5 (in the Indiana State Plane Coordinate System, West zone) have been two-dimensionally transformed in an attempt to match the five *reprojected* points in the Indiana State Plane Coordinate System, East zone, from Table 7.4.3.2-1, holding Point pairs “1 and 1-RP” and “4 and 4-RP” (Table 7.4.3.2-1) as “fixed” and allowing the other three points to float. The coordinates shown in Table 7.5.3.1-1 in the “…**2D Transformed**…” group are the results of this transformation. The zero-value residuals indicate that the coordinates of “1-RP” and “4-RP” from Table 7.4.3.2-1 are equal to the values listed in Table 7.5.3.1-1 for “1-X” and “4-X,” respectively. The remaining residuals are the differences between the properly reprojected positions shown in Table 7.4.3.2-1 with the **2D Transformed** positions shown in Table 7.5.3.1-1. Note that this changes the 2D scale and rotation of these points from the original system.

***Table 7.5.3.1-1:*** *Indiana SPCS Regional Two-Point 2D Similarity Transformation.*

| Indiana SPCS Regional Two-Point Similarity Transformation Example | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone “A” (Original Zone) *West Zone (1302), U.S. Survey Feet* | | | Zone “B” (2D Transformed) *East Zone (1301), U.S. Survey Feet* | | | Trans. Residuals *U.S. Survey Feet* | |
| # | Northing | Easting | # | Northing | Easting | North | East |
| **1** | 2,000,000 | 3,000,000 | **1-X** | 2,002,405.1223 | -17,243.0034 | +0.000 | +0.000 |
| **2** | 1,500,000 | 2,850,000 | **2-X** | 1,504,749.1903 | -175,087.6888 | +3.944 | -124.766 |
| **3** | 1,500,000 | 3,150,000 | **3-X** | 1,500,043.9210 | 124,917.4511 | +3.447 | -124.760 |
| **4** | 1,000,000 | 3,000,000 | **4-X** | 1,002,387.9890 | -32,927.2343 | +0.000 | +0.000 |
| **5** | 1,500,000 | 3,000,000 | **5-X** | 1,502,396.5557 | -25,085.1189 | +3.390 | -114.461 |

In Table 7.5.3.1-2, Points #1 through #5 (in the Indiana State Plane Coordinate System, West zone) have again been two-dimensionally transformed in an attempt to match the five *reprojected* points in the Indiana State Plane Coordinate System, East zone, from Table 7.4.3.2-1, using a unity factor (equal weight) for *all* point pairs, i.e., “1 and 1-RP,” “2 and 2-RP,” etc. The coordinates shown in Table 7.5.3.1-2 in the “…**2D Transformed**…” group are the results of this transformation. The residuals shown are the differences between the properly reprojected positions shown in Table 7.4.3.2-1 with the **2D Transformed** positions shown in Table 7.5.3.1-2. Note that this changes the 2D scale and rotation of these points from the original system.

***Table 7.5.3.1-2:*** *Indiana SPCS Regional Five-Point 2D Similarity Transformation.*

| Indiana SPCS Regional Five-Point 2D Similarity Transformation Example | | | | | | | |
|---|---|---|---|---|---|---|---|
| Zone “A” (Original Zone) *West Zone (1302), U.S. Survey Feet* | | | Zone “B” (2D Transformed) *East Zone (1301), U.S. Survey Feet* | | | Trans. Residuals *U.S. Survey Feet* | |
| # | Northing | Easting | # | Northing | Easting | North | East |
| **1** | 2,000,000 | 3,000,000 | **1-X** | 2,002,407.2793 | -17,315.7323 | -2.157 | +72.729 |
| **2** | 1,500,000 | 2,850,000 | **2-X** | 1,504,751.3670 | -175,160.4865 | +1.767 | -51.968 |
| **3** | 1,500,000 | 3,150,000 | **3-X** | 1,500,046.0567 | 124,844.6540 | +1.311 | -51.963 |
| **4** | 1,000,000 | 3,000,000 | **4-X** | 1,002,390.1444 | -33,000.1001 | -2.155 | +72.866 |
| **5** | 1,500,000 | 3,000,000 | **5-X** | 1,502,398.7118 | -25,157.9162 | +1.234 | -41.664 |

Should a user wish to convert from one system to another, and the two systems being "converted" are geometrically parallel with one another, a two-dimensional conformal transformation should produce satisfactory results. A base SPCS and its Modified State Plane Coordinate System counterpart serve as a good example. Figure 7.5.3.1-1 illustrates three transverse Mercator projections with parameters that differ *only* in their Central Meridian Scale Factors and their False Northings and Eastings.

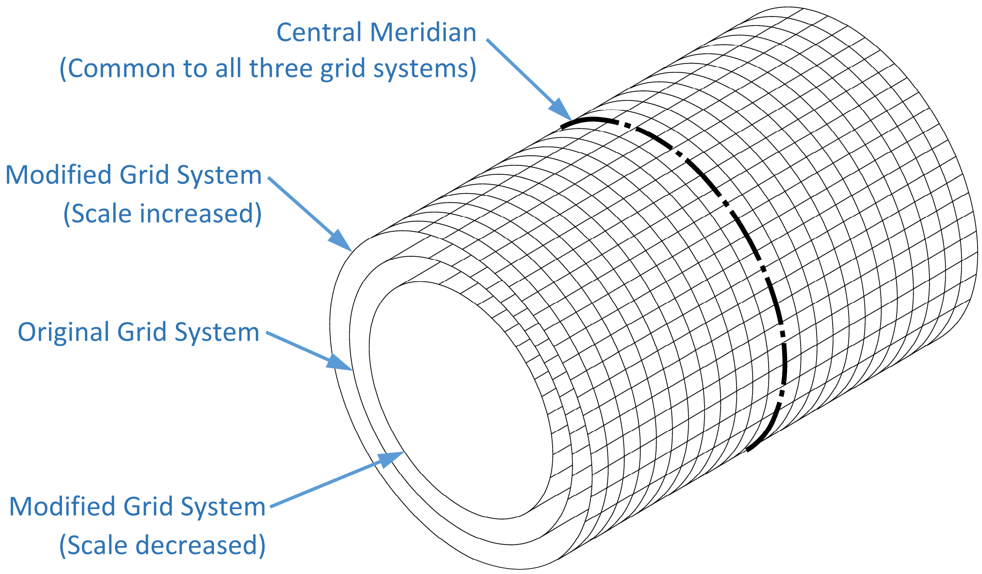



***Figure 7.5.3.1-1:*** *Parallel Cylinders.*

### 7.5.3.2 Three-Dimensional Conversions

Converting geographic latitude/longitude coordinates to a rectangular coordinate system (such as the State Plane Coordinate System) is referred to as a direct conversion, while the reverse direction (rectangular to geographic) is referred to as an inverse conversion. Direct and inverse conversions involve a series of mathematical equations that relate two sets of coordinates, the reference ellipsoid, and the map projection surface.

Coordinate conversions from one rectangular system to another on the same datum are done in a two-step process that is generally hidden to the user by most geospatial software programs. For example, the first step would involve converting State Plane coordinates to geographic coordinates (latitude/longitude), while the second step would then convert from geographic coordinates to InGCS coordinates. The underlying mathematical equations of direct and inverse plane map projections are precise, so resultant data accuracy is primarily related to the positional accuracy of the source data and the inherent distortions in the target map projection. Refer to Figure 7.5.3.2-1 for a graphical illustration of this workflow.

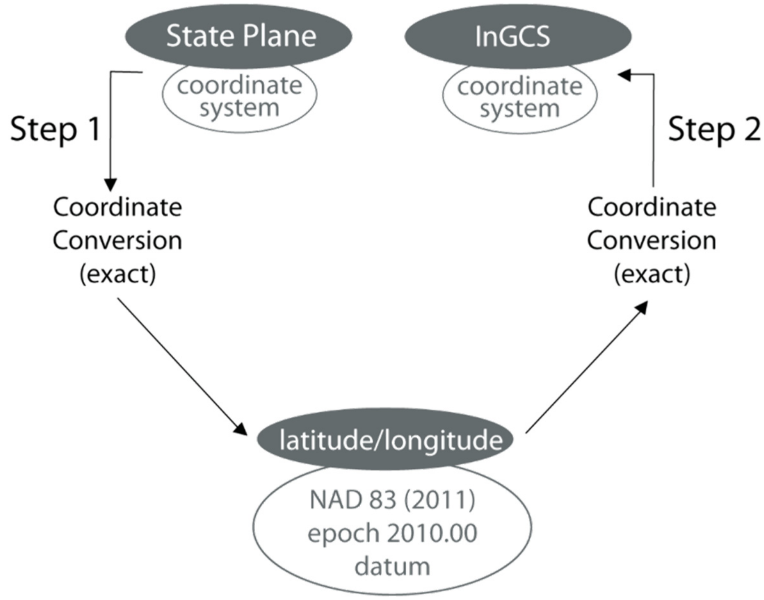



***Figure 7.5.3.2-1:*** *Conversion process from one rectangular system to another on the same datum.*

It is also possible to transform geographic coordinates from one datum to another (e.g., NAD 27 to NAD 83 (2011) epoch 2010.00), or from one adjustment of a datum to another adjustment of the same datum (e.g., NAD 83 (1997) to NAD 83 (2011) epoch 2010.00). Refer to Figure 7.5.3.2-2 for a graphical illustration of this workflow. The recent geodetic datum adjustments in the United States are not perfectly related to older datums (NAD 27) because the new adjustments removed errors and distortions in the geodetic network while at the same time redefining the mathematical model. The only way to perform an exact datum transformation is to recalculate the point's position using the original survey measurement observations that produced the latitude/longitude position.

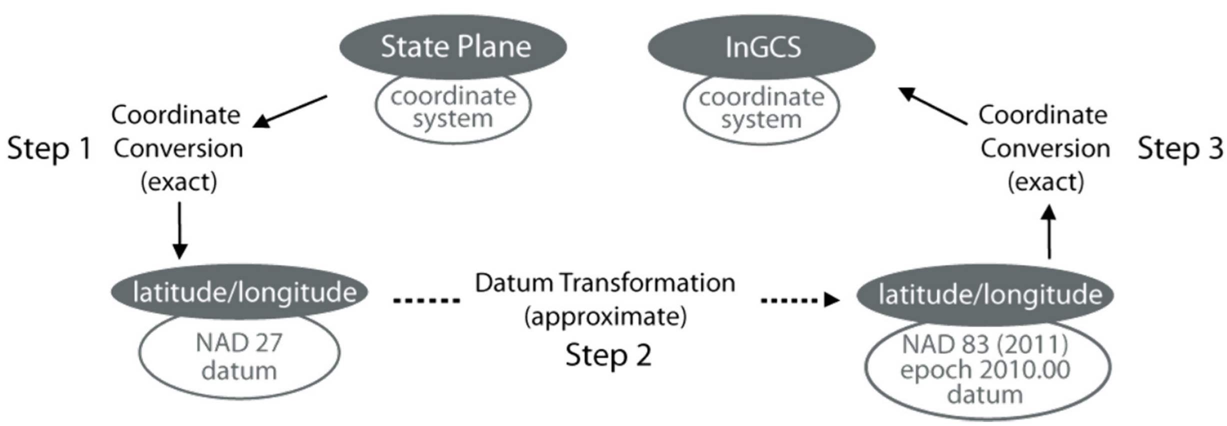



***Figure 7.5.3.2-2:*** *Coordinate transformation based on "best fit" transformation models.*

*(Wisconsin SCO 2015)*

### 7.5.4 Transformation Methods

Datum transformations are performed by various methods. Some of these methods support highly accurate geodetic and surveying work, and others are approximate and more suitable for mapping, visualization, and other purposes. Datum transformation methods may be categorized as follows:

*(Wisconsin SCO 2015)*

#### 7.5.4.1 Exact Transformation

The only exact method of datum transformation requires the original survey measurement information, using it to geodetically recompute positions in the new reference system.

*(Wisconsin SCO 2015)*

#### 7.5.4.2 Best-fit Transformation

Another method of datum transformation uses a least squares approach to apply a "best fit" to the data for a region. The quality of the fit is dependent upon the number, distribution, and quality of geodetic control points in the area. Exact transformation and least squares adjustments most often require geodetic and mathematical expertise to effectively produce and analyze results.

*(Wisconsin SCO 2015)*

#### 7.5.4.3 Modeled Transformation

A third transformation method uses a set of gridded data models to interpolate approximate correction values, which are then applied to produce the transformed coordinate values. Federally-produced software programs such as NADCON, CORPSCON, and VERTCON are based on this commonly-used method of addressing datum-to-datum transformations.

*(Wisconsin SCO 2015)*

### 7.5.5 Transformation Considerations

Transformations of geographic data should be based on thoughtful evaluation and assessment of desired use and future applications of the data, requirements for accuracy and quality, known limitations of the source data, and appropriate transformation methods.

Back-and-forth data transformation should be avoided as this process may result in unpredictable changes in data accuracy.

When planning your approach to transforming project data, the following questions should be considered to help guide the process:

Coordinate System

- What coordinate system is used for the source data? What coordinate system is desired for the transformed data?
- How large a geographical area does the project data cover? Does the coordinate system need to support data outside of its designed geographic extent?
  *Note: small project areas may not require a geodetically-referenced coordinate system; Large project areas may exceed coordinate system design extents.*

Geodetic System

- What datum is used for the source data? What datum is desired for the transformed data?

Data

- Does the source data meet or exceed the desired accuracy for the transformed data?
  *Transformation **cannot** improve data accuracy.*
- What are the linear and angular units of measure of the source and transformed data?
  *Use standard conversion factors and the appropriate number of significant figures.*
- Is the source data original or was it previously transformed?
  *Data documentation (metadata) should describe how the source data was collected, adjusted, processed, and prepared for publication and use.*

Transformation Tools & Process

- Does the use of the data require it to be transformed?
- Does the accuracy of the data exceed the accuracy of the transformation method?
  *Coordinate differences between same systems (e.g., NAD 83(1997) and NAD83 (2011) epoch 2010.00) are smaller than the limitations of standard modeled transformation software such as NADCON.*
- What is the distribution, quantity and quality of the points common to both the source and transformed data?
  *Select the transformation method most appropriate for the available source data.*

It is useful to point out in this section that some current desktop GIS software packages have incorporated methods for “reprojections on the fly,” allowing for integrated viewing of data in different coordinate systems in a common view. This type of transformation may be appropriate when neither high accuracy analysis nor data change is required.

*(Wisconsin SCO 2015)*

### 7.5.6 Accuracy and Precision

Accuracy is defined as how well a represented feature matches the actual object on the ground and often describes the quality of both input and resultant data. Precision is the measure of the reproducibility of a given process or procedure. Precise data processing and conversion is still inherently subject to the original accuracy of the data inputs. The procedures used to produce a map may be very precise, but if the data or methods used are not accurate, the results will be inaccurate. Precise transformation processes cannot improve the accuracy of data.

Imprecise transformation can reduce the accuracy of results. Transformation methods should be evaluated for appropriateness based on data requirements and use. For example, in the past, transformation process errors were often overshadowed by the accuracy of the data and considered negligible. Today, GNSS-based and sensor-based technology allow for increasingly accurate data collection and requires attention to procedures and differences that were negligible in the past.

Formal accuracy standards have been established to guide the collection and production of geographic data such as GNSS surveys, aerial imagery and geodetic networks. These guidelines outline specific field methods and adjustment procedures that must be followed to assure the final data meets or exceeds a stated accuracy.

*(Wisconsin SCO 2015)*

### 7.5.7 Significant Figures

Significant figures represent the number of digits in a number that can reliably be used. This is important in the context of measurements and mathematics operations because computed solutions are limited by the least accurate data items. For example, a measurement of 101 feet is significant only to the one foot level, even though computer software may display this value as 101.000 feet. Data cannot be improved after transformation, therefore attention to significant figures helps qualify the end result.

Significant figures are particularly important in coordinate systems and mapping because some software give a false sense of precision by displaying many digits to the right of the decimal point (whether significant or not) leading to a false sense of accuracy by subsequent users.

*(Wisconsin SCO 2015)*

### 7.5.8 Metadata

Lack of accurate and thorough documentation (metadata) is the most common source of error or ambiguity when converting or transforming geographic data. Without good metadata, assumptions may be made about the data that are not correct.

It is important to know the lineage of source data, from collection through processing and publication for use. Data originally collected at a low accuracy level cannot be improved by integration with high quality data or coordinate system conversion. Subsequent data conversions, transformation, and processing can preserve or deteriorate the quality of data depending on the methods used.

*(Wisconsin SCO 2015)*

### 7.5.9 Test, then Transform

Most importantly, transformation methods and software tools should be thoroughly and independently tested before transforming project data. Software vendors implement coordinate and geodetic system algorithms slightly different. While these implementations are based on federal standards and conversion algorithms where available, different software implementations have previously resulted in differing coordinate results. The best way to be confident in one's results is to test transformations first.

*(Wisconsin SCO 2015)*

## 7.6 Survey Plats, Surveyor's Reports, and Basis of Bearings

*Survey Plats:* Rule 12 (Land Surveying; Competent Practice), Section 13 (Retracement and Original Survey Plats) of the Indiana Administrative Code specifies that land surveyors are to show (amongst other items) angles or bearings on their plats of survey, together with the accompanying Surveyor's Reports. When bearing are shown, they are to indicate their basis. Grid bearings in transverse Mercator projections are based upon the central meridian of the particular zone. Examples of transverse Mercator projections include all zones within the InGCS and UTM systems as well as both of the Indiana State Plane zones.

Although Rule 12 does not currently include listing/tabulating project coordinates on Survey Plats as part of the minimum requirements for the competent practice of land surveying in Indiana, making that part of a Land Surveyor's routine practice (particularly when working in a published grid system, such as the InGCS) could be of benefit not only to that Surveyor, but also to the rest of the geospatial community. Providing tabulations of survey control points, alignment points, Section Corner monuments, and other notable points observed during Route Surveys for INDOT has been standard practice for many years.

Figure 7.6-1 provides a template that addresses Rule 12's Section 22 (stated below in the *Basis of Bearings* discussion), items #1-4, 6-8, and 10. Because various methods (static, post-processed kinematic, local base RTK, RTNs, etc.) of global positioning can be employed on a single project, it is recommended to address items #5 and 9 within the body of the Surveyor's Report.

| REPORTED PROJECT POINTS METADATA TABLE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| GEOMETRIC DATUM: NAD 83(2011) EPOCH 2010.00 | | | GRID SYSTEM-ZONE: InGCS-CRAWFORD | | | NSRS TIE MECHANISM: OPUS (STATIONS: INFC, INPA, INTC) | | |
| VERTICAL DATUM: NAVD 88 | | GEOID MODEL: GEOID12B | | | DATE FIELDWORK BEGAN: 2015/06/22 | | DATE FIELDWORK ENDED: 2015/08/25 | |
| POINT #/ NAME | GRID NORTHING | GRID EASTING | NORTH LATITUDE | WEST LONGITUDE | PURPOSE | CHARACTER | FOUND/SET/ CALC'D (NOT SET) | ABOVE/FLUSH/ BELOW GRADE |
| 1203 | 173,572.6790 | 851,516.1910 | 38°15'07.49487" | 86°16'36.26427" | RANDOM CONTROL POINT | 3/4" REBAR W/"POINT REFERENCE" CAP | SET | FLUSH |
| 6201 | 173,352.8350 | 838,073.2610 | 38°15'05.60868" | 86°19'24.78405" | P.T. 360+40.3 LINE "B" (1967) | 8" SQUARE CONC MARKER (NO PIN/PLUG) | FOUND | FLUSH |
| 6202 | 173,568.0550 | 838,858.1470 | 38°15'07.72123" | 86°19'14.93991" | P.O.T. 368+54.20 LINE "B" (1967) | 8" SQUARE CONC MARKER (NO PIN/PLUG) | FOUND | FLUSH |
| 6203 | 174,022.1400 | 840,505.8580 | 38°15'12.17782" | 86°18'54.27355" | P.O.T. 385+63.95 LINE "B" (1967) | 1" COPPER PLUG-CONC PAVED DITCH | FOUND | FLUSH |
| 6205 | 172,529.1820 | 851,688.2120 | 38°14'57.17580" | 86°16'34.13954" | LOCAL BOUNDARY MONUMENT | 7"X7" LIMESTONE WITH SCRIBED "X" | FOUND | 7"A.G. |
| 6206 | 175,020.8890 | 851,724.0560 | 38°15'21.80544" | 86°16'33.61463" | EAST 1/4-CORNER, SEC.15,T3S,R2E | 7"X7" SANDSTONE (NO MARKINGS) | FOUND | 20"A.G. |
| 6207 | 172,308.3990 | 851,684.0450 | 38°14'54.99346" | 86°16'34.19847" | SOUTHEAST CORNER, SEC.15,T3S,R2E | 1/2" REBAR W/"PRIMAVERA S0131"CAP W/SIGN | FOUND | 4"A.G. |
| 6208 | 173,707.1380 | 851,845.7850 | 38°15'08.81612" | 86°16'32.12855" | NORTH R/W 501+00, 225'LT (1967) | CONC R/W MARKER | FOUND | A.G. |
| 6209 | 174,159.3710 | 851,190.5730 | 38°15'13.30206" | 86°16'40.32841" | NORTH R/W (P.T.) 493+04.62, 225'LT (1967) | CONC R/W MARKER | FOUND | A.G. |
| 6210 | 173,154.1720 | 851,653.0650 | 38°15'03.35467" | 86°16'34.56117" | SOUTH R/W | CONC R/W MARKER | FOUND | A.G. |

***Figure 7.6-1:*** *Example Metadata Table for Survey Plats.*

*Surveyor's Reports:* As a successful result of Rule 12, Section 13, it has become common practice for Indiana Professional Surveyors to indicate on their plats of surveys and write in their Surveyor's Reports what their project's bearing system was based upon, i.e., how they determined "north" for that project. Examples of "north" on projects can include an assumed bearing, a record bearing between two physical monuments, the applicable projected grid coordinate system, etc. For projects based upon a projected coordinate system, these surveyors have been able to properly and succinctly identify their project's bearing system by simply citing the official name of the specific zone itself, rather than having to numerically list the value of the central meridian or provide additional technical jargon related to the zone. By citing the official zone name, subsequent users are easily able to obtain *all of the numerical values* associated with the zone (not just the central meridian and thus the basis of bearings) as they are readily available in publications such as NOAA's Manual NOS NGS 5 (State Plane Coordinate System of 1983), state websites containing coordinate reference system manuals or Handbooks and User Guides, embedded within most geospatial software platforms, etc.

The official names and numerical values defining the 92 zones of the InGCS were made available to the public via INDOT's website (www.in.gov/indot/InGCS.htm), within the IOGP's EPSG Geodetic Parameter Dataset (www.epsg-registry.org), and in a few geospatial platforms prior to the publication of the first draft of this Handbook and User Guide. For projects based upon the InGCS, this has paved the way for Indiana Professional Surveyors to continue the practice of simply citing specific zone names to sufficiently indicate their basis of bearings, should they choose to do so. Should they choose or need to provide expanded descriptions of the zones, example templates are provided later in this Section as well as in Appendix F.

*Basis of Bearings:* It is important to compare the basis of grid bearings for adjacent zones within the InGCS. As mentioned earlier in this document, the nominal limits of each zone of the InGCS are the boundaries of Indiana counties. For intuitive use by end users, each Indiana county was designated its own InGCS zone bearing the respective county's namesake. Since Indiana contains 92 counties, there were by default 92 zones. Disregarding the 92 unique zone names and then comparing the remaining numerical projection parameters (central meridian, central meridian scale factor, latitude of grid origin, false northing and easting) of adjacent zones, it is apparent that there are but 57 distinct sets, or groups, of projection parameters, in which each group contains identical numerical values. Of these 57 distinct groups, there are several adjacent groups that share the same central meridians, and thus basis of grid bearings; yet they have different central meridian scale factors and latitudes of grid origins, resulting in different grid coordinates. In other words, there are several adjacent zones throughout the InGCS that have identical grid bearings yet different grid coordinates. For a graphical summary of this, please refer to the InGCS Zones Overview Map in Appendix C.

Rule 12 further specifies in Section 22 (Measurements for Route Surveys) that "If the route survey references or is based on state plane coordinates or utilizes the Global Positioning System (GPS), the written surveyor's report shall identify the following:

1. The datum and projection.
2. The year of applicable datum adjustment.
3. The originating or controlling monuments.
4. The GPS base stations or positioning software used, for example, the Online Positioning User Service (OPUS).
5. The source and format of the corrections if real time kinematic GPS was used.
6. The Geoid model used, if applicable.
7. The scale, elevation, and combination factors used in the coordinate calculations.

8. Information on any translation to or from a local system.
9. The collection processes and methodology of final positioning.
10. Whether the distances shown are grid or ground."

The recommended templates in this Section and in Appendix F for the *Basis of Bearings* statement within a surveyor's report satisfies Rule 12's Section 22, items #1, 2, 8, and 10.

The following *Basis of Bearings* statements are provided as recommended templates for Indiana Professional Surveyors to include on their plats of surveys and within their Surveyors Reports. *Appendix F contains these formats for of all 92 zones of the InGCS.*

***InGCS "Adams" zone (no adjacent zone having identical projection parameters):***

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Adams" zone per NAD 83(2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Adams" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

InGCS "Adams" Zone Parameters
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 84°57'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 40°33'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S. Ft)
False Easting: 240,000.000 m (787,400.00 U.S. Ft)

***InGCS "Pike" zone (one adjacent zone having identical projection parameters):***

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Pike" zone per NAD 83(2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Pike" and "Warrick" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

InGCS "Pike" and "Warrick" Zone Parameters
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°18'00" west longitude
Central Meridian scale factor: 1.0000°
Latitude of Grid Origin: 37°51'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S. Ft)
False Easting: 240,000.000 m (787,400.00 U.S. Ft)

***InGCS "Orange" zone (two adjacent zones having identical projection parameters):***

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Orange" zone per NAD 83(2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Orange," "Crawford," and "Lawrence" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

InGCS "Crawford," "Lawrence," and "Orange" Zone Parameters
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 38°06'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S. Ft)
False Easting: 240,000.000 m (787,400.00 U.S. Ft)

For a project that spans multiple InGCS zones with different grid coordinates and the decision is made to base the project on more than one of the underlying zones (i.e., segregating the project into multiple zones), it is critical to highlight where the change(s) occurs and to provide adequate information on the plat of survey, design and construction plans, in surveyors reports, etc. so that future users can reproduce the work in the appropriate zone(s).

Switching a project from one InGCS zone to another can change the grid coordinates, their scale (and in turn (though very slightly), grid distances and areas), and orientation (azimuths and bearings), but does not change the underlying ellipsoid positions (latitude, longitude, ellipsoid height) or orthometric heights. For a linear project (such as a highway or utility transmission line project) with 2D (horizontal) alignments, switching from one InGCS zone to another at a certain geopolitical location (county line, PLSS, Grant, Donation, Location, etc.) may also make for a plausible case to introduce a "Station Equation" so as to further highlight that a change has occurred.

Figure 7.6-2 provides an example coordinate, bearing, and station equation for changing the associated project and horizontal alignments from the “Crawford” zone to the “Harrison” zone. *In stark contrast to a station equation “defining” the relationship between two horizontal alignments,* ***the coordinate and bearing equations listed in this example does NOT “define” the differences between the two zones.*** However, the act of highlighting where the change occurs in the project alerts future practitioners as to how and where to relate the horizontal alignment(s) in the two zones to one another, within the displayed decimal precision.

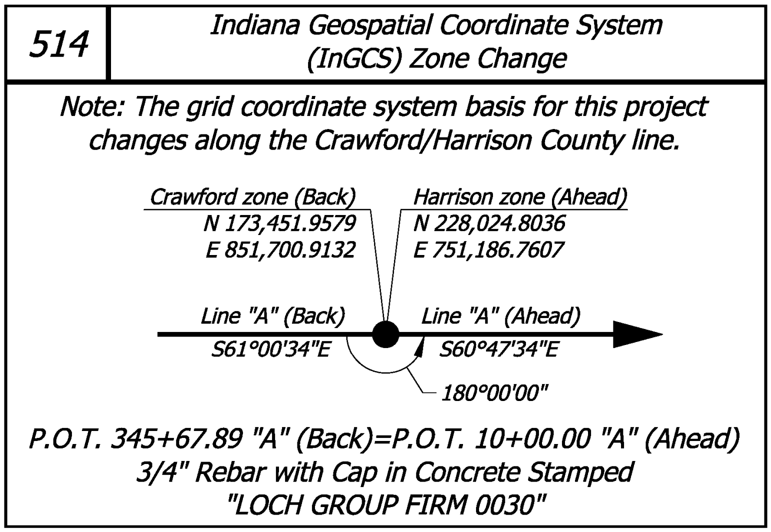
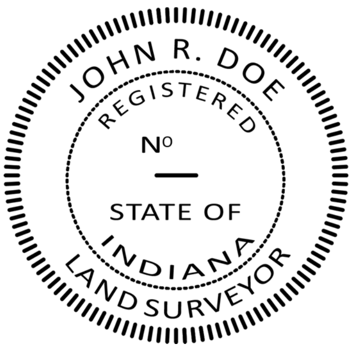



***Figure 7.6-2:*** *Example coordinate, bearing, and station equation.*

### 7.7 Boundary Surveys




The traditional definition of Land Surveying states that it is the science, art, and technology of determining the relative positions of points on, above, or below the surface of the Earth, or of establishing such points. While the explosion of advancements in positioning technology have dramatically increased the accuracy and precision of measurements and the speed by which they are conducted in boundary surveys, these "better" measurements and the resulting project coordinates only provide a better picture of the respective spatial relationships to the controlling features involved in boundary surveys than before.

In other words, even though advances in measurement technology have certainly provided professional surveyors with the tools to more accurately and precisely report the distances and bearings between points, angles between lines, and areas embraced within the  bounds of surveyed tracts, all based upon grid coordinates from coordinate reference systems that can be related to a global reference frame and can be transformed across time and between other spatial reference frames, the original *controlling* features that they observe and base many of their boundary surveys upon today were, in most cases, set and accepted as true with equipment such as the Gunter's Chain in Figure 7.7-1 long before the advent of the laser (EDM) or GPS.

*Stone Wall*
*(Boundary Evidence)*

***Figure 7.7-1:*** *Gunter's Chain used in early U.S. Public Land Surveys.*

Examples include metes and bounds surveys, U.S. Public Land Surveys, military grants, donations, etc. Measurements of the controlling features provide boundary surveyors with the spatial relationships of points *from which* they can *begin* evaluating boundary control evidence gathered during the course of boundary surveys.

### 7.7.1 InGCS Grid Coordinates and Priority in Boundary Control

When used correctly, the InGCS' zones provide excellent canvas' for professional land surveyors to portray their boundary survey plats upon and to seamlessly share the results with other geospatial practitioners. But keep in mind that, in the landscape of boundary surveying, the "project coordinates" reported on survey plats nearly always rank at the bottom of priority compared to other elements encountered when applying proper boundary surveying principles to arrive at prudent decisions. These "project coordinates" can range from a local/arbitrarily-based coordinate system, to a scaled-to-ground (modified SPCS), to a Site-Specific LDP, to a state-sanctioned set of LDPs, such as the InGCS. In other words, a projected grid coordinate system does *not* relieve the boundary surveyor from performing the multitude of tasks involved with properly performing boundary surveys. Amongst other tasks, a short list of activities engaged in when performing boundary surveys includes:

- Public records research (deeds, recorded survey plats, legal surveys, etc.)
- Evaluation of recorded documents
- Coordination with local land owners
- Field reconnaissance
- Analyzing field evidence
- Applying proper boundary surveying principles to arrive at prudent decisions
- Calculate boundary corners, lines, curves, etc.
- Set survey monuments at the necessary boundary corners or at offsets thereof
- Prepare boundary survey plats, boundary descriptions, Surveyor's Reports
- Provide the client with plats, descriptions, and reports
- Record the plats, descriptions, and Surveyor's Reports at the appropriate County Recorder's Office
- Etc., etc.

*GNSS unit observing a boundary marker.*


*2nd Principal Meridian's Initial Point (Orange County, Indiana).*

A general summary of the priority in the rules of authority/construction in evaluating boundary control evidence gathered during the course of a boundary survey is as follows:

- Unwritten rights
- Senior rights
- Written Intentions of Parties
    - Call for a Survey
    - Call for a Monument
        - Natural
        - Artificial
        - Record
    - *Distance*
    - *Direction*
    - *Area*
    - ***Coordinates***

The *bottom* four (distance, direction, area, and coordinates) items relate most closely to measurements and byproducts of those measurements (area and coordinates). What does this mean for the "explosion of advancements in positioning technology" and LDPs such as the InGCS? It simply means that professional land surveyors and other geospatial practitioners should not let current or future measurement technologies give us a false sense of *overconfidence* in digital data over the intent of the parties, controlling calls in deeds, physical monuments, etc.

*U.S. Public Land Survey Section Corner Stone.*

Reciting the (unofficial) Boundary Surveyor's mantra: *"Monuments over Measurements."*


*Cast Iron U.S.P.L.S Quarter-Corner Marker.*

To again provide an excerpt from Michael McInnis' "*The Ever Moving Datum, Ever Changing Earth Conundrum*" article, but on the topic of boundary surveying: "At the end of the day, a boundary surveyor is more concerned with property corners relative to the Section or legal monuments that control the survey (precision) as opposed to their global accuracy. However, if the surveyor publishes a boundary survey purported to be on an accurate basis (required for State Plane/UTM) or wants to make the survey portable across a multitude of coordinate systems (highly recommended), then both accuracy and precision are in play." This brings us back to the InGCS and the importance of thoroughly documenting metadata about the project, but also to what ***controls*** the ***local*** *boundary* survey, i.e. the **true** location of the boundary corners, ***not*** the project coordinates, which in this discussion, are InGCS grid coordinates. But, good project coordinates tied to the NSRS (such as the InGCS) along with good project metadata can document where a particular survey marker was located at a certain date, regardless if *that particular marker and its documented location (coordinates)* occupied the "true" location of the particular boundary corner. Should that marker be destroyed, its position could then be reestablished.

Figure 7.7.1-1 below, originally from Jerry Penry, LS (Nebraska, South Dakota), illustrates the futility of publishing the highly “precise” position of a surface monument and (erroneously) purporting that it occupies the “true” location of the Corner. In this instance, the stone marked “1/4” was the Original Government Quarter-Section Corner Stone (note: “stones” were used by the Original GLO Surveyors in the mountainous/hilly areas of South Dakota and Nebraska).

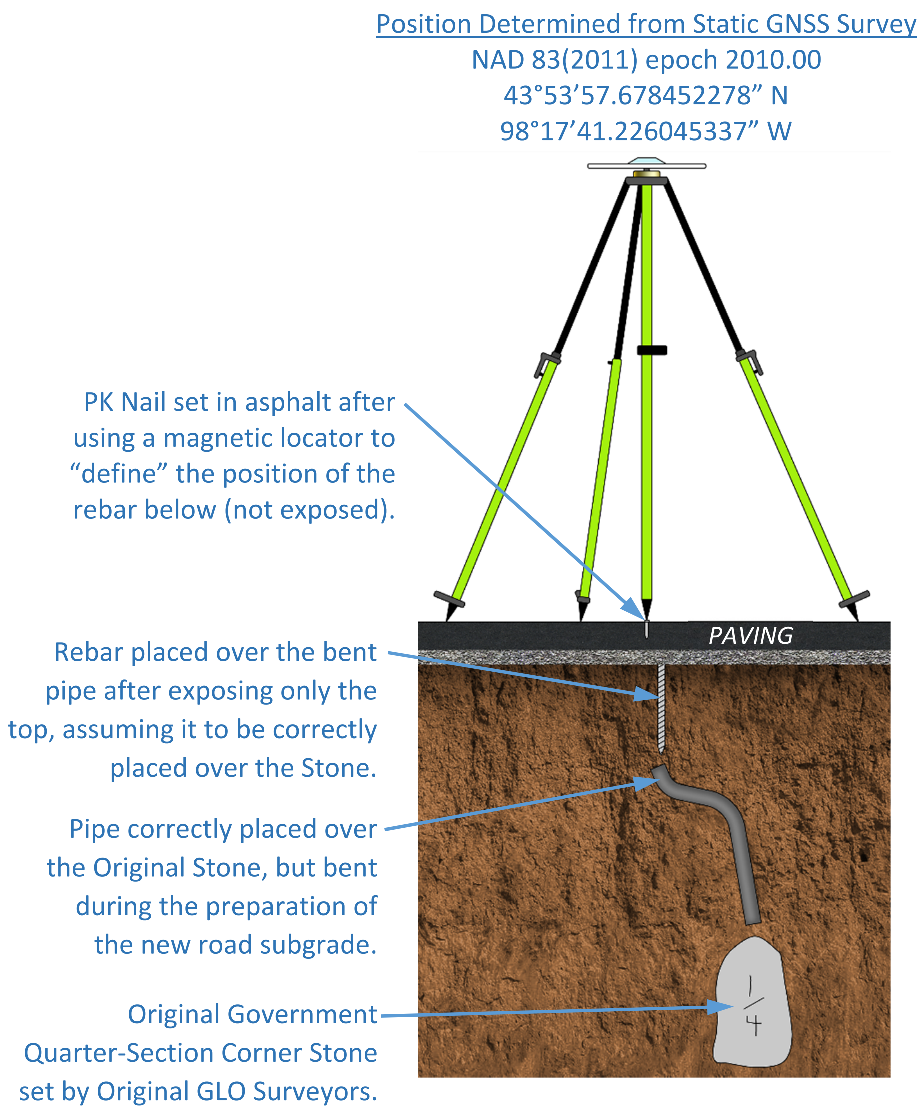



***Figure 7.7.1-1:*** *High Precision, Incorrect Location.*

# Chapter 8 Legislative Adoption and Registration with the NGS

## 8.1 Indiana Code (IC) and Administrative Code (IAC) Adoption

It is anticipated that as the InGCS becomes frequently used, it will also become generally accepted by a wide audience of Indiana professional surveyors, engineers, GIS, cartographic, and academic professionals around the state. At that time, effort may be made to include definition or recognition of the InGCS in Indiana Code, Title 32 (Property) as well as Title 865 (State Board of Registration for Professional Surveyors), Rule 12 (Land Surveying; Competent Practice) of the Indiana Administrative Code. If so, it is strongly encouraged that such effort be made in cooperation with the Indiana Society of Professional Land Surveyors (ISPLS) and the Indiana State Board of Registration for Professional Surveyors. Inclusion will encourage fundamental viable acceptance by engineering, surveying, and mapping professionals within the state as well as Federal agencies such as NGS, FEMA, etc.

## 8.2 NGS Policy on Registration of the InGCS

The Indiana Department of Transportation, ISPLS, and other concerned organizations will be urged to promote adoption of the InGCS by the National Geodetic Survey (NGS), guided by their policy on changes to plane coordinate systems. The existing NGS policy on plane coordinate systems is given below.

**NGS "POLICY ON CHANGES TO PLANE COORDINATE SYSTEMS"** (April 11, 2001)
(www.ngs.noaa.gov/INFO/Policy/SPCS4.html)

The National Geodetic Survey (NGS) recognizes there may be States that want to implement changes to their existing North American Datum of 1983 (NAD 83) State Plane Coordinate System (SPCS) parameters or to create and employ supplemental plane coordinate projections. These changes could include: changing the number of zones, changing existing zone boundaries, and/or changing the geometric parameters (e.g., false northing/easting, origin, central meridian, etc.), and/or creating additional coordinate systems. NGS also recognizes that State and local surveying, mapping, and Geographic Information System (GIS) agencies may develop grid systems to support a variety of agency or local activities that may be in conflict with the policy detailed below. This policy details only those elements which must be met for NGS to publish these coordinate systems as part of the National Spatial Reference System (NSRS).

While NGS does not encourage States to change the current definition of the existing SPCS, NGS does recommend any proposed changes be thoroughly discussed in detail with NGS technical staff, including the NGS State Geodetic Advisor, if such an office exists in the State, prior to submitting a request to the Director, NGS.

NGS will adopt changes to SPCS or add supplemental projections into NSRS only under the following conditions:

1. All requests for changes must be submitted in writing to the Director, NGS, and must be co-signed by those State agencies and organizations most involved in the use, collection, and distribution of spatial data including, but not limited to, the State Department of Transportation, State Office of GIS, and state land surveyor professional organizations. Hereafter these groups are referred to as the "State." Required agencies and organizations will be determined by NGS on a state-by-state basis. A similar request must also be submitted to the U.S. Geological Survey (USGS) to ensure integrity of NSRS with USGS national mapping products and services.

2. All new SPC zones or supplemental projections shall use the two basic map projections, the Lambert conformal conic or the Mercator (transverse or oblique), defined at the surface of the ellipsoid of the current Datum (Geodetic Reference System 1980 - GRS 80).

3. All changes must be adopted by State Law (or State Regulation when such Regulation is regulated by public notices and hearings and no opposition exist). Such Law must include a complete description of the revised SPCS zones and geometric parameters. A specified conversion factor between meters and feet (U.S. Survey or International) is strongly recommended to be included in the legislation. NGS will publish coordinates only in those legislated units.

4. Zones will continue to be defined by International, State and county boundaries, and by the counties contained therein. (See Federal Register Notice "Policy on Publication of Plane Coordinates," Vol. 42, Nol. 57, pages 15943-15944, published March 24, 1977.)

5. SPCS changes will ensure that the resulting coordinate differences are sufficiently large (by at least 10,000 meters) to ensure that no confusion will exist with the current NAD 83 coordinate values.

6. A naming convention shall be developed that ensures a distinct labeling between the existing and revised new coordinate zones.

7. Should NGS estimate significant expenses resulting from changes to the existing SPCS, NGS may require State reimbursement. These costs would be for coordinate conversion, data base extraction and publication software required to support computation, publication and distribution of new coordinate values as part of NSRS.

8. To facilitate public awareness, the State shall develop an education program that includes an article detailing the rationale for the development of the changes, the process of review and ex-amination of the issues, the final design criteria, and a workshop or seminar to be presented at a State-wide surveying and mapping conference. The article shall be submitted for publication in one or more surveying and mapping periodicals (e.g., American Congress on Surveying and Mapping Bulletin, Professional Surveyor, or P.O.B. magazines). In addition, this article will be made available on the web sites of the sponsoring agencies defined as the "State." Any requests for technical support from NGS requiring travel expenses for NGS personnel shall be reimbursed by the State.

# References

## *Documents on Map Projections, Datums, and Geospatial Metadata*


Armstrong, M.L., Singh, R., and Dennis, M.L., 2014. *Oregon Coordinate Reference System Handbook and User Guide* (Version 2.01), Oregon Department of Transportation, Geometronics Unit, Salem, Oregon, USA, 65 pp., ftp.odot.state.or.us/ORGN/Documents/ocrs_handbook_user_guide.pdf.

Dennis, M.L., Miller, N., and Brown, G., 2014. *Iowa Regional Coordinate System Handbook and User Guide* (Version 2.10), Iowa Department of Transportation, 76 pp., www.iowadot.gov/rtn/pdfs/IaRCS_Handbook.pdf.

Dennis, M.L., 2015. *An Illustrated Guide to Geodesy for Engineering, Surveying, and GIS* (Arizona Geographic Information Council Education & Training Symposium 2014), Geodetic Analysis, LLC., Sedona, AZ, USA, 52 pp., https://geodetic.xyz/misc/

Dennis, M.L., 2016. *Ground Truth – Design and Documentation of Low Distortion Projections for Surveying and GIS* (Arizona Professional Land Surveyors (APLS) Conference 2016), Geodetic Analysis, LLC., Sedona, AZ, USA, PowerPoint-131 pp., PDF-34 pp., https://geodetic.xyz/ldps/

Henning, W. (lead author), 2011. *National Geodetic Survey User Guidelines for Single Base Real Time GNSS Positioning* (Version 2.1), U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geodetic Survey, Silver Spring, MD, USA, 131 pp., www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v2.1.pdf. *[appendices D and E discus "calibrations/localizations" and low distortion projections, respectively. Note that these appendices do not appear on versions of this document after v2.1]*

Henning, W. (lead author), 2014. *National Geodetic Survey User Guidelines for Singe Base Real Time GNSS Positioning* (Version 3.1), U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geodetic Survey, Silver Spring, MD, USA, 73pp., http://www.ngs.noaa.gov/PUBS_LIB/UserGuidelinesForSingleBaseRealTimeGNSSPositioningv.3.1APR2014-1.pdf.

Iliffe, J.C. and Lott, R., 2008. *Datums and Map Projections: For Remote Sensing, GIS and* Surveying (2nd edition), Whittles Publishing, United Kingdom, 192 pp.

Indiana Department of Transportation, June 2013. *Indiana Design Manual*, Indiana Department of Transportation, Indianapolis, Indiana, USA, 3,829 pp., http://www.in.gov/indot/design_manual/index.htm

Indiana State Board of Registration for Professional Surveyors, 2016. *Indiana Administrative Code – Title 865 State Board of Registration for Professional Surveyors,* Indiana General Assembly, Indianapolis, Indiana, USA, 52 pp., http://www.in.gov/legislative/iac/iac_title?iact=865

McInnis, M., 2014. *The Ever Moving Datum, Ever Changing Earth Conundrum*, Navigational Electronics, Inc. (NEI), Lafayette, LA, USA, 2 pp., http://www.neigps.com/wp-content/uploads/2014/03/NAD83-CORS96-vs-NAD83-2011.pdf

Minkel, D., 2011. *Upcoming Changes to the National Spatial Reference System* (American Congress on Surveying and Mapping (ACSM) Survey Summit 2011), U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geodetic Survey, Silver Spring, MD, USA, 35 pp., http://www.ngs.noaa.gov/web/science_edu/presentations_library/files/new_reference_frame_(acsm).ppt

National Geospatial-Intelligence Agency (2014). *Department of Defense World Geodetic System of 1984: Its Definition and Relationships with Local Geodetic Systems* (Version 1.0.0), NGA.STND.0036_1.0.0_WGS8 (National Geospatial-Intelligence Agency Standardization Document), http://earth-info.nga.mil/GandG/publications/NGA_STND_0036_1_0_0_WGS84/NGA.STND.0036_1.0.0_WGS84.pdf

Stem, J.E., 1990. *State Plane Coordinate System of 1983, NOAA Manual NOS NGS 5,* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geodetic Survey, Rockville, Maryland, USA, 119 pp., www.ngs.noaa.gov/PUBS_LIB/ManualNOSNGS5.pdf.

Vincenty, T., 1975. Direct and inverse solutions of geodesics on the ellipsoid with application of nested equations, *Survey Review*, Vol. 23, No. 176, pp. 88-93, www.ngs.noaa.gov/PUBS_LIB/inverse.pdf.

Wisconsin Department of Transportation (WisDOT), 2009. *Facilities Development Manual (FDM)*, Madison, WI, FDM 9-20-27 (2009/07/22), pp. 10, http://roadwaystandards.dot.wi.gov/standards/fdm/

Wisconsin State Cartographer's Office, 2012. *Wisconsin Coordinate Reference Systems* (2nd edition), Madison, WI, 112 pp., http://www.sco.wisc.edu/images/stories/publications/WisCoordRefSys_June2015.pdf

## *Web sites related to coordinate and spatial reference systems*

### International Earth Rotation and Reference Systems Service

International Terrestrial Reference Frame: https://www.iers.org/IERS/EN/DataProducts/ITRF/itrf.html
International Terrestrial Reference System: https://www.iers.org/IERS/EN/DataProducts/ITRS/itrs.html

### National Geodetic Survey

Antenna Calibration: http://www.ngs.noaa.gov/ANTCAL/
Calibration Base Lines: http://www.ngs.noaa.gov/CBLINES/calibration.html
CORS (Active Geodetic Control): http://www.ngs.noaa.gov/CORS/
Download NGS Software: http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml
Educational Videos: http://www.ngs.noaa.gov/corbin/class_description/NGS_Video_Library.shtml
FAQs: http://www.ngs.noaa.gov/faq.shtml
Geodetic Advisors: http://www.ngs.noaa.gov/ADVISORS/
Geodetic Glossary: http://www.ngs.noaa.gov/CORS-Proxy/Glossary/xml/NGS_Glossary.xml
Geodetic Tool Kit: http://www.ngs.noaa.gov/TOOLS/
Geoid Page: http://www.ngs.noaa.gov/GEOID/
National Adjustment (NAD 83(2011) epoch 2010.00): http://www.ngs.noaa.gov/web/surveys/NA2011/
National Readjustment (NAD 83(NSRS2007)): http://www.ngs.noaa.gov/NationalReadjustment/
New Datums: http://www.geodesy.noaa.gov/datums/newdatums/index.shtml
NOS Education Discovery Kits: http://oceanservice.noaa.gov/education/tutorial_geodesy/welcome.html
Online Positioning User Service (OPUS): http://www.ngs.noaa.gov/OPUS/

Policy on Changes to Plane Coordinate Systems: http://www.in.gov/indot/design_manual/index.htm
Survey Marks & Datasheets (Active & Passive Geodetic Control): http://www.ngs.noaa.gov/datasheets/
User-Contributed Software (DSWorld, etc.): http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml
Vertcon: http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html

**National Geospatial-Intelligence Agency**
WGS84 — http://earth-info.nga.mil/GandG/wgs84/index.html
Earth Gravity Model —
https://www.nga.mil/ProductsServices/GeodesyandGeophysics/Pages/EarthGravityModel.aspx
Coordinate Systems Analysis —
https://www.nga.mil/ProductsServices/GeodesyandGeophysics/Pages/CoordinateSystemAnalysis.aspx

**U.S. Army Corps of Engineers (USACE)**
Corpscon: http://www.agc.army.mil/Missions/Corpscon.aspx

**Wisconsin State Cartographer's Office**
Wisconsin Coordinate Reference Systems Information — http://www.sco.wisc.edu/coordinate-reference-systems/coordinate-reference-systems.html

## *Miscellaneous*

Vincenty Formula: http://www.movable-type.co.uk/scripts/latlong-vincenty.html

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# APPENDIX A

## Numerical Deliverables (Projection Parameters) Catalog

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# Indiana Geospatial Coordinate System (InGCS)

## InGCS Metadata, Geodetic Datum, Map Projection Zone Definitions & Grid Coordinate Validation Points

### GEODETIC DATUM: NAD 83

**RESPONSIBLE AGENCY:** Indiana Department of Transportation (INDOT), Land & Aerial Survey Division

**CONTACT PERSON/POSITION:** Eric N. Banschbach, PS - INDOT Manager Land & Aerial Survey Office

**CONTACT EMAIL:** ebanschbach@indot.in.gov

**DEVELOPED BY:** Matthew G. Badger, PS - Lochmueller Group

**APPROVED BY:** The InGCS Technical Development Team

**APPROVED DATE:** 2015/03/26

**DATE ADOPTED BY INDOT:** 2015/07/28

**SCOPE (USAGE):** Engineering Survey

**AREA OF USE:** The designed area of use for these map projections lie within the State of Indiana, USA.

**GEODETIC DATUM:** The Indiana Geospatial Coordinate System (InGCS) is referenced to the latest realization of the National Spatial Reference System (NSRS), which is currently defined geometrically as NAD 83(2011). For projects based upon the InGCS, the burden of identifying the datum tag (realization) in metadata will be upon the practitioner.

For agencies, groups, proprietary geospatial software providers, etc. preparing to include the InGCS in their respective geodetic parameter datasets, coordinate system libraries, etc., it is recommended that they minimally include the current realization of NAD 83, i.e. NAD 83(2011) and any subsequent realizations. Please note that there have been “double-correction” issues in the magnitude of approximately two meters (three-dimensionally) identified with certain commercially available field system's software when using Real Time (GNSS) Networks (RTN) and other projected coordinate systems, such as Stare Plane, when attempting to correctly position respective to NAD 83(2011). End users of the InGCS should measure the success of their proprietary geospatial software by the ability to unambiguously perform geodetic computations and repeatedly observe undisturbed geodetic survey marks published by the National Geodetic Survey bearing NAD 83(2011) (and any future realizations) values within industry-acceptable tolerances for the work being performed, regardless of the global positioning method employed (RTN, RTK, PPP, Static, etc.).

**PROJECTION METHOD:** All InGCS Zones are based upon the Transverse Mercator projection method.

**DESIGNATION OF ZONES:** Zones within the InGCS were designated the names of the corresponding Indiana Counties for the sake of simplicity and intuitive use by end users. Indiana has 92 Counties. Therefore, the InGCS has 92 zones. A certain zone may or may not have the identical projection parameters of an adjacent zone(s). When comparing the projection parameters of the InGCS' 92 distinct zones, there are 57 separate groups yielding identical parameters. These groups are numbered and listed below for use by the European Petroleum Survey Group (EPSG) for abbreviation purposes within their Dataset. It is requested that proprietary geospatial software providers include the official 92 named zones via 92 separate entries.

**ANGULAR UNITS:** The Degrees, Minutes and Seconds (DMS) values listed below define the corresponding Central Meridians and Latitudes of Grid Origins. These DMS values were assigned at intervals of three minutes so as to keep decimal conversions as "clean" as practical, while not sacrificing the intended map distortion objectives of the System. By assigning the DMS values at intervals of three minutes, decimal conversions round evenly at two decimal places. For applications that require decimal degree input rather than DMS, it is strongly recommended users validate that their decimal degree conversions have not yielded non-zero values after the second decimal place. If non-zero values have occurred after the second decimal place, the conversions have been computed erroneously.

**LINEAR UNITS:** The False Eastings and False Northings listed below are in meters, which is the defining linear unit for these parameters. The provided Validation Points are also listed in meters. The "working" linear unit for end users in Indiana will be the "United States Survey Foot" definition (1 meter = 39.37 inches).

**VALIDATION POINTS:** All grid coordinate values listed below for the Validation Points are based upon the same position of latitude and longitude of **42° North** and **85° West**. This position lies approximately 31 kilometers northwest of the northeast corner of Indiana. This single, common geodetic position yields positive grid values in all Zones listed herein.

| Zone Name | Indiana 2-Digit County Code | Projection Group Abbreviation Code | *(North Latitude)* Latitude of Grid Origin Deg. | Min. | Sec. | *(WestLongitude)* Central Meridian Deg. | Min. | Sec. | Central Meridian Scale Factor | False Easting (X) (meters) | False Northing (Y) (meters) | Validation Point Easting (X) (meters) | Validation Point Northing (Y) (meters) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adams | 01 | 01 | 40 | 33 | 00 | 84 | 57 | 00 | 1.000034 | 240,000 | 36,000 | 235,857.321 | 197,042.576 |
| Allen | 02 | 02 | 40 | 54 | 00 | 85 | 03 | 00 | 1.000031 | 240,000 | 36,000 | 244,142.667 | 158,173.879 |
| Bartholomew | 03 | 03 | 39 | 00 | 00 | 85 | 51 | 00 | 1.000026 | 240,000 | 36,000 | 310,425.254 | 369,491.117 |
| Benton | 04 | 04 | 40 | 27 | 00 | 87 | 18 | 00 | 1.000029 | 240,000 | 36,000 | 430,567.721 | 210,705.421 |
| Blackford | 05 | 05-18 | 40 | 03 | 00 | 85 | 24 | 00 | 1.000038 | 240,000 | 36,000 | 273,141.593 | 252,641.732 |
| Boone | 06 | 06-32 | 39 | 36 | 00 | 86 | 30 | 00 | 1.000036 | 240,000 | 36,000 | 364,282.128 | 303,618.467 |
| Brown | 07 | 07 | 39 | 00 | 00 | 86 | 18 | 00 | 1.000030 | 240,000 | 36,000 | 347,710.206 | 369,960.596 |
| Carroll | 08 | 08 | 40 | 24 | 00 | 86 | 39 | 00 | 1.000026 | 240,000 | 36,000 | 376,709.323 | 215,014.436 |
| Cass | 09 | 09 | 40 | 33 | 00 | 86 | 24 | 00 | 1.000028 | 240,000 | 36,000 | 355,995.543 | 197,988.761 |
| Clark | 10 | 10-22-72 | 38 | 09 | 00 | 85 | 36 | 00 | 1.000021 | 240,000 | 36,000 | 289,711.598 | 463,672.324 |
| Clay | 11 | 11 | 39 | 09 | 00 | 87 | 09 | 00 | 1.000024 | 240,000 | 36,000 | 418,137.860 | 354,724.927 |
| Clinton | 12 | 12 | 40 | 09 | 00 | 86 | 36 | 00 | 1.000032 | 240,000 | 36,000 | 372,567.295 | 242,697.736 |
| Crawford | 13 | 13-47-59 | 38 | 06 | 00 | 86 | 30 | 00 | 1.000025 | 240,000 | 36,000 | 364,280.761 | 470,138.638 |
| Daviess | 14 | 14-28 | 38 | 27 | 00 | 87 | 06 | 00 | 1.000018 | 240,000 | 36,000 | 413,993.876 | 432,329.722 |
| Dearborn | 15 | 15-58-78 | 38 | 39 | 00 | 84 | 54 | 00 | 1.000029 | 240,000 | 36,000 | 231,714.683 | 408,002.771 |
| Decatur | 16 | 16-70 | 39 | 06 | 00 | 85 | 39 | 00 | 1.000036 | 240,000 | 36,000 | 293,855.057 | 358,247.257 |
| DeKalb | 17 | 17 | 41 | 15 | 00 | 84 | 57 | 00 | 1.000036 | 240,000 | 36,000 | 235,857.313 | 119,303.715 |
| Delaware | 18 | 05-18 | 40 | 03 | 00 | 85 | 24 | 00 | 1.000038 | 240,000 | 36,000 | 273,141.593 | 252,641.732 |
| Dubois | 19 | 19-51 | 38 | 12 | 00 | 86 | 57 | 00 | 1.000020 | 240,000 | 36,000 | 401,565.536 | 459,787.679 |
| Elkhart | 20 | 20-43-85 | 40 | 39 | 00 | 85 | 51 | 00 | 1.000033 | 240,000 | 36,000 | 310,425.747 | 186,285.784 |
| Fayette | 21 | 21-24-81 | 39 | 15 | 00 | 85 | 03 | 00 | 1.000038 | 240,000 | 36,000 | 244,142.696 | 341,391.242 |
| Floyd | 22 | 10-22-72 | 38 | 09 | 00 | 85 | 36 | 00 | 1.000021 | 240,000 | 36,000 | 289,711.598 | 463,672.324 |
| Fountain | 23 | 23-86 | 39 | 57 | 00 | 87 | 18 | 00 | 1.000025 | 240,000 | 36,000 | 430,566.959 | 266,225.351 |
| Franklin | 24 | 21-24-81 | 39 | 15 | 00 | 85 | 03 | 00 | 1.000038 | 240,000 | 36,000 | 244,142.696 | 341,391.242 |
| Fulton | 25 | 25-50-71 | 40 | 54 | 00 | 86 | 18 | 00 | 1.000031 | 240,000 | 36,000 | 347,710.313 | 158,990.378 |
| Gibson | 26 | 26 | 38 | 09 | 00 | 87 | 39 | 00 | 1.000013 | 240,000 | 36,000 | 459,565.693 | 466,893.589 |
| Grant | 27 | 27 | 40 | 21 | 00 | 85 | 42 | 00 | 1.000034 | 240,000 | 36,000 | 297,997.659 | 219,487.851 |
| Greene | 28 | 14-28 | 38 | 27 | 00 | 87 | 06 | 00 | 1.000018 | 240,000 | 36,000 | 413,993.876 | 432,329.722 |
| Hamilton | 29 | 29-80 | 39 | 54 | 00 | 86 | 00 | 00 | 1.000034 | 240,000 | 36,000 | 322,854.027 | 269,702.978 |
| Hancock | 30 | 30-48 | 39 | 39 | 00 | 85 | 48 | 00 | 1.000036 | 240,000 | 36,000 | 306,283.225 | 297,287.836 |
| Harrison | 31 | 31-88 | 37 | 57 | 00 | 86 | 09 | 00 | 1.000027 | 240,000 | 36,000 | 335,281.630 | 486,340.679 |
| Hendricks | 32 | 06-32 | 39 | 36 | 00 | 86 | 30 | 00 | 1.000036 | 240,000 | 36,000 | 364,282.128 | 303,618.467 |
| Henry | 33 | 33 | 39 | 45 | 00 | 85 | 27 | 00 | 1.000043 | 240,000 | 36,000 | 277,284.487 | 285,974.624 |
| Howard | 34 | 34-52 | 40 | 21 | 00 | 86 | 09 | 00 | 1.000031 | 240,000 | 36,000 | 335,282.011 | 219,890.110 |
| Huntington | 35 | 35-92 | 40 | 39 | 00 | 85 | 30 | 00 | 1.000034 | 240,000 | 36,000 | 281,426.845 | 186,057.323 |
| Jackson | 36 | 36 | 38 | 42 | 00 | 85 | 57 | 00 | 1.000022 | 240,000 | 36,000 | 318,710.339 | 402,881.394 |
| Jasper | 37 | 37-64 | 40 | 42 | 00 | 87 | 06 | 00 | 1.000027 | 240,000 | 36,000 | 413,995.442 | 182,516.908 |
| Jay | 38 | 38 | 40 | 18 | 00 | 85 | 00 | 00 | 1.000038 | 240,000 | 36,000 | 240,000.000 | 224,803.768 |
| Jefferson | 39 | 39 | 38 | 33 | 00 | 85 | 21 | 00 | 1.000028 | 240,000 | 36,000 | 268,998.598 | 419,157.924 |
| Jennings | 40 | 40 | 38 | 48 | 00 | 85 | 48 | 00 | 1.000025 | 240,000 | 36,000 | 306,282.496 | 391,654.136 |
| Johnson | 41 | 41-49 | 39 | 18 | 00 | 86 | 09 | 00 | 1.000031 | 240,000 | 36,000 | 335,282.011 | 336,476.565 |
| Knox | 42 | 42 | 38 | 24 | 00 | 87 | 27 | 00 | 1.000015 | 240,000 | 36,000 | 442,993.988 | 438,649.761 |
| Kosciusko | 43 | 20-43-85 | 40 | 39 | 00 | 85 | 51 | 00 | 1.000033 | 240,000 | 36,000 | 310,425.747 | 186,285.784 |
| LaGrange | 44 | 44-57 | 41 | 15 | 00 | 85 | 27 | 00 | 1.000037 | 240,000 | 36,000 | 277,284.263 | 119,400.561 |
| Lake | 45 | 45-56 | 40 | 42 | 00 | 87 | 24 | 00 | 1.000026 | 240,000 | 36,000 | 438,853.181 | 183,170.285 |
| LaPorte | 46 | 46-66-75 | 40 | 54 | 00 | 86 | 45 | 00 | 1.000027 | 240,000 | 36,000 | 384,995.147 | 159,654.089 |
| Lawrence | 47 | 13-47-59 | 38 | 06 | 00 | 86 | 30 | 00 | 1.000025 | 240,000 | 36,000 | 364,280.761 | 470,138.638 |
| Madison | 48 | 30-48 | 39 | 39 | 00 | 85 | 48 | 00 | 1.000036 | 240,000 | 36,000 | 306,283.225 | 297,287.836 |
| Marion | 49 | 41-49 | 39 | 18 | 00 | 86 | 09 | 00 | 1.000031 | 240,000 | 36,000 | 335,282.011 | 336,476.565 |
| Marshall | 50 | 25-50-71 | 40 | 54 | 00 | 86 | 18 | 00 | 1.000031 | 240,000 | 36,000 | 347,710.313 | 158,990.378 |
| Martin | 51 | 19-51 | 38 | 12 | 00 | 86 | 57 | 00 | 1.000020 | 240,000 | 36,000 | 401,565.536 | 459,787.679 |
| Miami | 52 | 34-52 | 40 | 21 | 00 | 86 | 09 | 00 | 1.000031 | 240,000 | 36,000 | 335,282.011 | 219,890.110 |
| Monroe | 53 | 53-55 | 38 | 57 | 00 | 86 | 30 | 00 | 1.000028 | 240,000 | 36,000 | 364,281.134 | 375,781.826 |
| Montgomery | 54 | 54-67 | 39 | 27 | 00 | 86 | 57 | 00 | 1.000031 | 240,000 | 36,000 | 401,567.313 | 321,022.846 |
| Morgan | 55 | 53-55 | 38 | 57 | 00 | 86 | 30 | 00 | 1.000028 | 240,000 | 36,000 | 364,281.134 | 375,781.826 |
| Newton | 56 | 45-56 | 40 | 42 | 00 | 87 | 24 | 00 | 1.000026 | 240,000 | 36,000 | 438,853.181 | 183,170.285 |
| Noble | 57 | 44-57 | 41 | 15 | 00 | 85 | 27 | 00 | 1.000037 | 240,000 | 36,000 | 277,284.263 | 119,400.561 |
| Ohio | 58 | 15-58-78 | 38 | 39 | 00 | 84 | 54 | 00 | 1.000029 | 240,000 | 36,000 | 231,714.683 | 408,002.771 |
| Orange | 59 | 13-47-59 | 38 | 06 | 00 | 86 | 30 | 00 | 1.000025 | 240,000 | 36,000 | 364,280.761 | 470,138.638 |
| Owen | 60 | 60 | 39 | 09 | 00 | 86 | 54 | 00 | 1.000026 | 240,000 | 36,000 | 397,423.611 | 354,235.478 |
| Parke | 61 | 61-83 | 39 | 36 | 00 | 87 | 21 | 00 | 1.000022 | 240,000 | 36,000 | 434,709.379 | 305,198.679 |

| Zone Name | Indiana 2-Digit County Code | Projection Group Abbreviation Code | *(North Latitude)* Latitude of Grid Origin | | | *(WestLongitude)* Central Meridian | | | Central Meridian Scale Factor | False Easting (X) (meters) | False Northing (Y) (meters) | Validation Point | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Deg. | Min. | Sec. | Deg. | Min. | Sec. | | | | Easting (X) (meters) | Northing (Y) (meters) |
| Perry | 62 | 62 | 37 | 48 | 00 | 86 | 42 | 00 | 1.000020 | 240,000 | 36,000 | 380,851.312 | 503,745.518 |
| Pike | 63 | 63-87 | 37 | 51 | 00 | 87 | 18 | 00 | 1.000015 | 240,000 | 36,000 | 430,565.053 | 499,355.108 |
| Porter | 64 | 37-64 | 40 | 42 | 00 | 87 | 06 | 00 | 1.000027 | 240,000 | 36,000 | 413,995.442 | 182,516.908 |
| Posey | 65 | 65 | 37 | 45 | 00 | 87 | 57 | 00 | 1.000013 | 240,000 | 36,000 | 484,424.394 | 512,105.909 |
| Pulaski | 66 | 46-66-75 | 40 | 54 | 00 | 86 | 45 | 00 | 1.000027 | 240,000 | 36,000 | 384,995.147 | 159,654.089 |
| Putnam | 67 | 54-67 | 39 | 27 | 00 | 86 | 57 | 00 | 1.000031 | 240,000 | 36,000 | 401,567.313 | 321,022.846 |
| Randolph | 68 | 68-89 | 39 | 42 | 00 | 85 | 03 | 00 | 1.000044 | 240,000 | 36,000 | 244,142.720 | 291,429.823 |
| Ripley | 69 | 69 | 38 | 54 | 00 | 85 | 18 | 00 | 1.000038 | 240,000 | 36,000 | 264,856.185 | 380,290.971 |
| Rush | 70 | 16-70 | 39 | 06 | 00 | 85 | 39 | 00 | 1.000036 | 240,000 | 36,000 | 293,855.057 | 358,247.257 |
| St. Joseph | 71 | 25-50-71 | 40 | 54 | 00 | 86 | 18 | 00 | 1.000031 | 240,000 | 36,000 | 347,710.313 | 158,990.378 |
| Scott | 72 | 10-22-72 | 38 | 09 | 00 | 85 | 36 | 00 | 1.000021 | 240,000 | 36,000 | 289,711.598 | 463,672.324 |
| Shelby | 73 | 73 | 39 | 18 | 00 | 85 | 54 | 00 | 1.000030 | 240,000 | 36,000 | 314,568.249 | 336,228.284 |
| Spencer | 74 | 74 | 37 | 45 | 00 | 87 | 03 | 00 | 1.000014 | 240,000 | 36,000 | 409,850.295 | 509,927.647 |
| Starke | 75 | 46-66-75 | 40 | 54 | 00 | 86 | 45 | 00 | 1.000027 | 240,000 | 36,000 | 384,995.147 | 159,654.089 |
| Steuben | 76 | 76 | 41 | 30 | 00 | 85 | 00 | 00 | 1.000041 | 240,000 | 36,000 | 240,000.000 | 91,536.493 |
| Sullivan | 77 | 77 | 38 | 54 | 00 | 87 | 30 | 00 | 1.000017 | 240,000 | 36,000 | 447,137.413 | 383,265.043 |
| Switzerland | 78 | 15-58-78 | 38 | 39 | 00 | 84 | 54 | 00 | 1.000029 | 240,000 | 36,000 | 231,714.683 | 408,002.771 |
| Tippecanoe | 79 | 79-91 | 40 | 12 | 00 | 86 | 54 | 00 | 1.000026 | 240,000 | 36,000 | 397,423.611 | 237,652.628 |
| Tipton | 80 | 29-80 | 39 | 54 | 00 | 86 | 00 | 00 | 1.000034 | 240,000 | 36,000 | 322,854.027 | 269,702.978 |
| Union | 81 | 21-24-81 | 39 | 15 | 00 | 85 | 03 | 00 | 1.000038 | 240,000 | 36,000 | 244,142.696 | 341,391.242 |
| Vanderburgh | 82 | 82 | 37 | 48 | 00 | 87 | 33 | 00 | 1.000015 | 240,000 | 36,000 | 451,280.026 | 505,491.860 |
| Vermillion | 83 | 61-83 | 39 | 36 | 00 | 87 | 21 | 00 | 1.000022 | 240,000 | 36,000 | 434,709.379 | 305,198.679 |
| Vigo | 84 | 84 | 39 | 15 | 00 | 87 | 27 | 00 | 1.000020 | 240,000 | 36,000 | 442,995.003 | 344,289.561 |
| Wabash | 85 | 20-43-85 | 40 | 39 | 00 | 85 | 51 | 00 | 1.000033 | 240,000 | 36,000 | 310,425.747 | 186,285.784 |
| Warren | 86 | 23-86 | 39 | 57 | 00 | 87 | 18 | 00 | 1.000025 | 240,000 | 36,000 | 430,566.959 | 266,225.351 |
| Warrick | 87 | 63-87 | 37 | 51 | 00 | 87 | 18 | 00 | 1.000015 | 240,000 | 36,000 | 430,565.053 | 499,355.108 |
| Washington | 88 | 31-88 | 37 | 57 | 00 | 86 | 09 | 00 | 1.000027 | 240,000 | 36,000 | 335,281.630 | 486,340.679 |
| Wayne | 89 | 68-89 | 39 | 42 | 00 | 85 | 03 | 00 | 1.000044 | 240,000 | 36,000 | 244,142.720 | 291,429.823 |
| Wells | 90 | 90 | 40 | 33 | 00 | 85 | 15 | 00 | 1.000034 | 240,000 | 36,000 | 260,713.402 | 197,071.604 |
| White | 91 | 79-91 | 40 | 12 | 00 | 86 | 54 | 00 | 1.000026 | 240,000 | 36,000 | 397,423.611 | 237,652.628 |
| Whitley | 92 | 35-92 | 40 | 39 | 00 | 85 | 30 | 00 | 1.000034 | 240,000 | 36,000 | 281,426.845 | 186,057.323 |

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# APPENDIX B

## InGCS Release Announcement to Geospatial Software Vendors

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**INDIANA DEPARTMENT OF TRANSPORTATION**

Land and Aerial Survey Office
120 South Shortridge Road
Indianapolis, IN 46219

PHONE: (317) 610-7251
FAX: (317) 356-9351

**Michael R. Pence, Governor**
**Brandye Hendrickson, Commissioner**

Geospatial Software Vendors,

The Indiana Department of Transportation wishes to inform you that, as of 2015/07/28, INDOT has approved and adopted a new set of low distortion map projections, referred to as the "Indiana Geospatial Coordinate System," or InGCS, for use in the agency's geospatial projects (which includes Civil Engineering, Land Surveying, Aerial Surveying, GIS, etc.) across Indiana. We anticipate this system will be used in the private sector as well. Information about the InGCS can be found on INDOT's website at http://www.in.gov/indot/ingcs. The official zone names, parameters, projection methods, and other specifications, are available in the "2015 InGCS Approved & Adopted Definition File" on the website for download when adding the InGCS to your respective platform.

For geospatial software vendors offering field positioning systems using global positioning techniques, please make special note of the "Geodetic Datum" statement within the "2015 InGCS Approved & Adopted Definition File" regarding NAD 83(2011) and "double-correction" issues identified in Real Time (GNSS) Networks. For quality control purposes, INDOT plans to perform field tests on the performance of selected vendor's platforms when using Real Time (GNSS) Networks on National Geodetic Survey (NGS) passive control bearing NAD 83(2011) values. Test results are slated to be published in the forthcoming "InGCS Handbook and User Guide" for assessment by the end user community.

INDOT has been working closely with the European Petroleum Survey Group (EPSG) to ensure the InGCS is included in its Geodetic Parameter Dataset. The difference between INDOT's official document, available on our website, and the EPSG's Datasheets are the groupings of zones that contain identical projection parameters. These differences are noted within EPSG's Datasheets, and the datasheets refer to INDOT's zone designations as the official/authoritative source. For consistency across platforms and ease of use by the end user community, it is strongly recommended to use INDOT's official document when adding the InGCS to your platform.

We are currently working on the next phase of this project. This phase includes preparing an InGCS Handbook and User Guide, rewriting the appropriate sections of the INDOT Design Manual, providing educational seminars and workshops, and so on. Updates on this endeavor will be posted on the website.

Should you have any questions, my contact information is provided below and available on the website.

Kind regards,

Eric N Banschbach, P.S.
*Manager, Land & Aerial Survey Office*
*Indiana Department of Transportation*
*120 South Shortridge Road*
*Indianapolis, Indiana 46219-6705*
*(317) 610-7251 ext 205.*
ebanschbach@indot.in.gov

*www.in.gov/dot/*
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Indiana
A State that Works

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# APPENDIX C

## InGCS Individual Zone Datasheets

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# InGCS Zones

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)

## General InGCS Map Projection Information

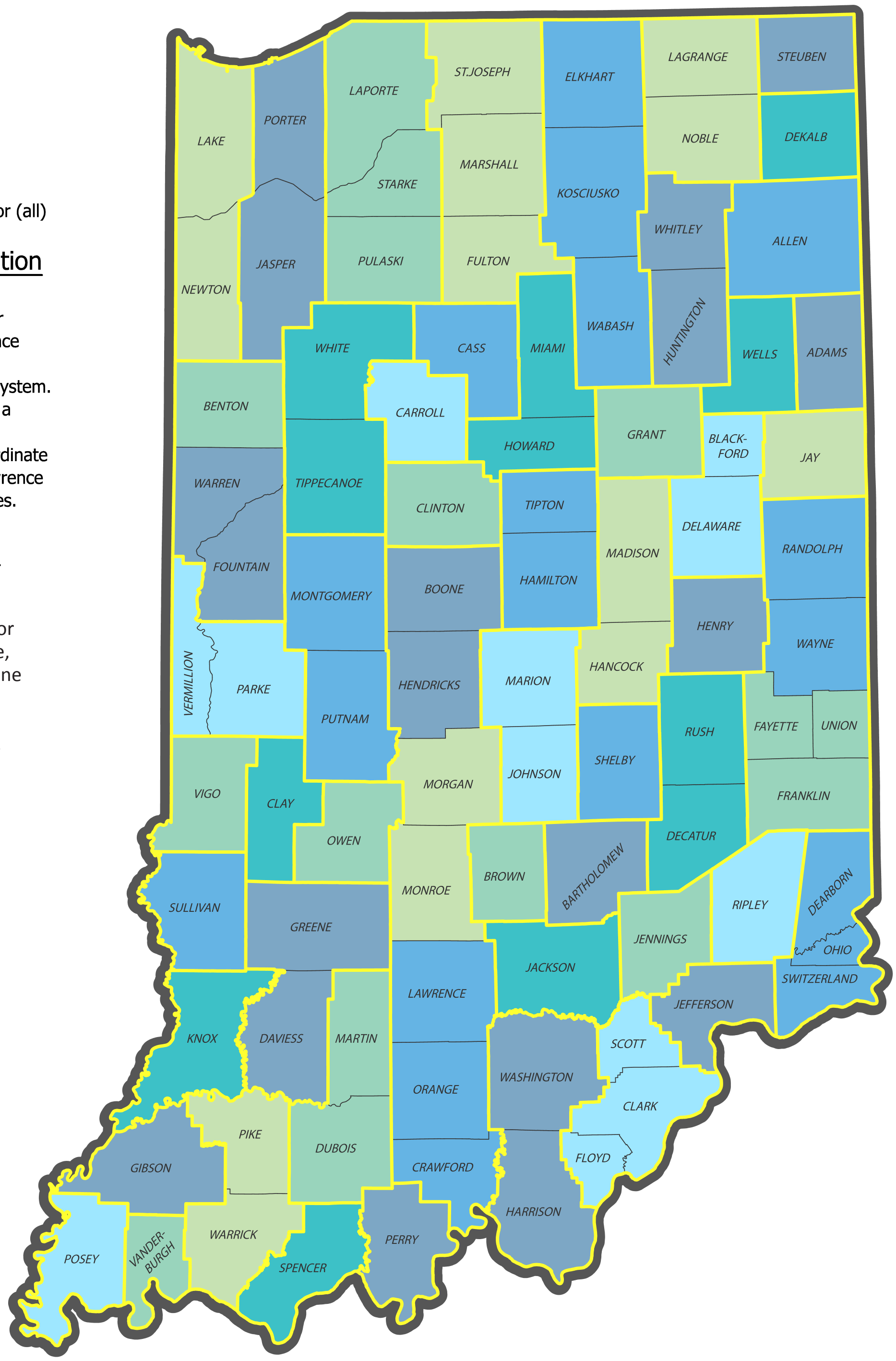
Number of zones: 92 (one per county)
Number of zone groups: 57
Number of grid bearing systems: 53
Map projection type: Transverse Mercator (all)

## InGCS Zone Groups Designation

Zone groups are depicted by contiguous counties with identical color shading. For example, Crawford, Orange, and Lawrence counties are in the same group and are therefore in a common grid coordinate system. Monroe and Morgan counties, though in a common coordinate system between themselves, are in a difference grid coordinate system than Crawford, Orange, and Lawrence counties or Hendricks and Boone counties.

## InGCS Grid Bearing Systems

Zone groups with common central meridians/basis of grid bearings are depicted with bold, yellow borders. For example, Crawford, Orange, Lawrence, Monroe, Morgan, Hendricks, and Boone counties have the same basis of grid bearings, even though these counties comprise three different zone groups.



# InGCS Zones Overview Map

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)

## General InGCS Map Projection Information

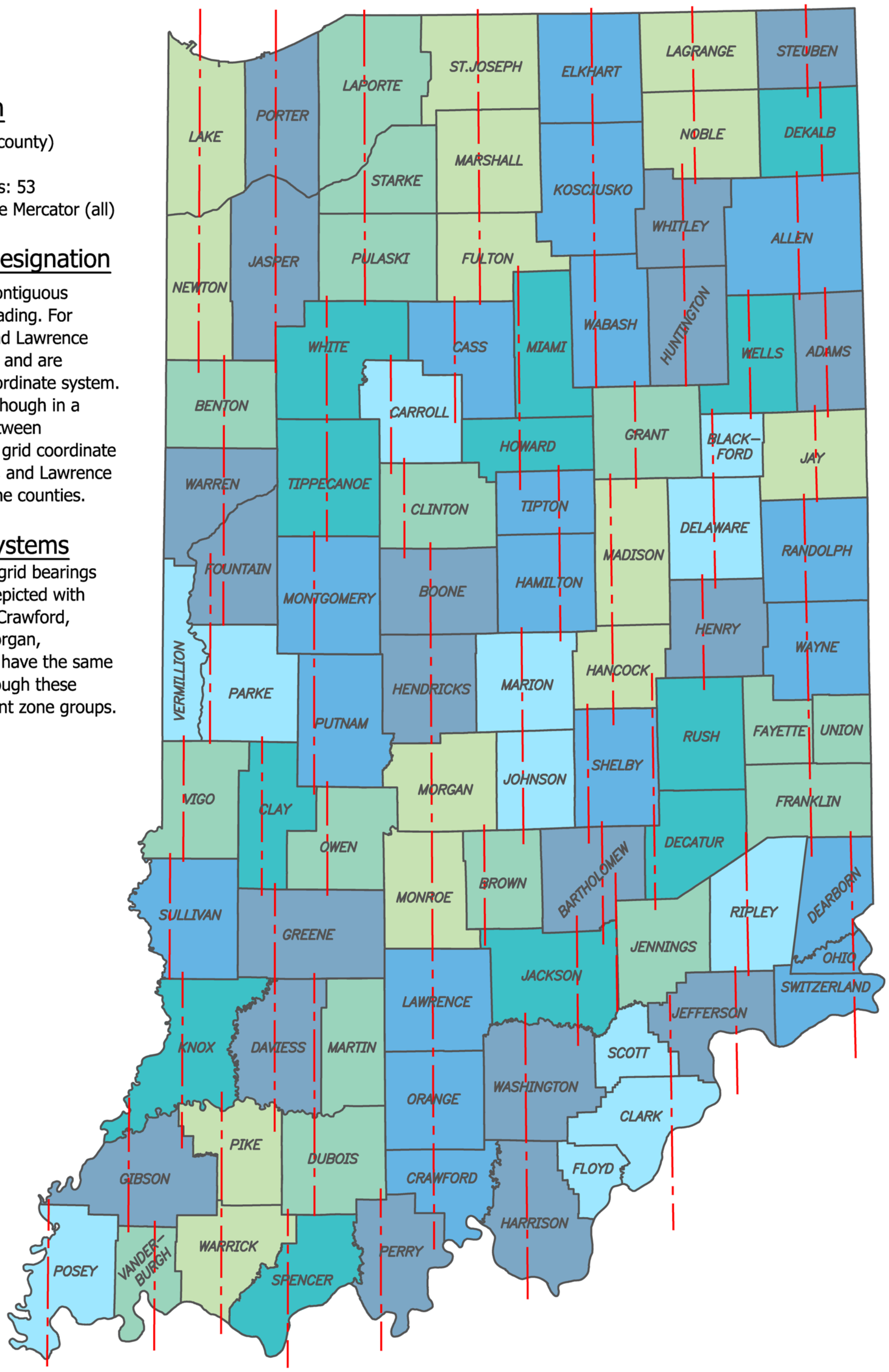
Number of zones: 92 (one per county)
Number of zone groups: 57
Number of grid bearing systems: 53
Map projection type: Transverse Mercator (all)

## InGCS Zone Groups Designation

Zone groups are depicted by contiguous counties with identical color shading. For example, Crawford, Orange, and Lawrence counties are in the same group and are therefore in a common grid coordinate system. Monroe and Morgan counties, though in a common coordinate system between themselves, are in a difference grid coordinate system than Crawford, Orange, and Lawrence counties or Hendricks and Boone counties.

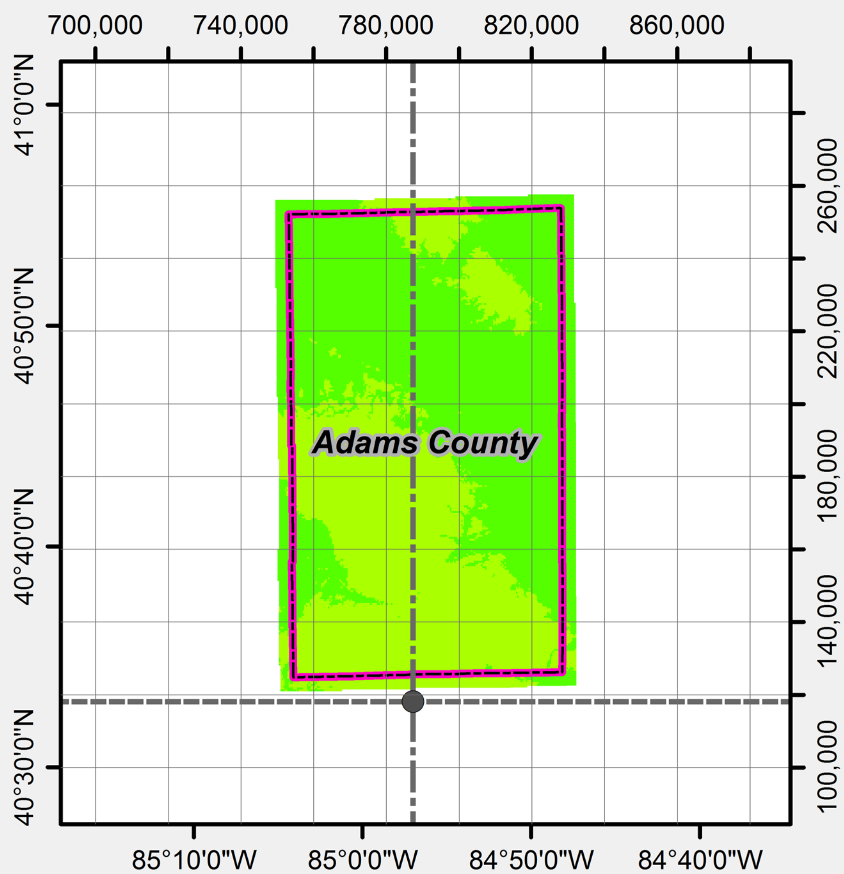
## InGCS Grid Bearing Systems

The central meridians/basis of grid bearings of the appropriate zones are depicted with bold centerlines. For example, Crawford, Orange, Lawrence, Monroe, Morgan, Hendricks, and Boone counties have the same basis of grid bearings, even though these counties comprise three different zone groups.



# ADAMS COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°33'00"N |
| Central Meridian: | 84°57'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 034 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Adams County | 1 | 2 | 3 |

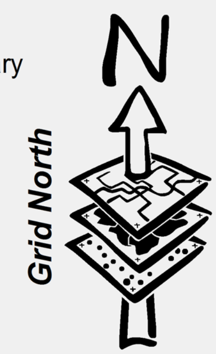
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

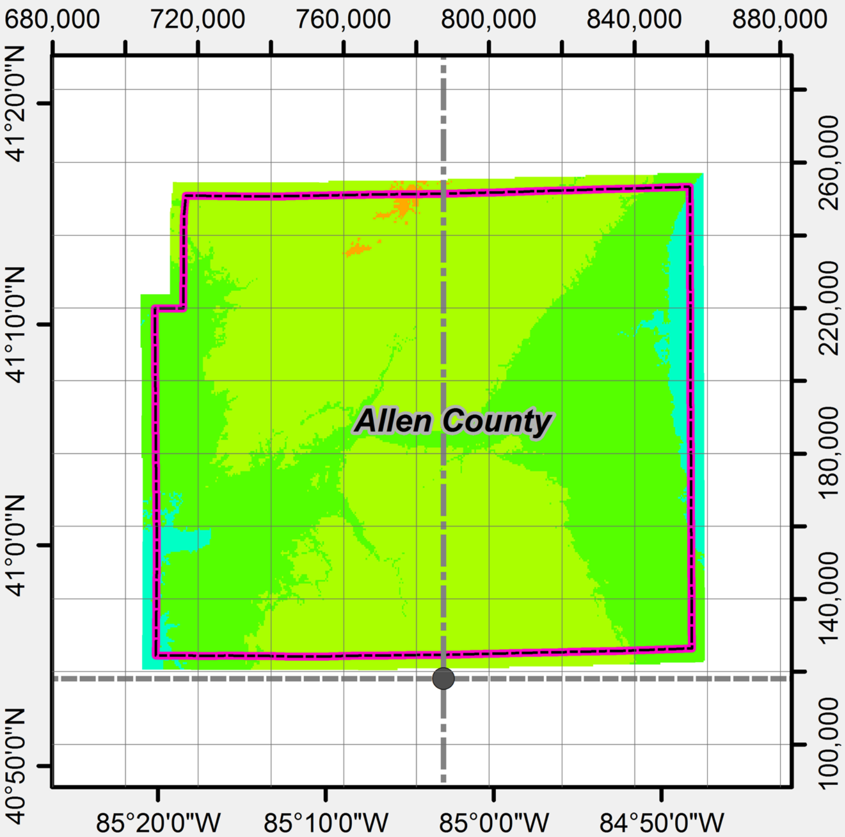
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# ALLEN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°54'00"N |
| Central Meridian: | 85°03'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 031 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Allen County | 2 | 5 | 7 |

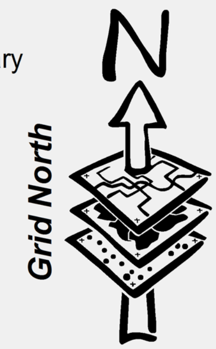
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

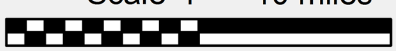
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

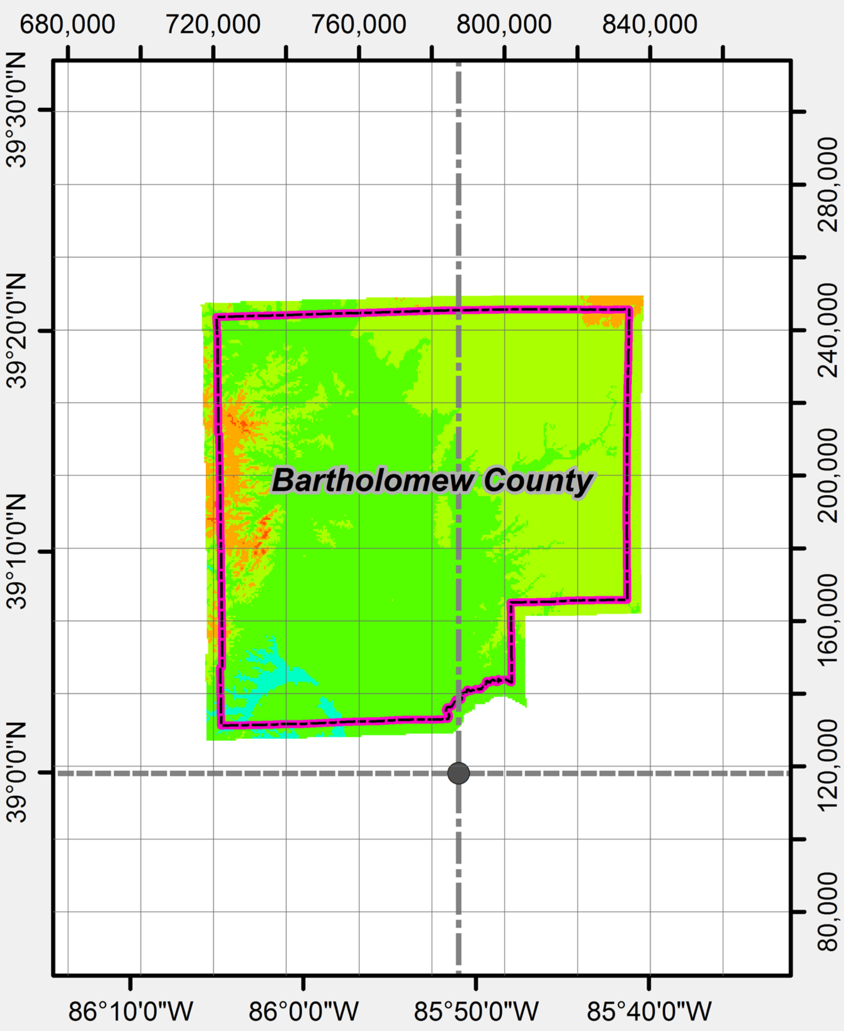
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# BARTHOLOMEW COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°00'00"N
Central Meridian: 85°51'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 026

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Bartholomew County | 2 | 5 | 8 |

*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm

*Grid North*

*Note: Map grid is shown in units of U.S. Survey feet.*

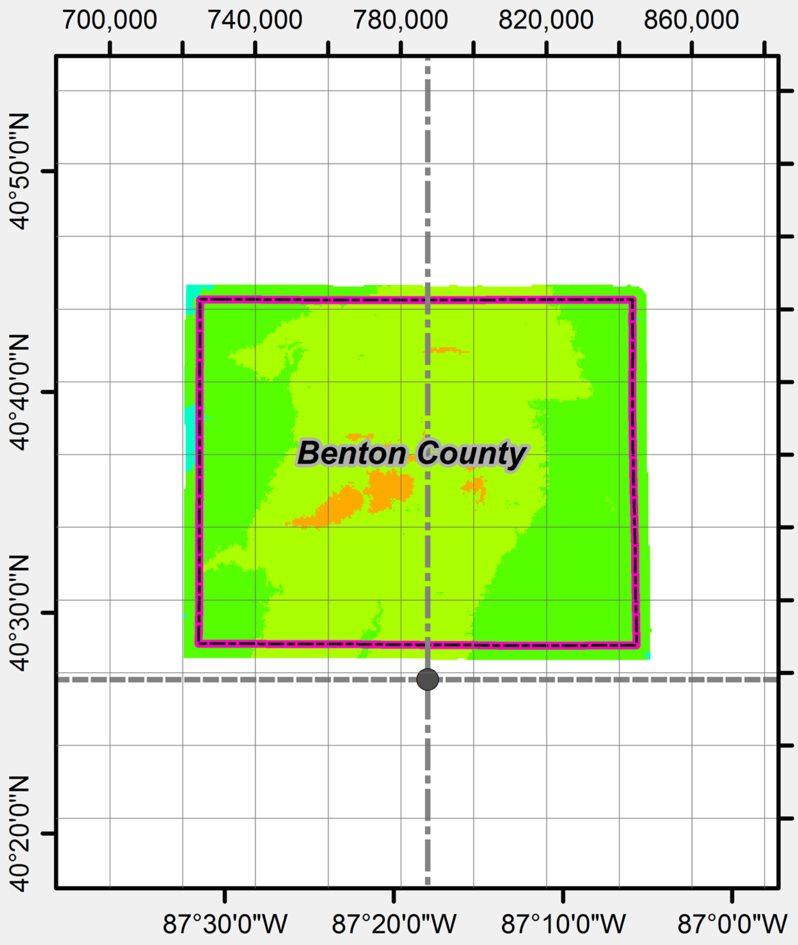
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# BENTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°27'00"N |
| Central Meridian: | 87°18'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 029 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Benton County | 2 | 5 | 6 |

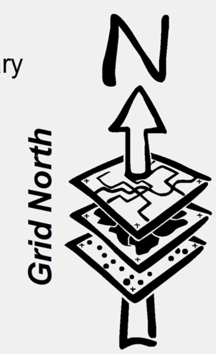
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

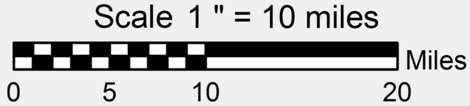
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

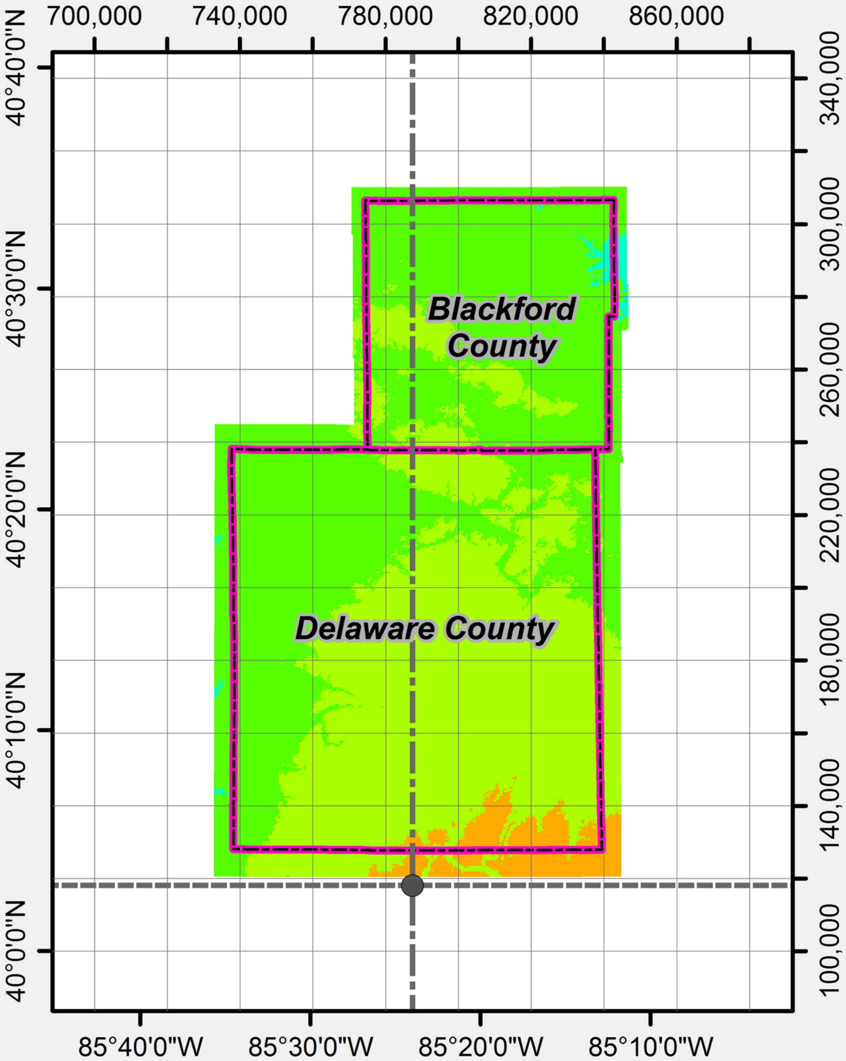
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# BLACKFORD COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°03'00"N |
| Central Meridian: | 85°24'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 038 |

*Note: Blackford and Delaware Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Blackford County | 2 | 4 | 6 |
| Delaware County | 2 | 5 | 7 |

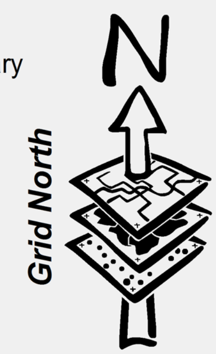
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

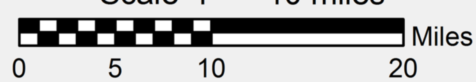
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

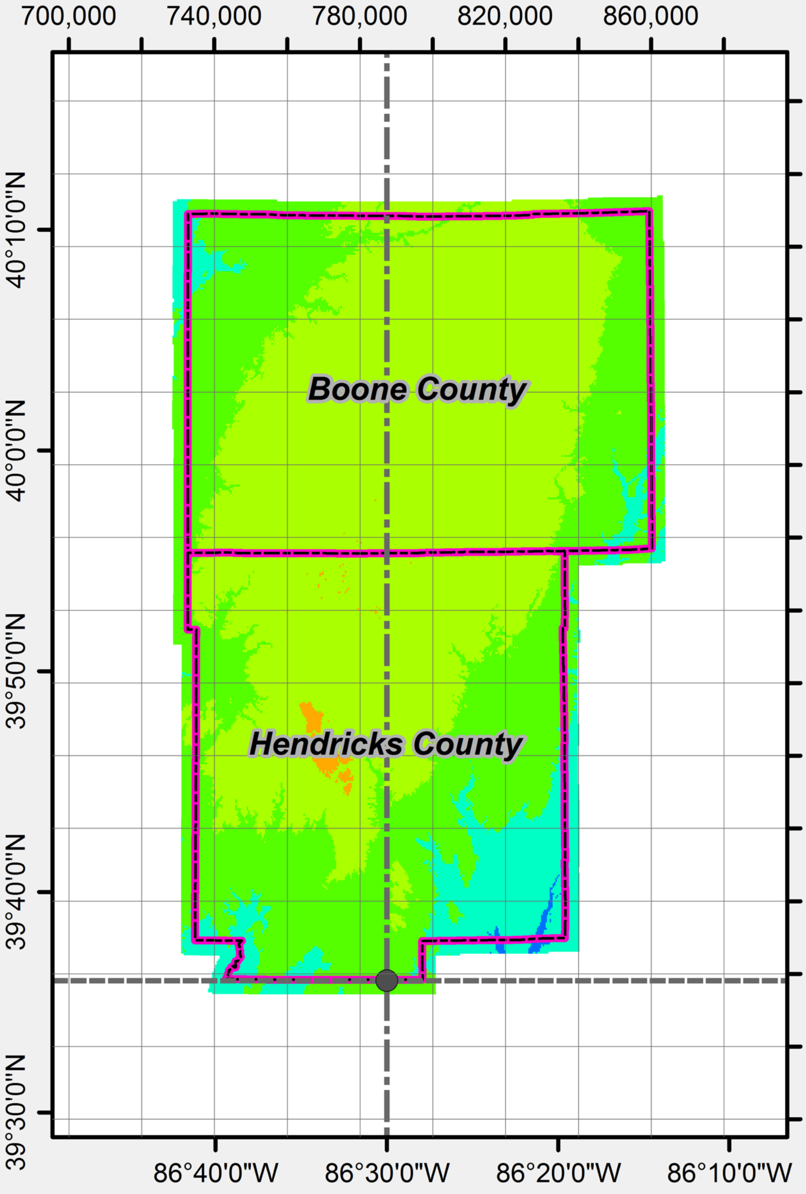
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# BOONE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°36'00"N
Central Meridian: 86°30'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 036

*Note: Boone and Hendricks Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Boone County | 2 | 5 | 6 |
| Hendricks County | 3 | 8 | 9 |

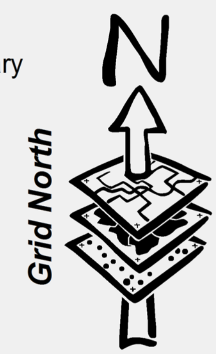
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

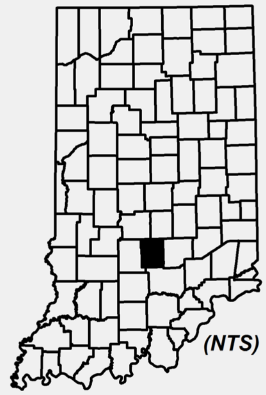
Scale 1 " = 10 miles

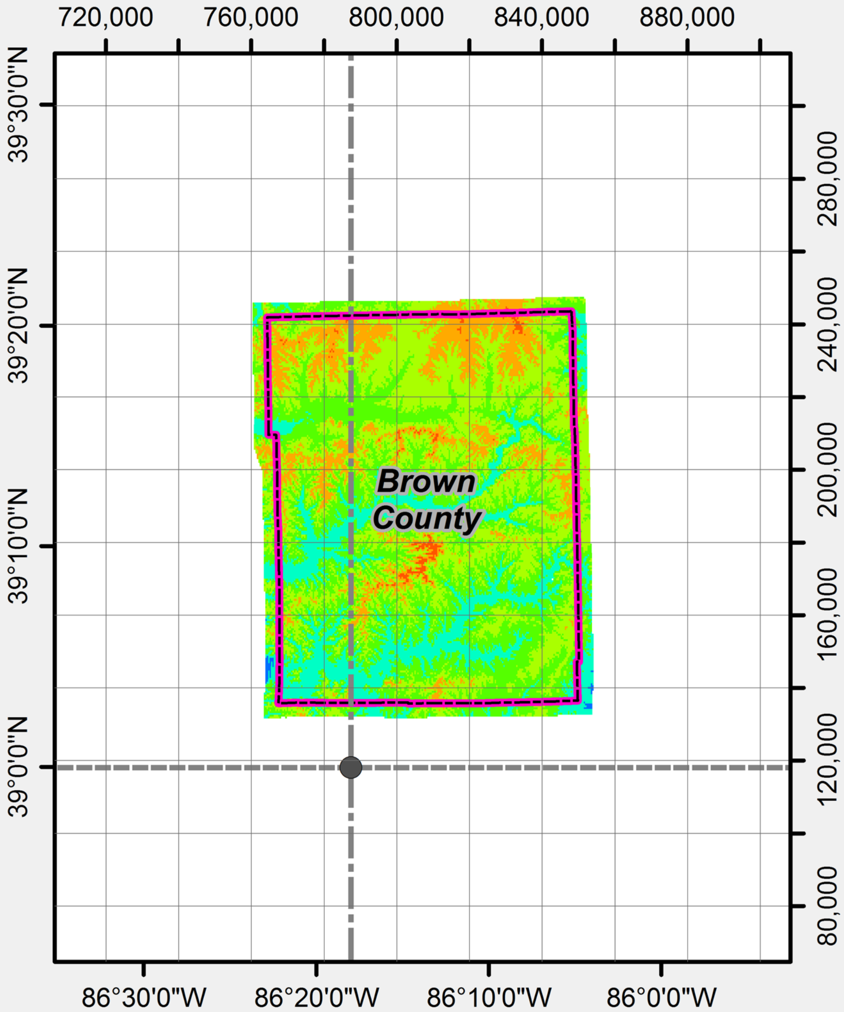
0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# BROWN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°00'00"N
Central Meridian: 86°18'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 030

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Brown County | 4 | 9 | 10 |

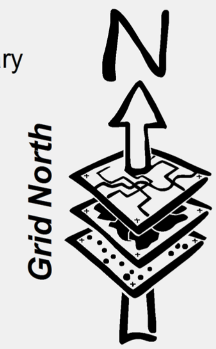
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

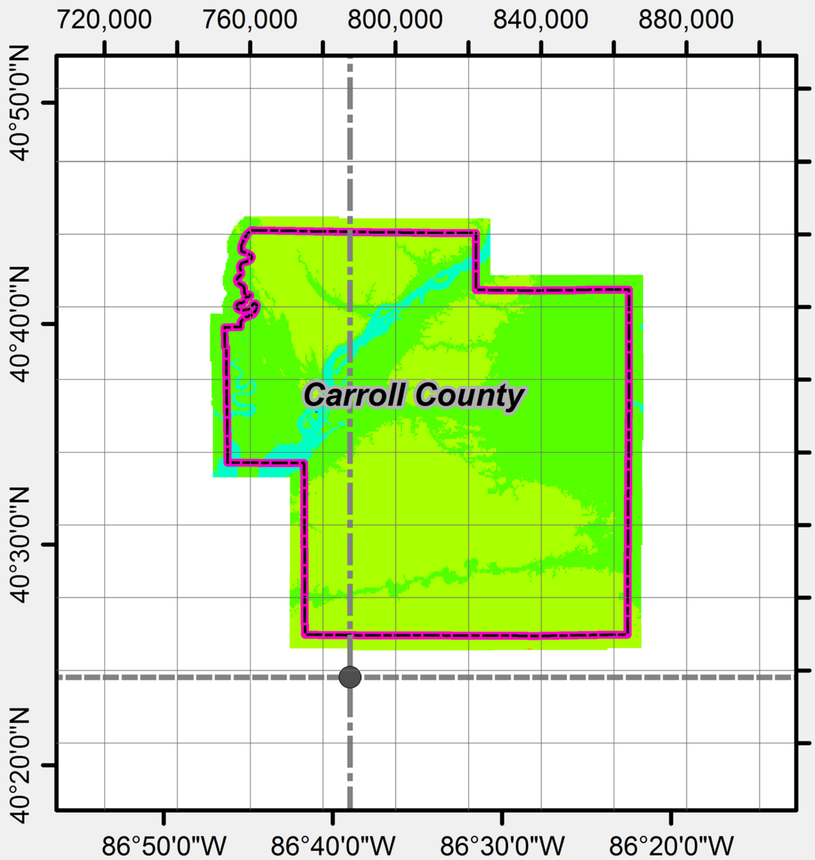
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# CARROLL COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°24'00"N
Central Meridian: 86°39'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 026

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Carroll County | 2 | 5 | 6 |

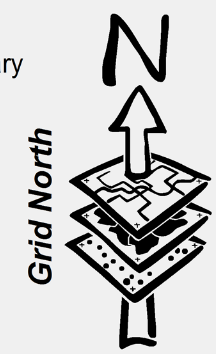
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

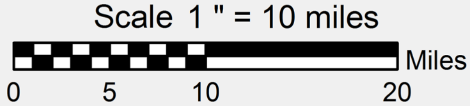
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

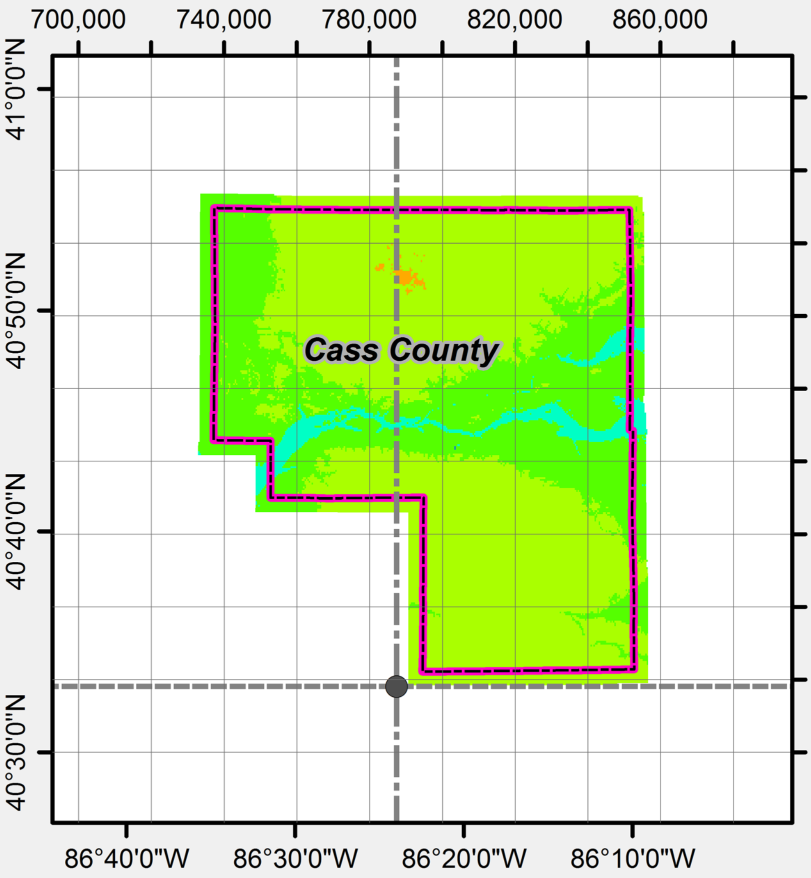
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# CASS COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°33'00"N |
| Central Meridian: | 86°24'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 028 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Cass County | 2 | 5 | 7 |

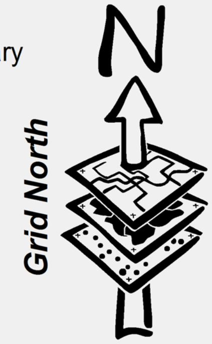
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

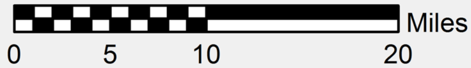
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

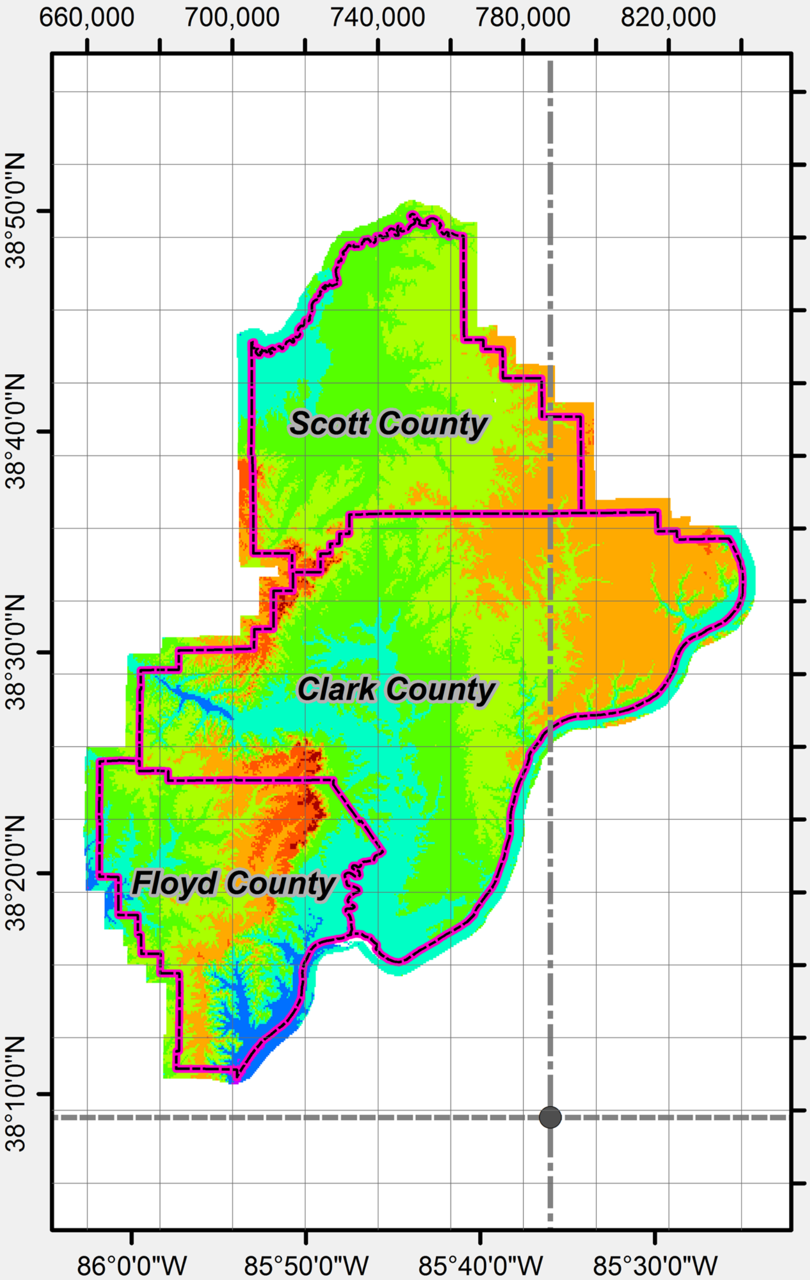
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# CLARK COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°09'00"N
Central Meridian: 85°36'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 021

*Note: Clark, Floyd, and Scott Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Clark County | 5 | 9 | 13 |
| Floyd County | 6 | 13 | 15 |
| Scott County | 4 | 9 | 13 |

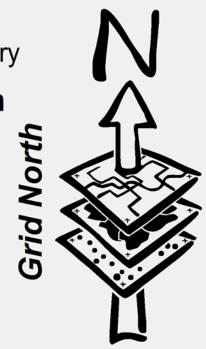
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

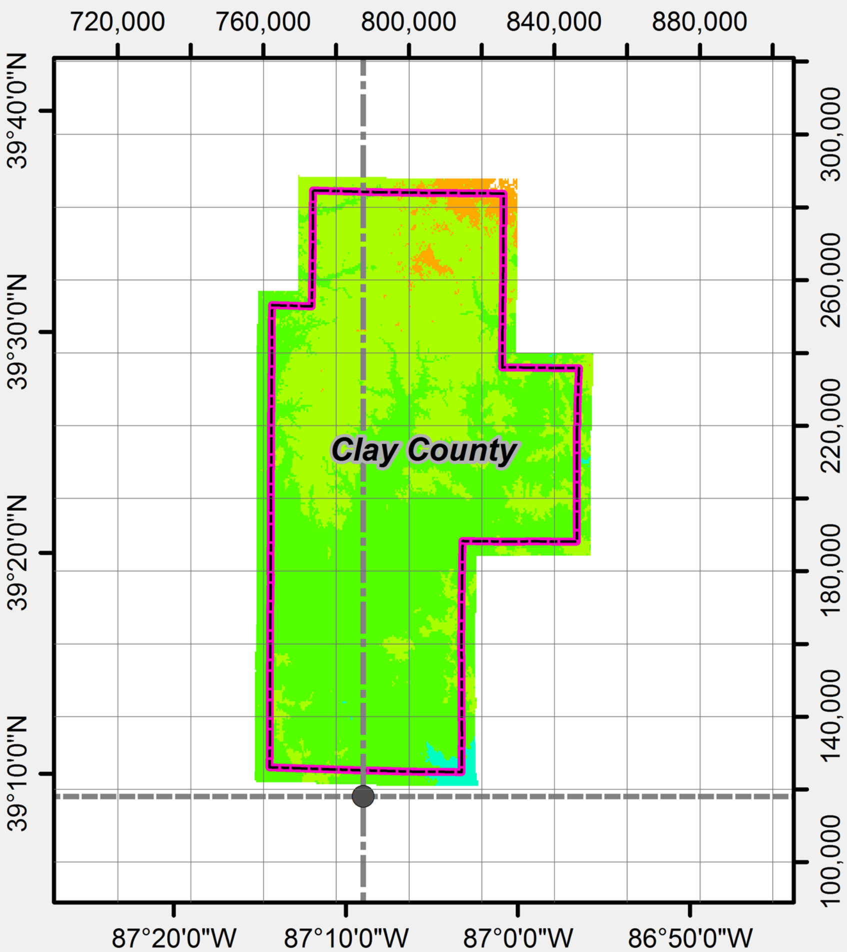
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# CLAY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°09'00"N |
| Central Meridian: | 87°09'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 024 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Clay County | 2 | 5 | 6 |

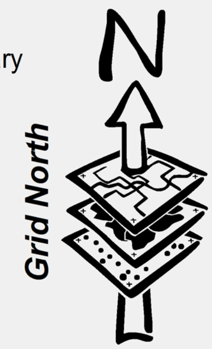
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

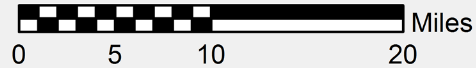
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

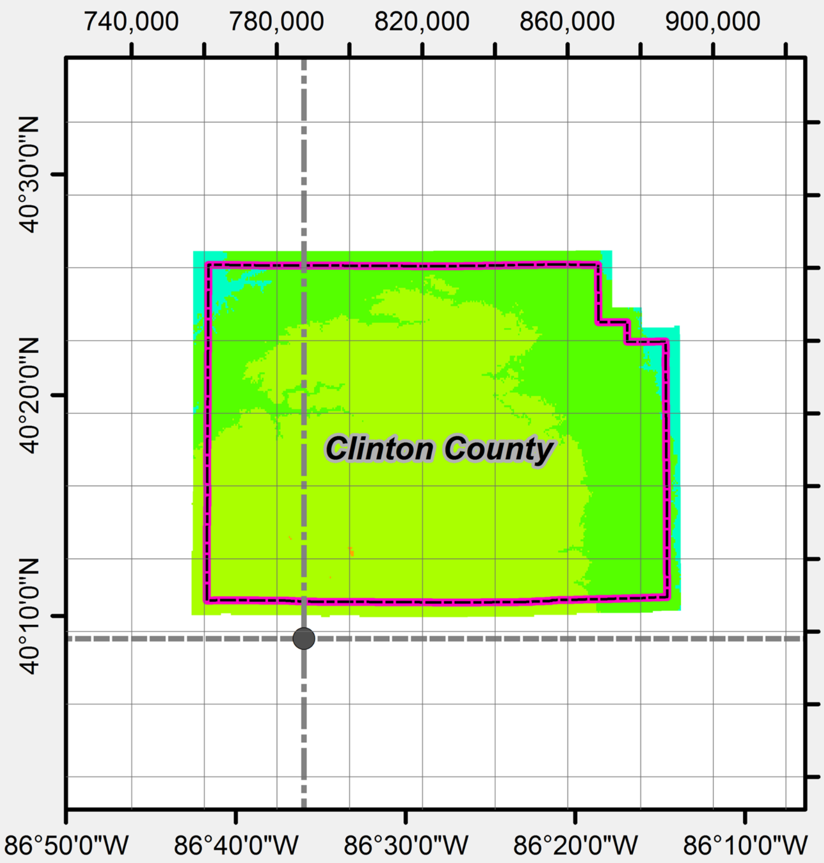
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# CLINTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°09'00"N |
| Central Meridian: | 86°36'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 032 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Clinton County | 2 | 5 | 6 |

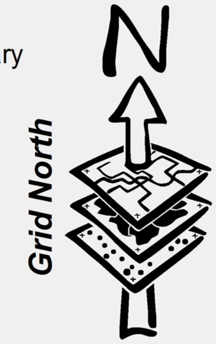
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

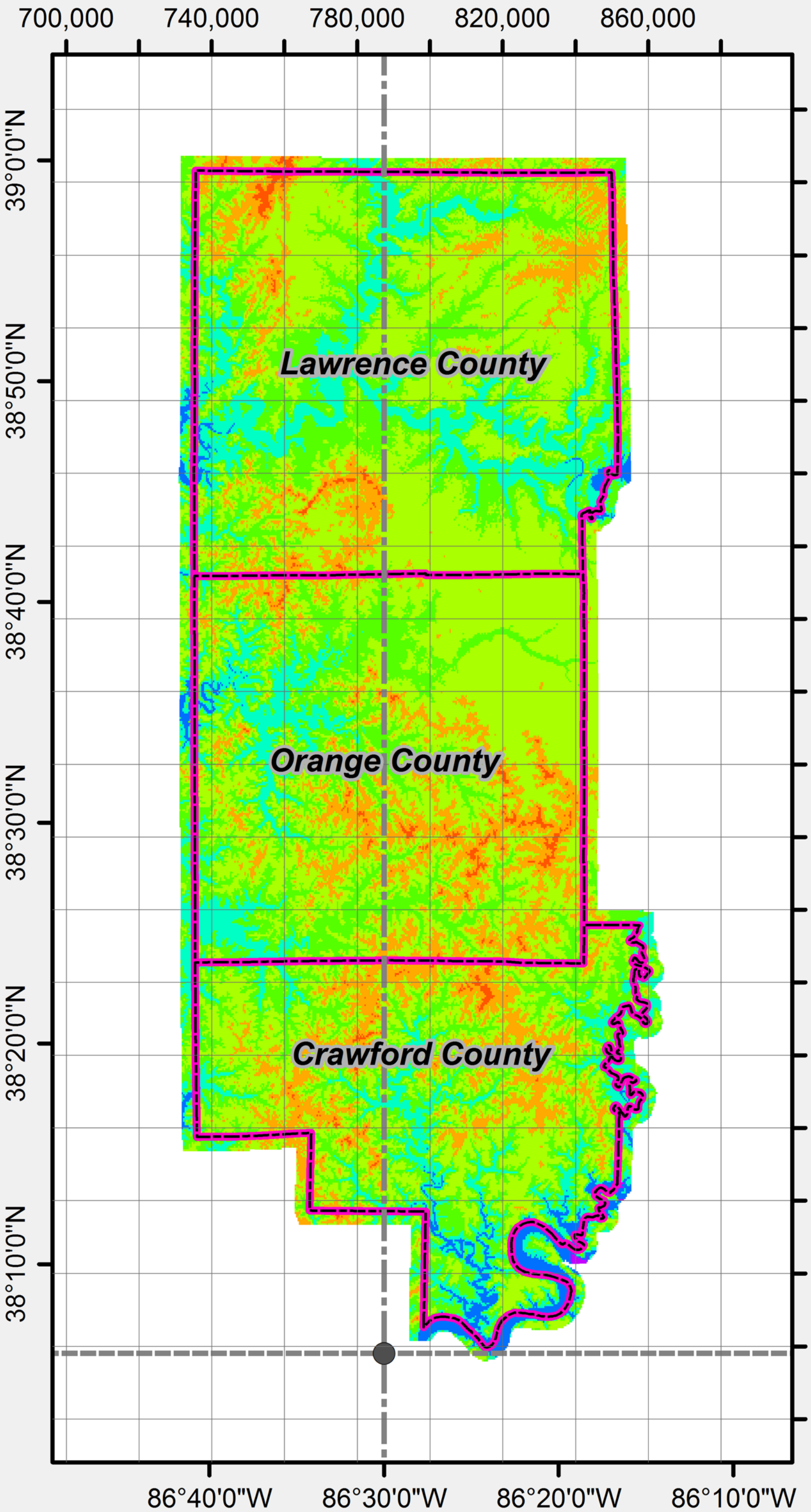
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# CRAWFORD COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°06'00"N |
| Central Meridian: | 86°30'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 025 |

*Note: Crawford, Lawrence, and Orange Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Crawford County | 4 | 11 | 14 |
| Lawrence County | 4 | 8 | 11 |
| Orange County | 4 | 8 | 10 |

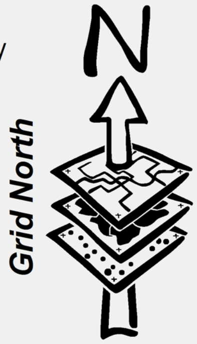
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

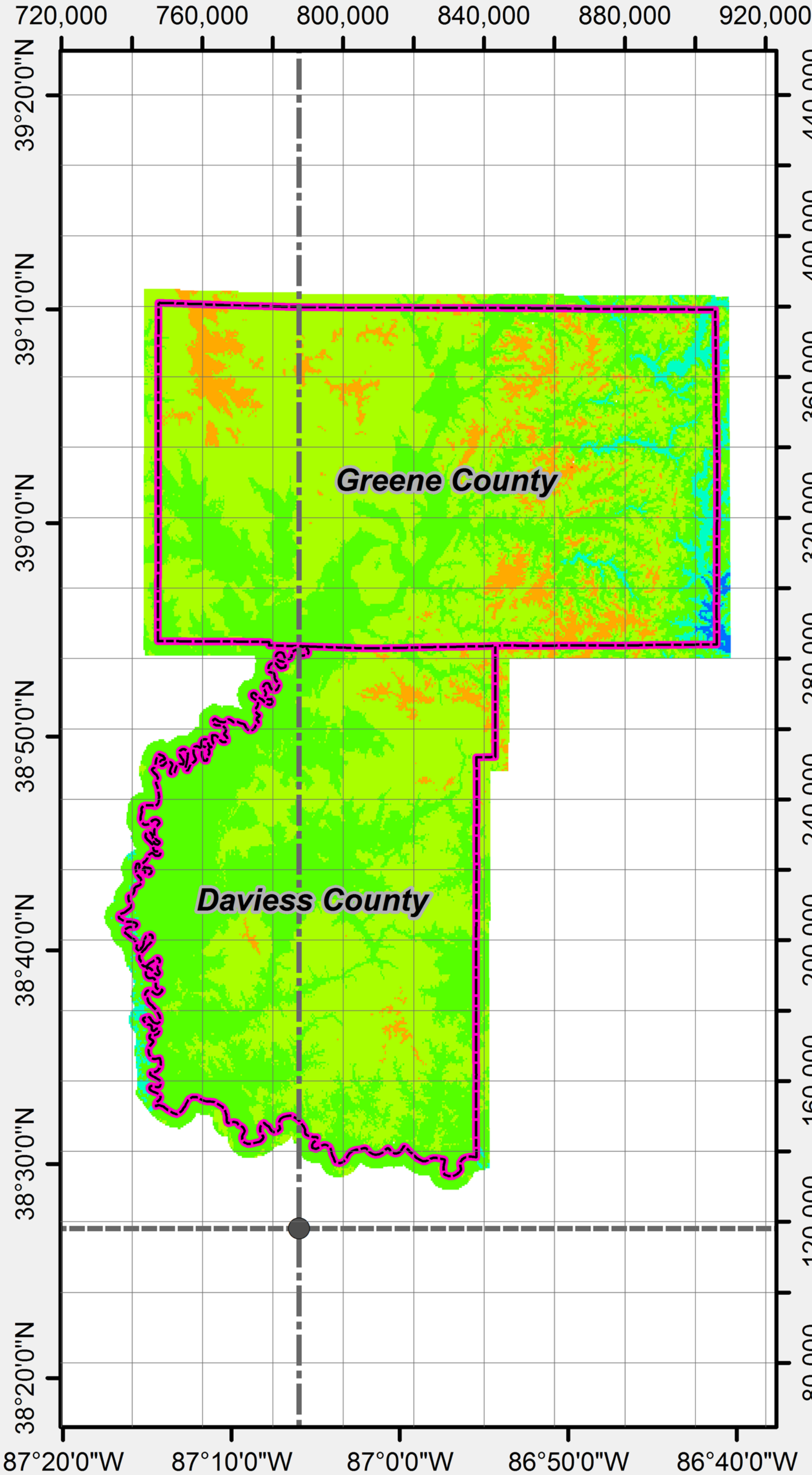
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# DAVIESS COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°27'00"N |
| Central Meridian: | 87°06'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 018 |

*Note: Daviess and Greene Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Daviess County | 2 | 5 | 6 |
| Greene County | 2 | 6 | 9 |

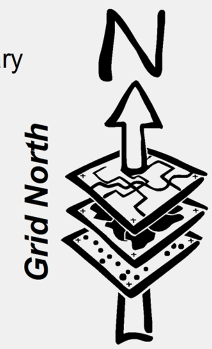
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

False Northing/Easting
Central Meridian
Origin Latitude
County Boundary

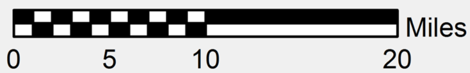
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

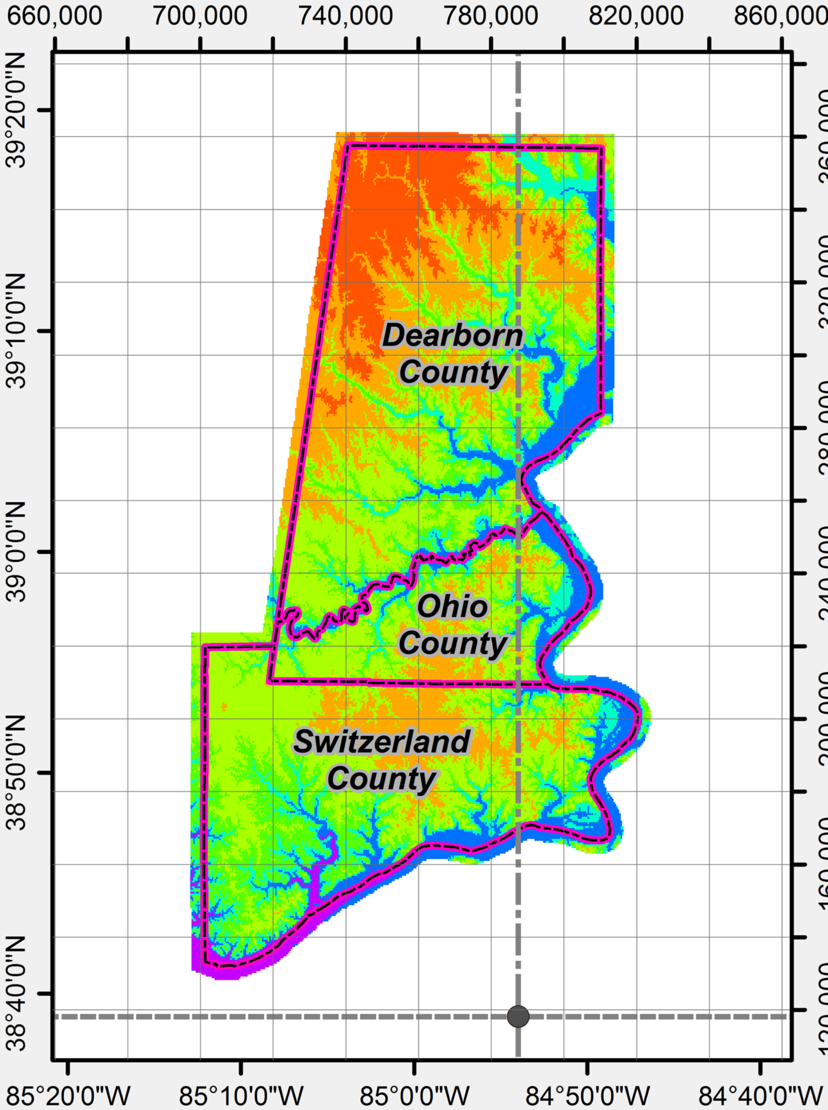
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# DEARBORN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°39'00"N
Central Meridian: 84°54'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 029

*Note: Dearborn, Ohio, and Switzerland Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Dearborn County | 7 | 12 | 13 |
| Ohio County | 6 | 13 | 13 |
| Switzerland County | 6 | 15 | 20 |

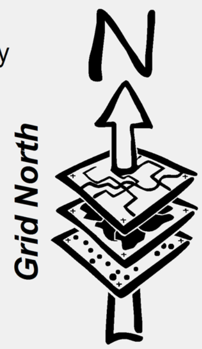
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

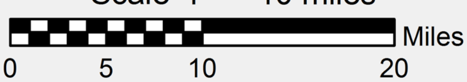
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

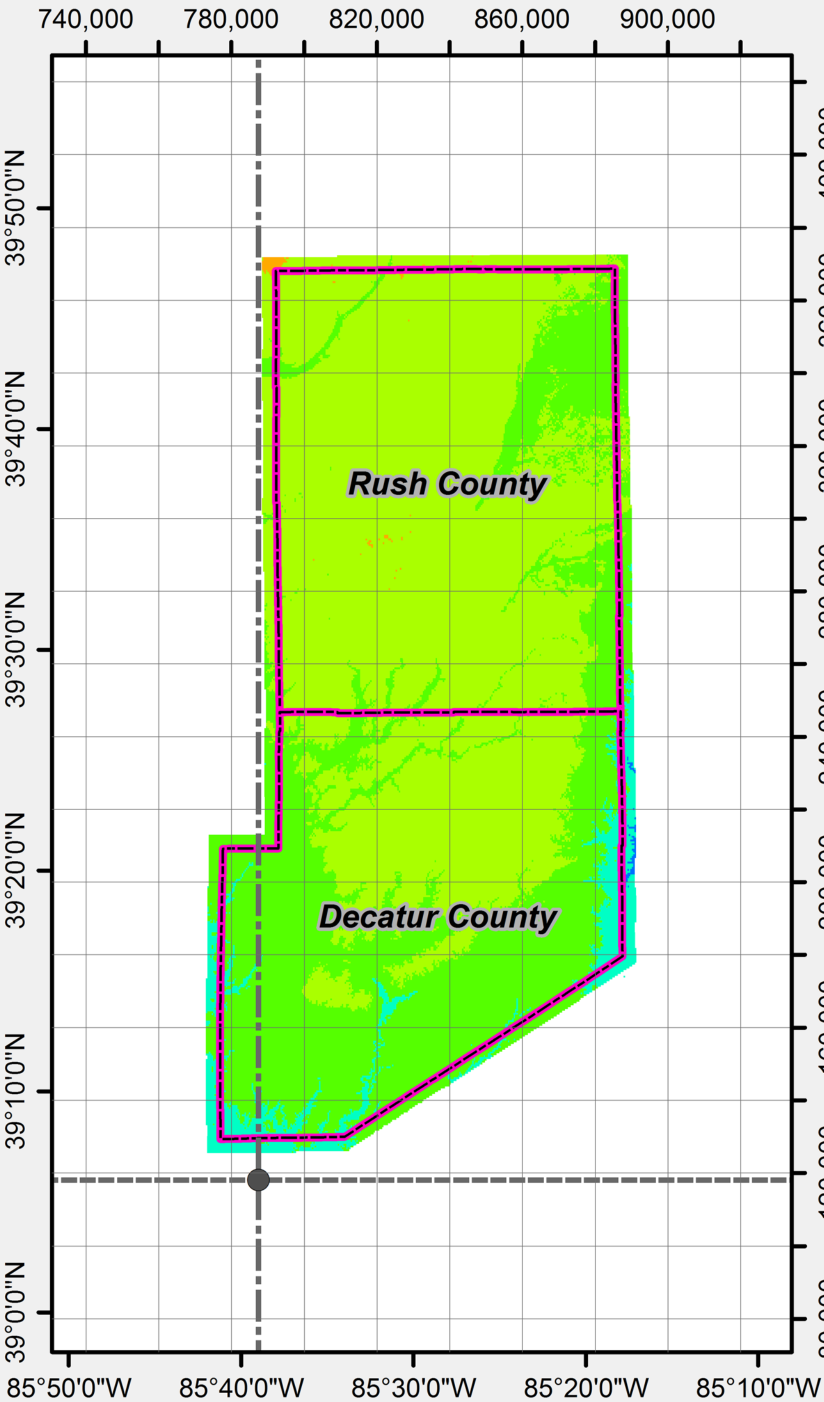
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# DECATUR COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°06'00"N
Central Meridian: 85°39'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 036

*Note: Decatur and Rush Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Decatur County | 2 | 6 | 8 |
| Rush County | 2 | 4 | 5 |

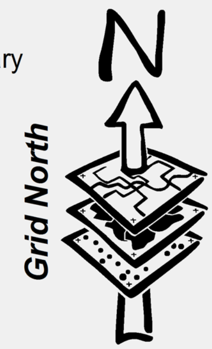
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

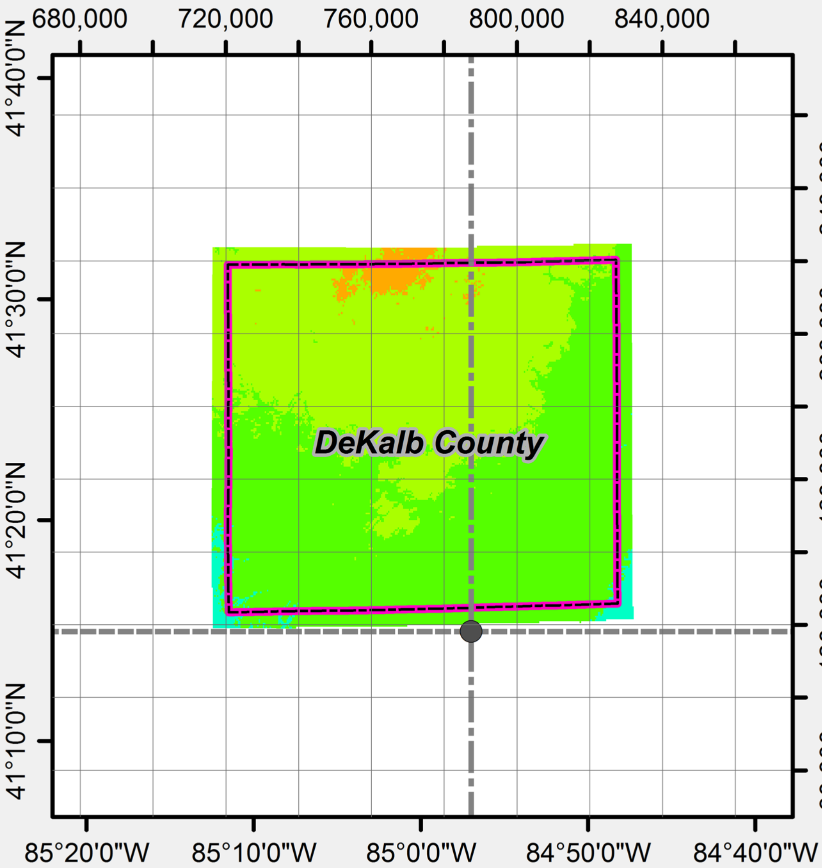
Scale 1 " = 10 miles

Miles 0 5 10 20

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# DEKALB COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 41°15'00"N
Central Meridian: 84°57'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 036

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| DeKalb County | 2 | 5 | 6 |

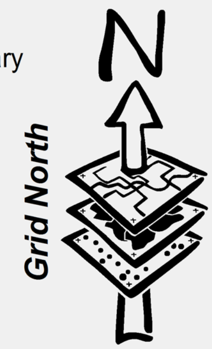
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

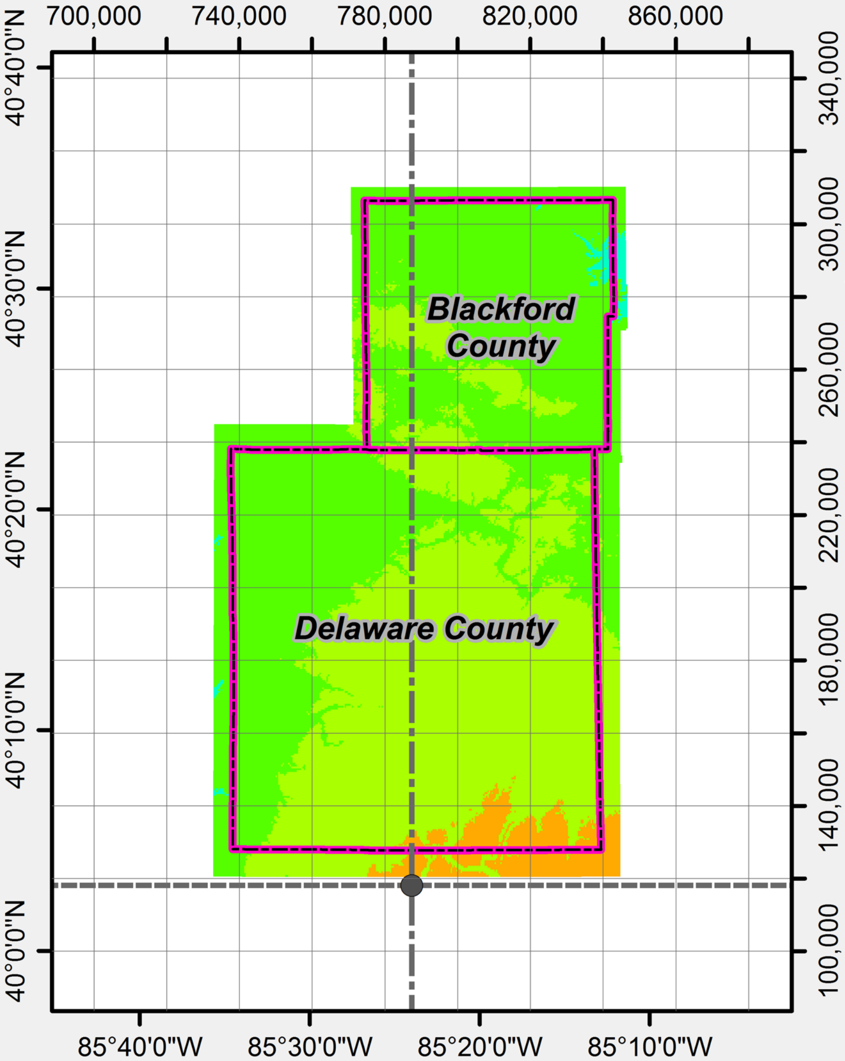
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# DELAWARE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°03'00"N |
| Central Meridian: | 85°24'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 038 |

*Note: Blackford and Delaware Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Blackford County | 2 | 4 | 6 |
| Delaware County | 2 | 5 | 7 |

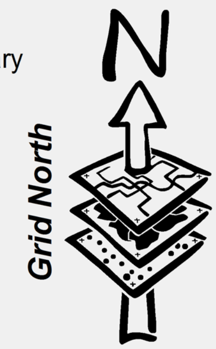
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

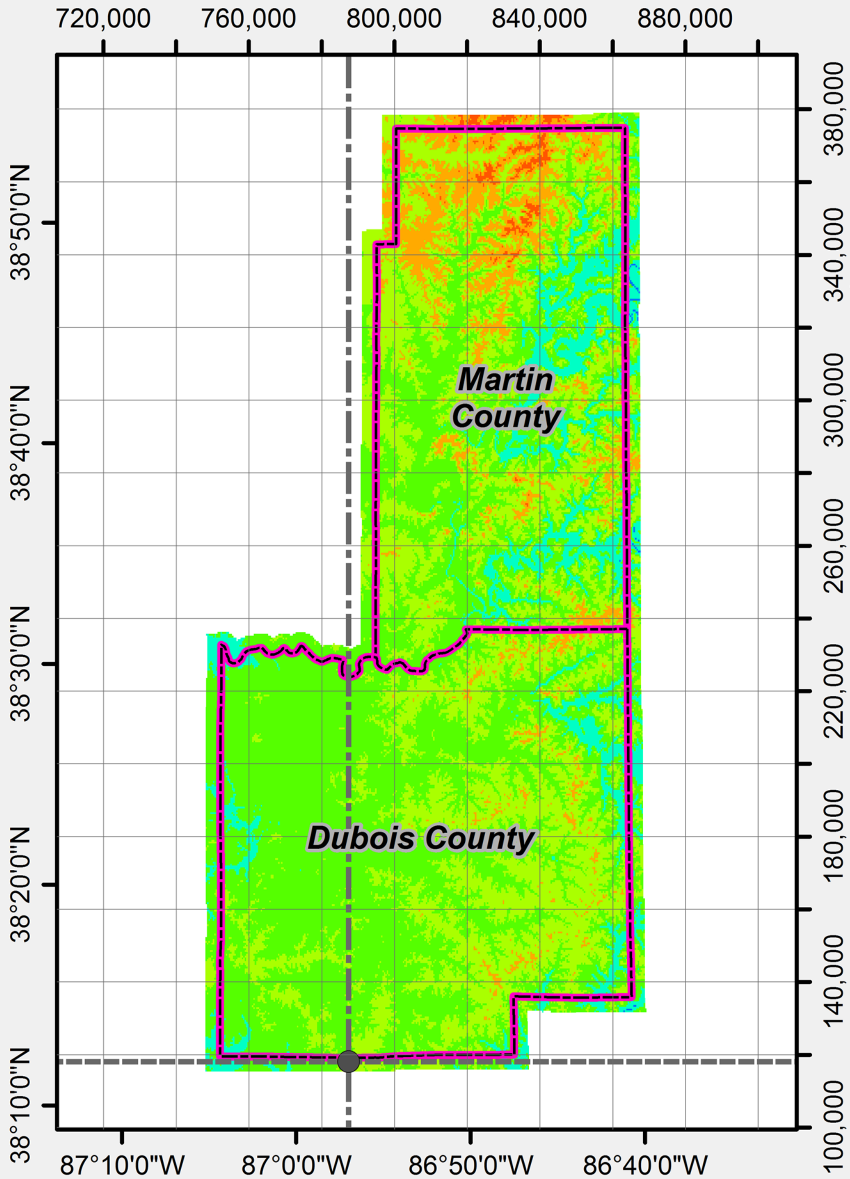
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# DUBOIS COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°12'00"N
Central Meridian: 86°57'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 020
*Note: Dubois and Martin Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Dubois County | 3 | 6 | 7 |
| Martin County | 4 | 8 | 10 |

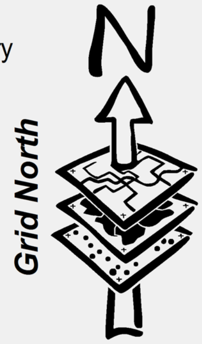
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

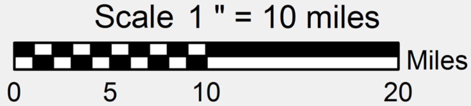
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

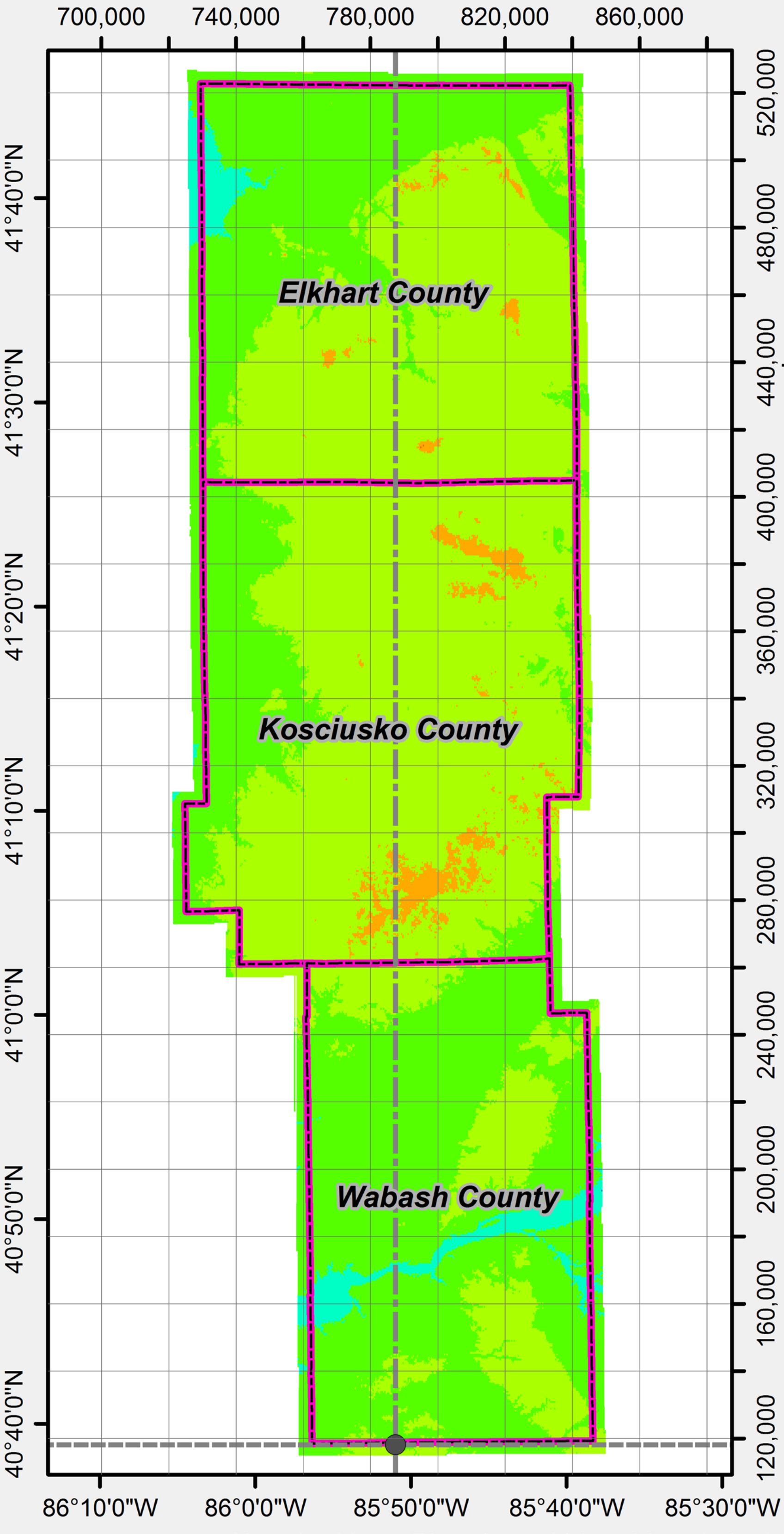
Scale 1 " = 10 miles

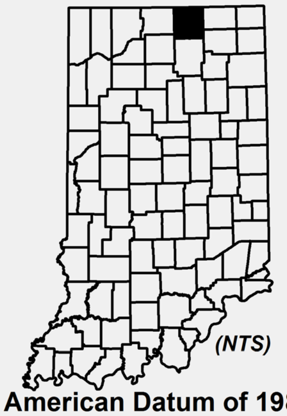



Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# ELKHART COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°39'00"N
Central Meridian: 85°51'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 033

*Note: Elkhart, Kosciusko, and Wabash Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Elkhart County | 2 | 5 | 6 |
| Koscisusko County | 2 | 5 | 6 |
| Wabash County | 2 | 5 | 8 |

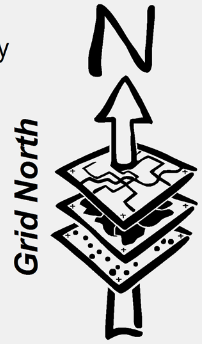
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

False Northing/Easting
Central Meridian
Origin Latitude
County Boundary

**Linear Distortion**

<-15 ppm
-15 to -10 ppm
-10 to -5 ppm
-5 to 0 ppm
0 to 5 ppm
5 to 10 ppm
10 to 15 ppm
>15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

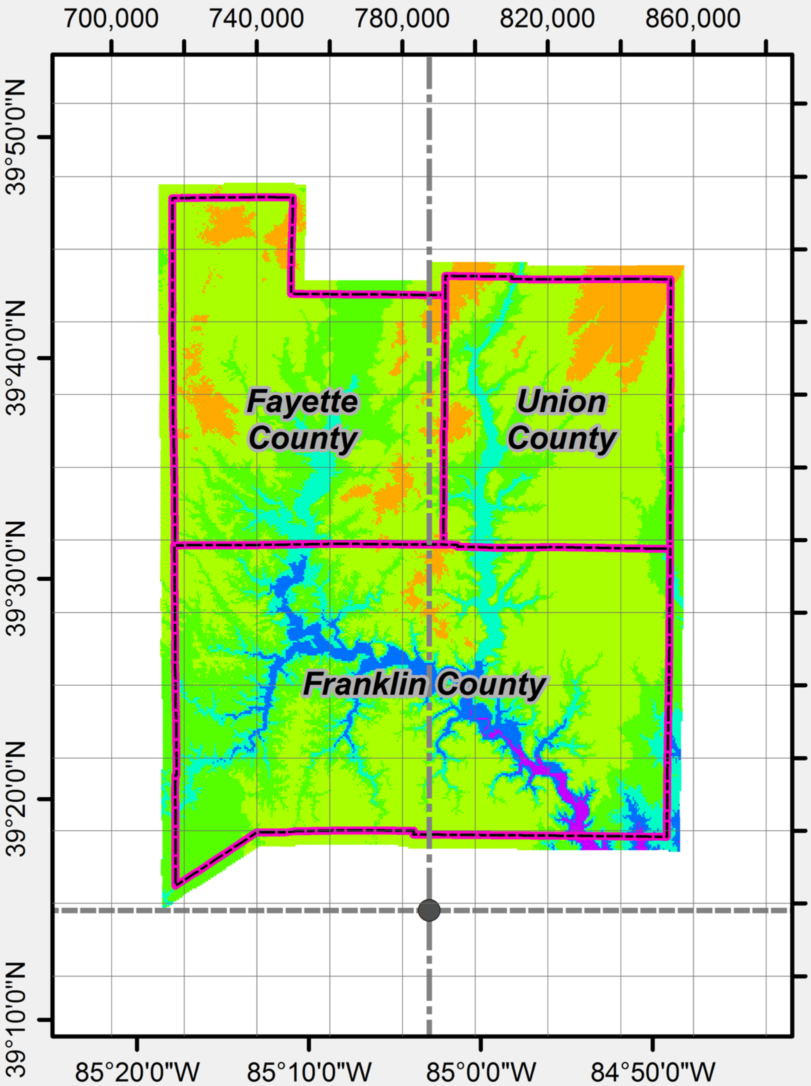
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# FAYETTE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°15'00"N |
| Central Meridian: | 85°03'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 038 |

*Note: Fayette, Franklin, and Union Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fayette County | 3 | 6 | 8 |
| Franklin County | 4 | 12 | 15 |
| Union County | 3 | 7 | 8 |

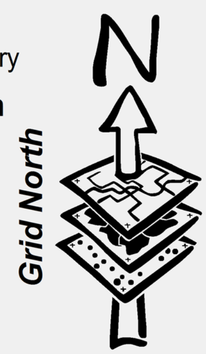
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

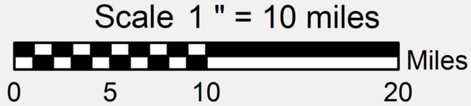
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

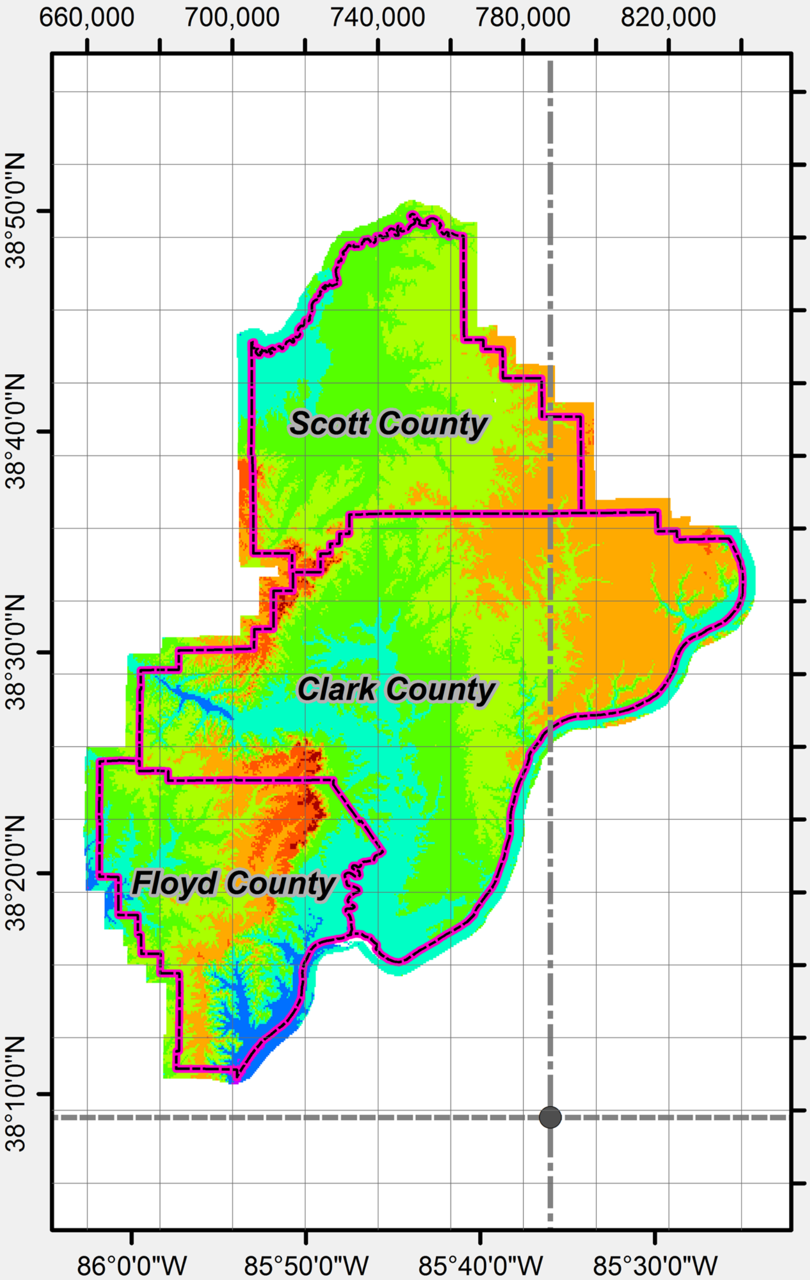
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# FLOYD COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°09'00"N |
| Central Meridian: | 85°36'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 021 |

*Note: Clark, Floyd, and Scott Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Clark County | 5 | 9 | 13 |
| Floyd County | 6 | 13 | 15 |
| Scott County | 4 | 9 | 13 |

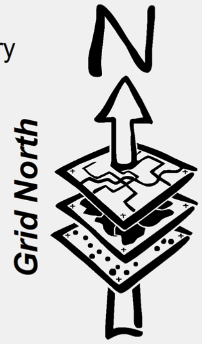
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

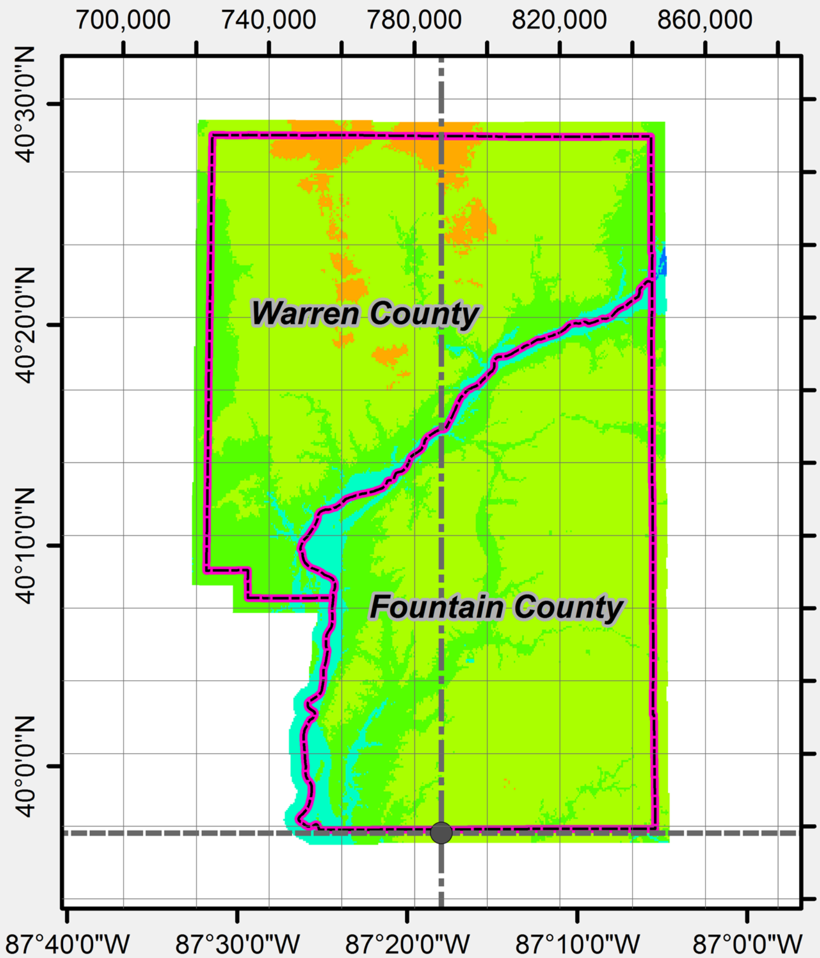
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# FOUNTAIN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°57'00"N
Central Meridian: 87°18'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 025

*Note: Fountain and Warren Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fountain County | 2 | 7 | 9 |
| Warren County | 3 | 7 | 8 |

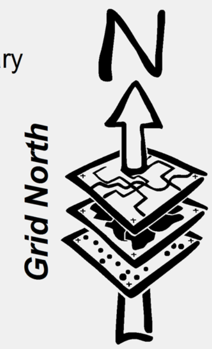
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

False Northing/Easting
Central Meridian
Origin Latitude
County Boundary

**Linear Distortion**

<-15 ppm
-15 to -10 ppm
-10 to -5 ppm
-5 to 0 ppm
0 to 5 ppm
5 to 10 ppm
10 to 15 ppm
>15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

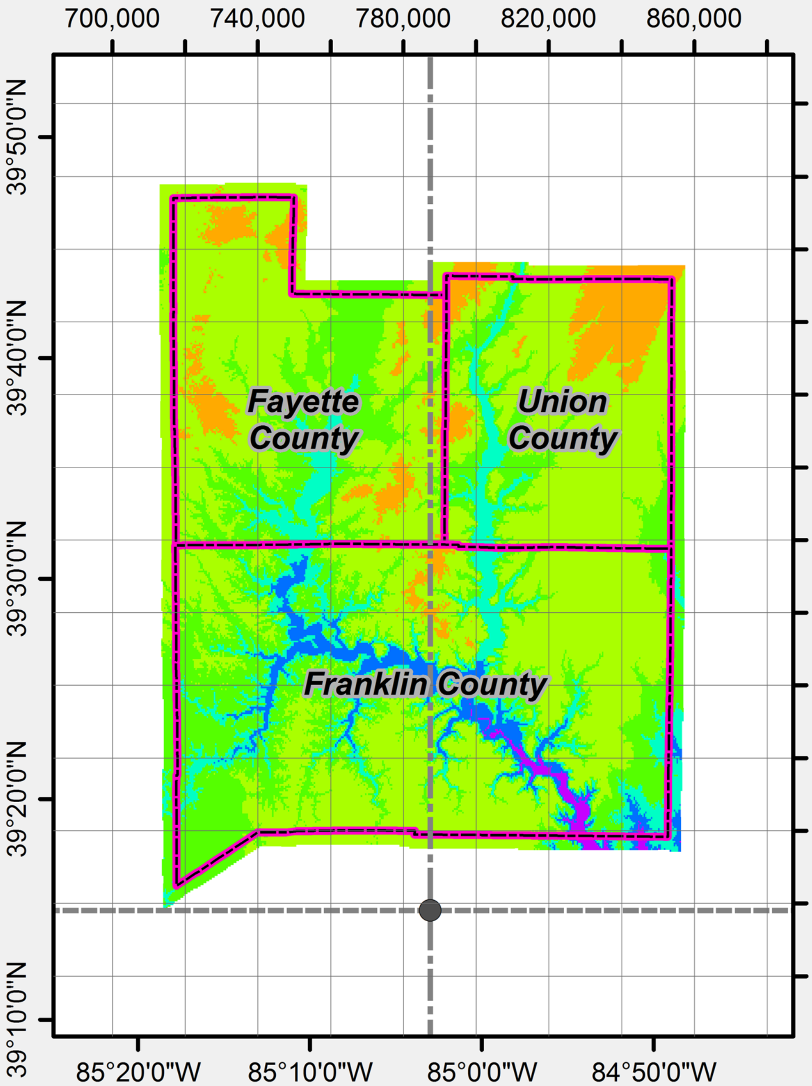
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# FRANKLIN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°15'00"N
Central Meridian: 85°03'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 038

*Note: Fayette, Franklin, and Union Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fayette County | 3 | 6 | 8 |
| Franklin County | 4 | 12 | 15 |
| Union County | 3 | 7 | 8 |

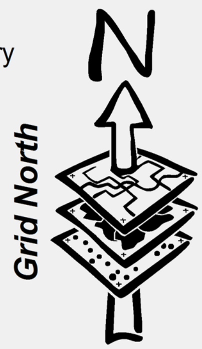
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

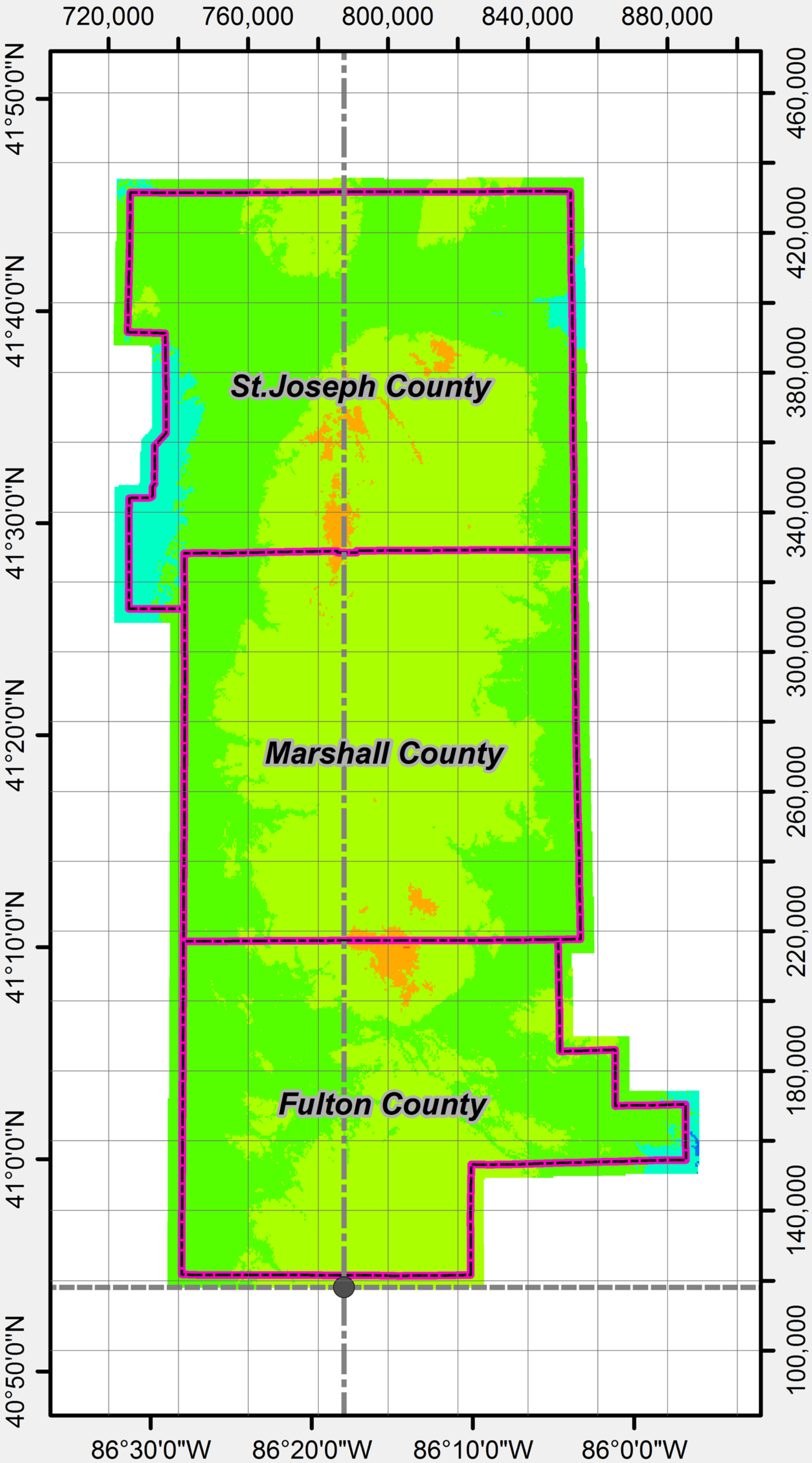
Scale 1 " = 10 miles

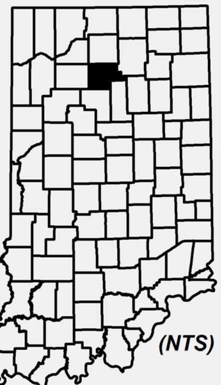
0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# FULTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°54'00"N |
| Central Meridian: | 86°18'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 031 |

*Note: Fulton, Marshall, and St.Joseph Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fulton County | 2 | 5 | 7 |
| Marshall County | 2 | 4 | 5 |
| St.Joseph County | 3 | 6 | 8 |

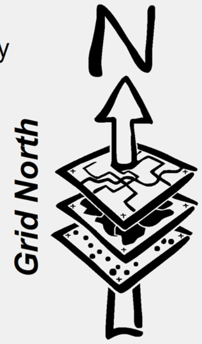
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

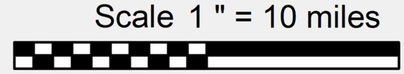
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

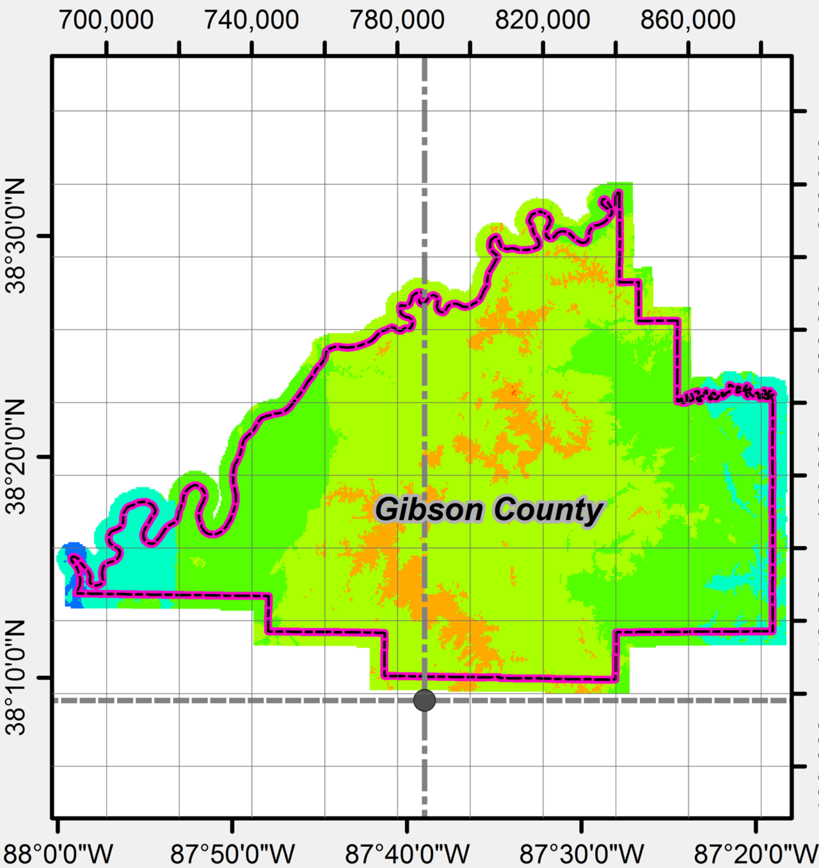
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# GIBSON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°09'00"N
Central Meridian: 87°39'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 013

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Gibson County | 3 | 7 | 9 |

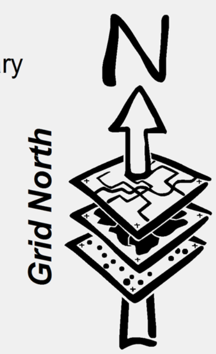
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

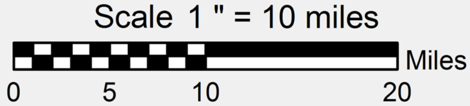
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

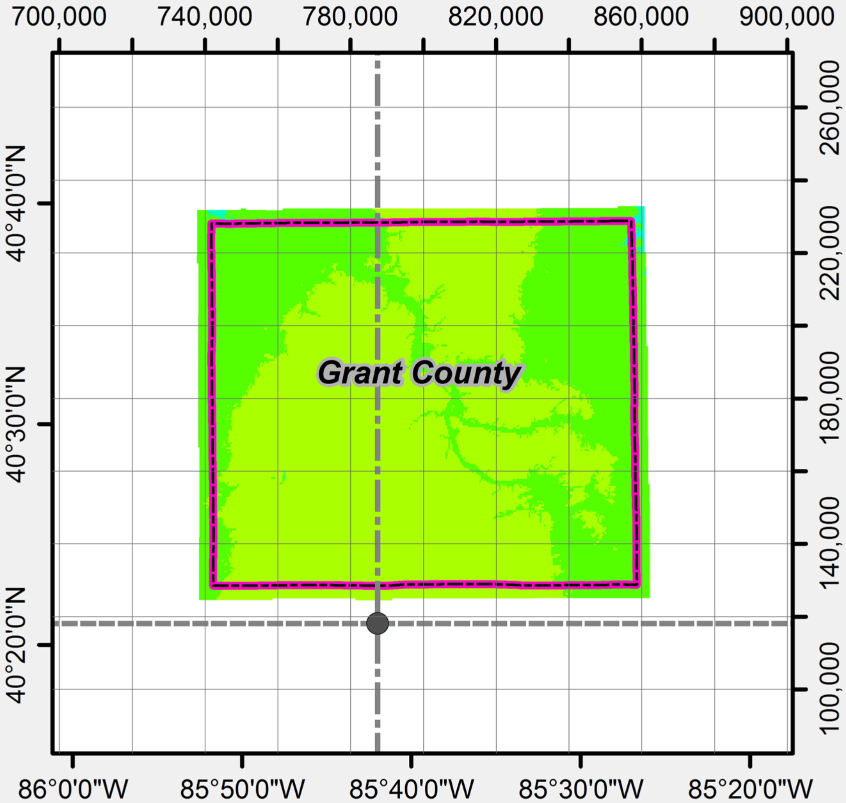
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# GRANT COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°21'00"N
Central Meridian: 85°42'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 034

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Grant County | 2 | 3 | 5 |

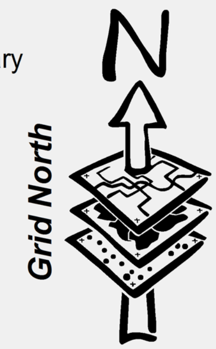
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

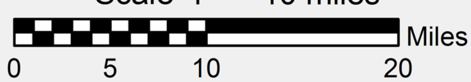
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

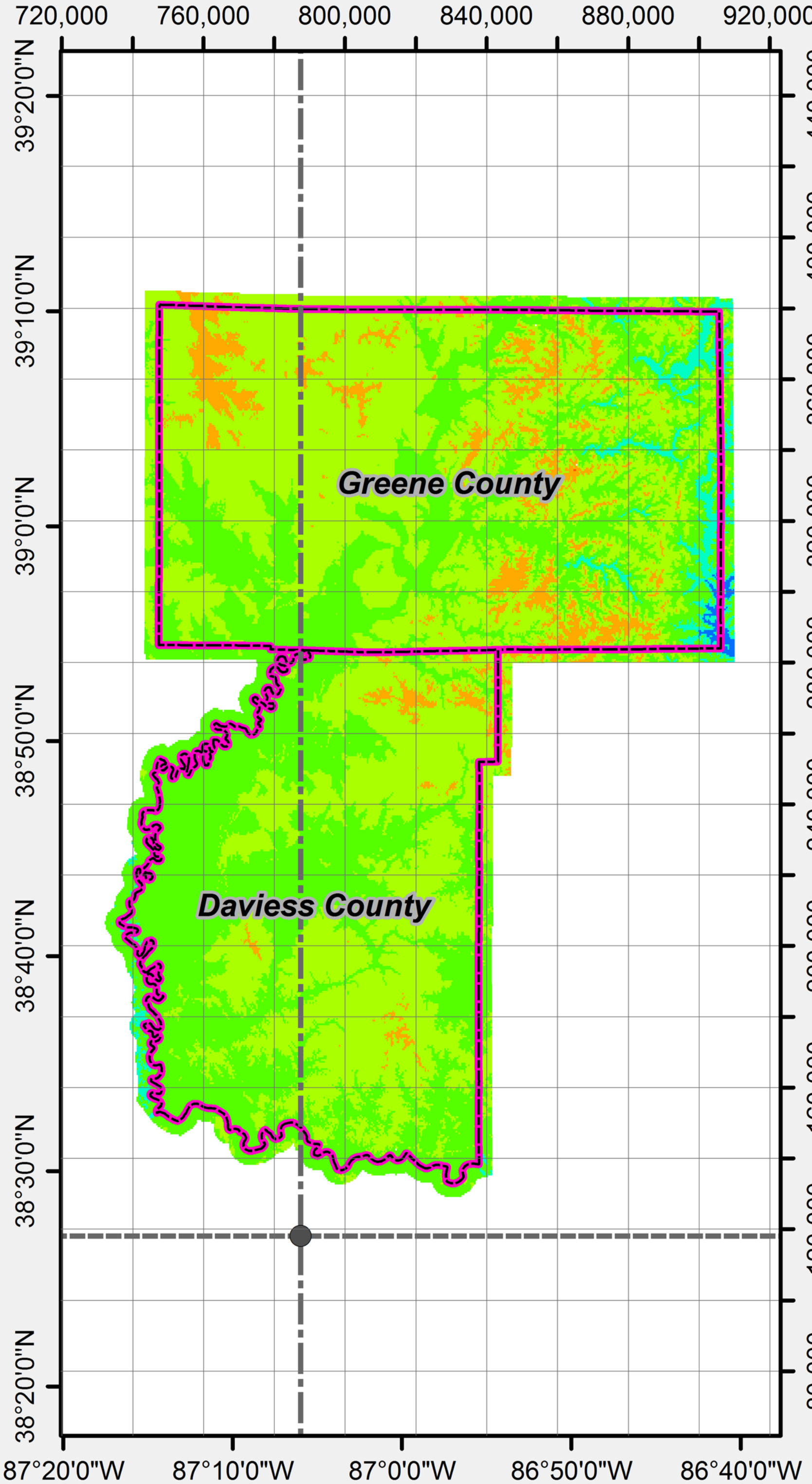
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# GREENE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°27'00"N
Central Meridian: 87°06'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 018

*Note: Daviess and Greene Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Daviess County | 2 | 5 | 6 |
| Greene County | 2 | 6 | 9 |

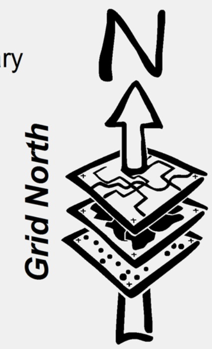
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

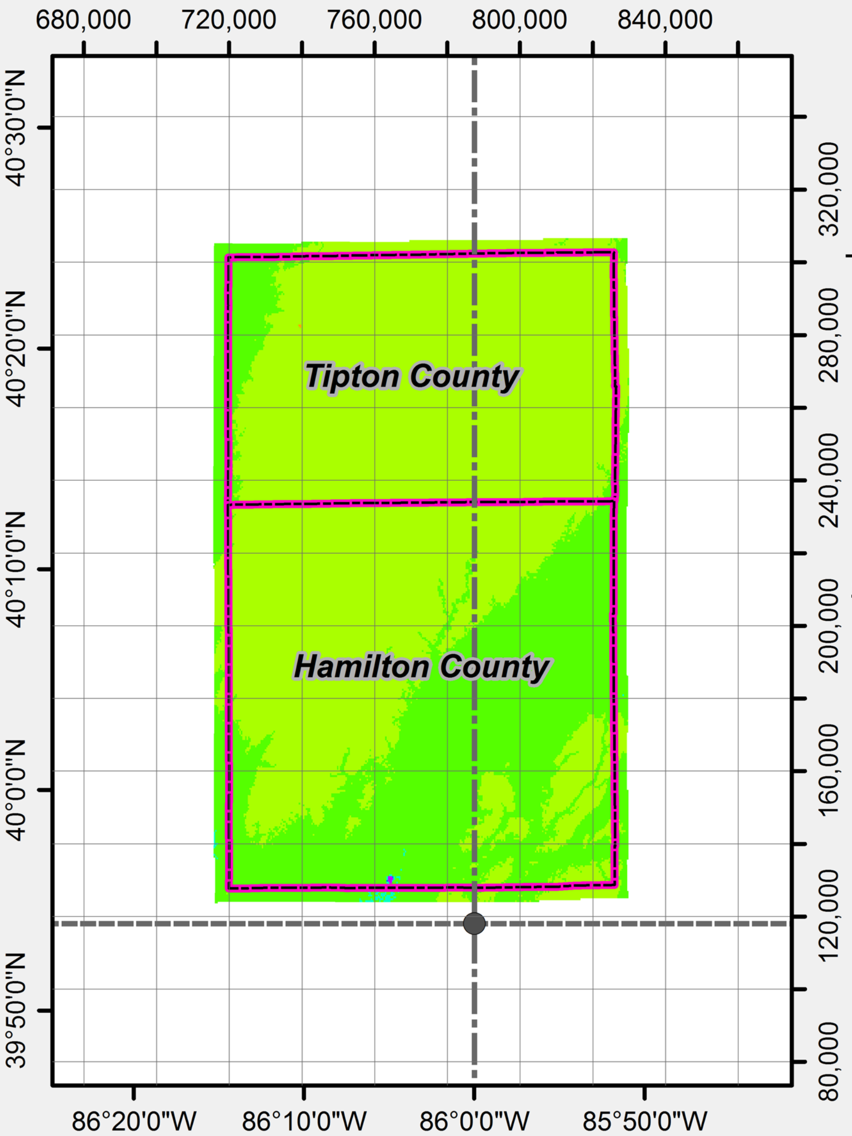
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HAMILTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°54'00"N |
| Central Meridian: | 86°00'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 034 |

*Note: Hamilton and Tipton Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Hamilton County | 1 | 3 | 4 |
| Tipton County | 1 | 2 | 3 |

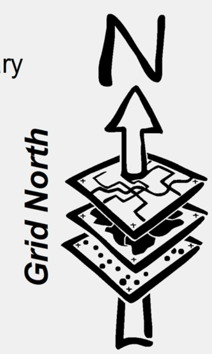
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

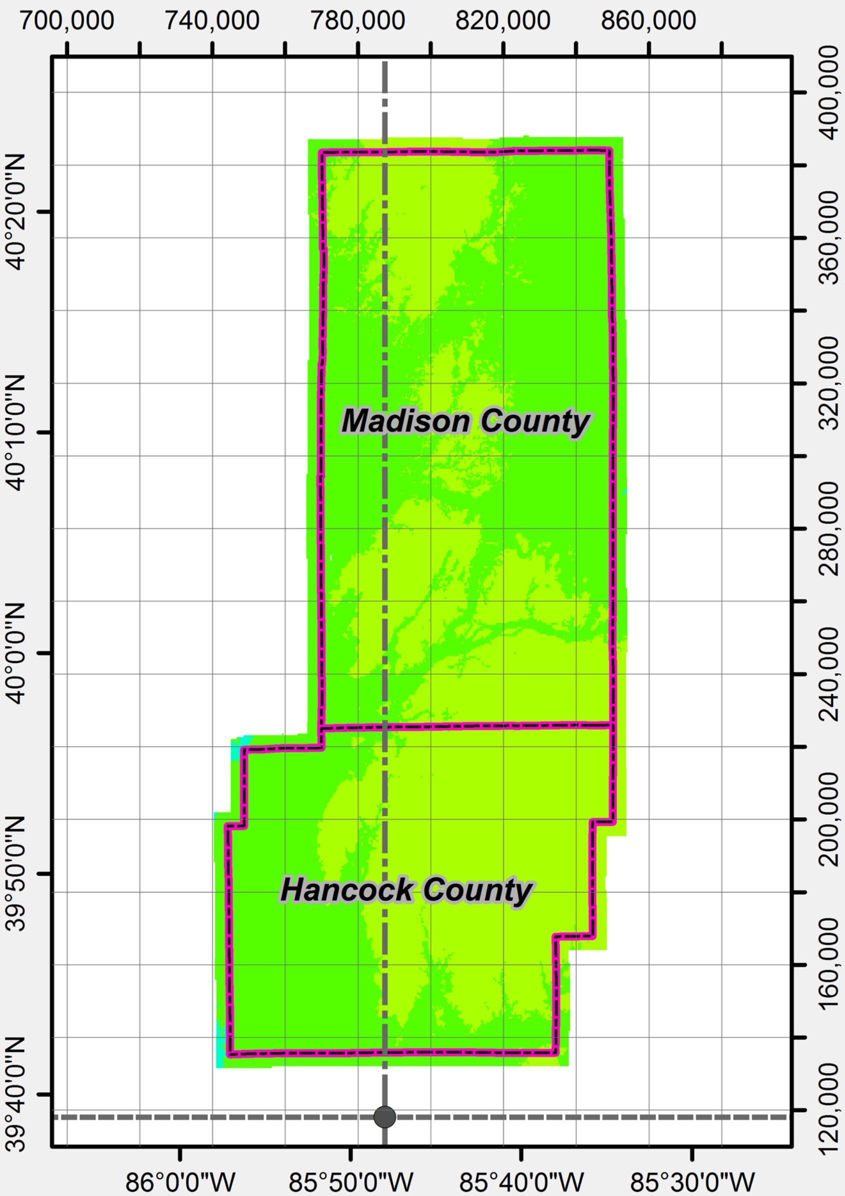
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HANCOCK COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°39'00"N |
| Central Meridian: | 85°48'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 036 |

*Note: Hancock and Madison Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Hancock County | 2 | 3 | 5 |
| Madison County | 1 | 3 | 4 |

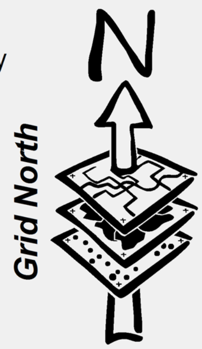
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

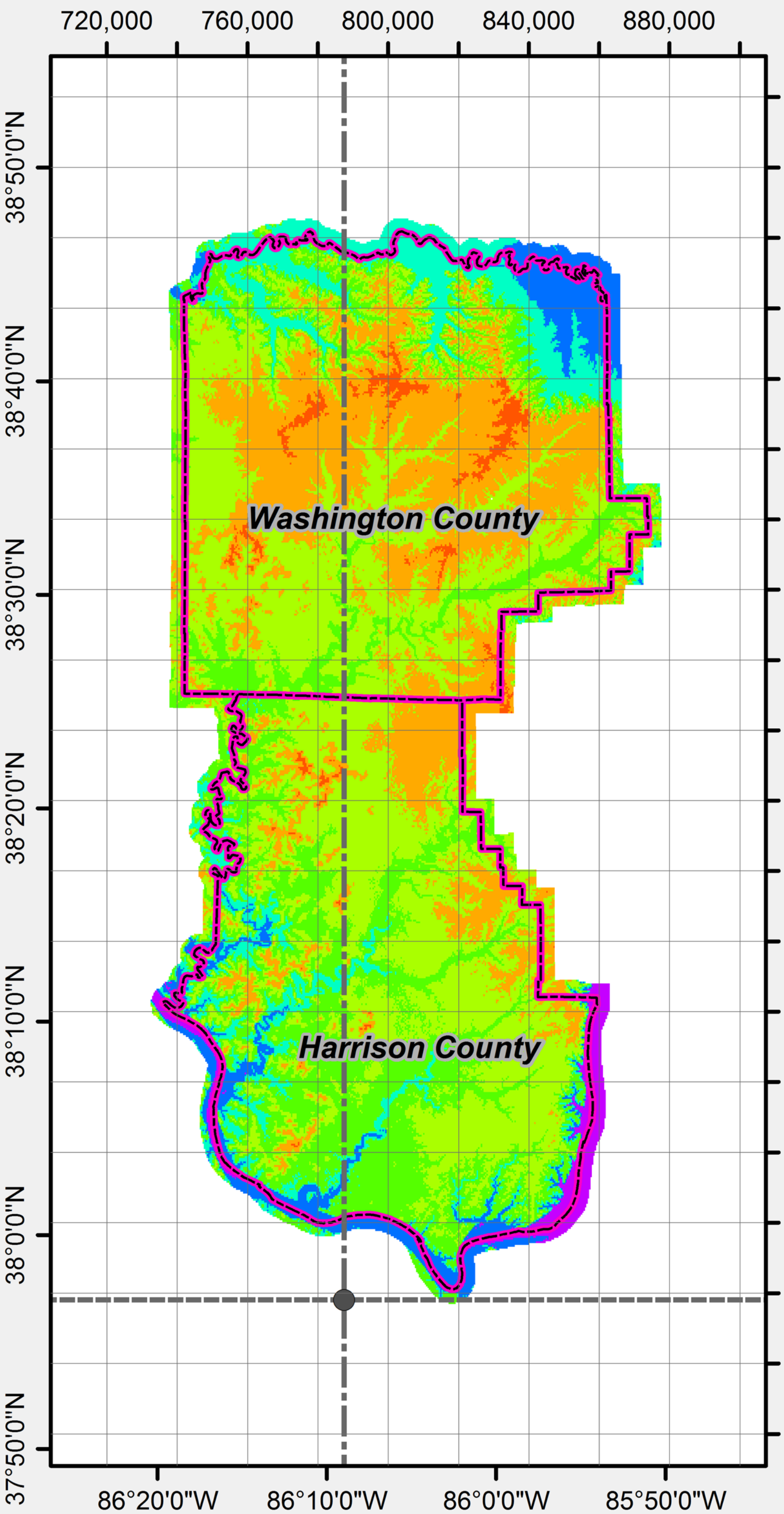
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HARRISON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 37°57'00"N
Central Meridian: 86°09'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 027

*Note: Harrison and Washington Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Harrison County | 4 | 15 | 18 |
| Washington County | 5 | 11 | 13 |

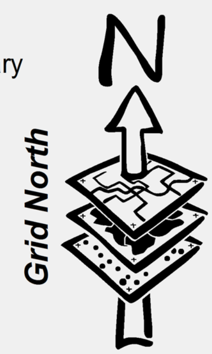
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

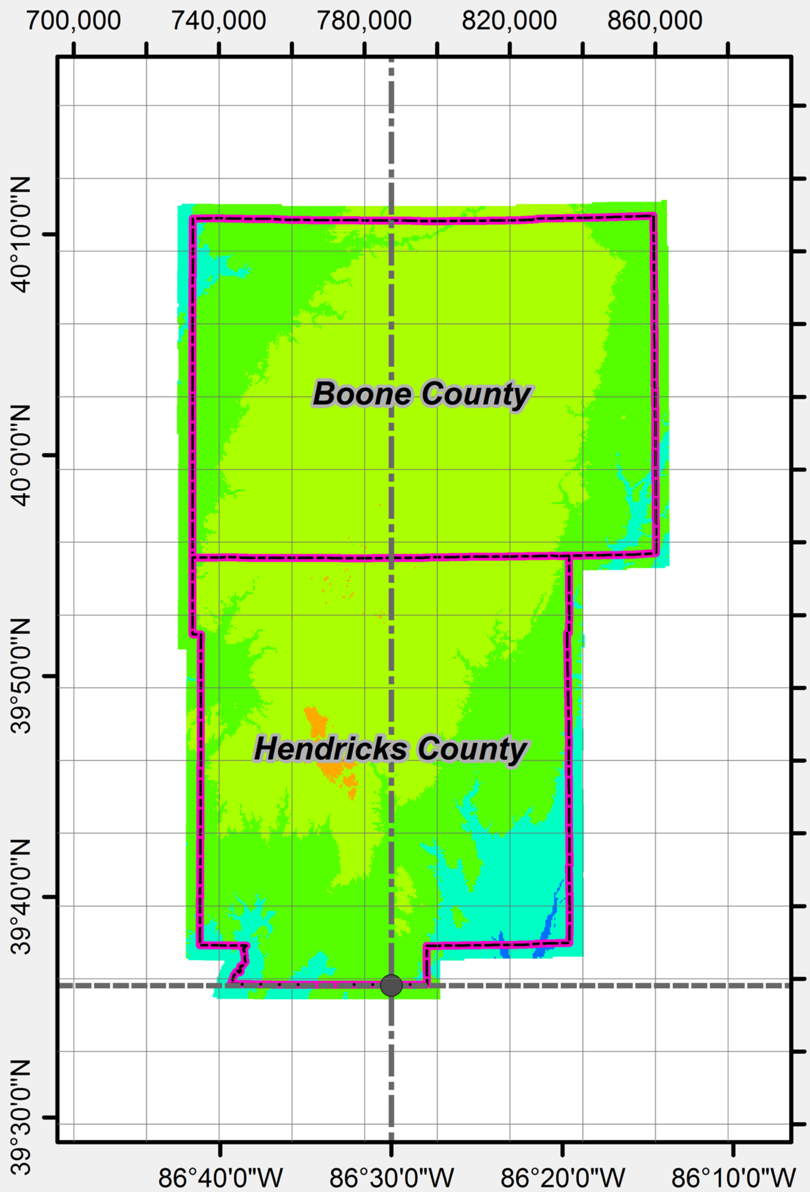
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HENDRICKS COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°36'00"N |
| Central Meridian: | 86°30'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 036 |

*Note: Boone and Hendricks Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Boone County | 2 | 5 | 6 |
| Hendricks County | 3 | 8 | 9 |

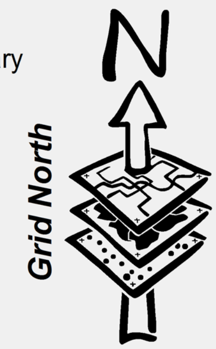
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

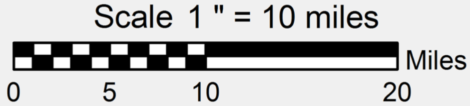
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

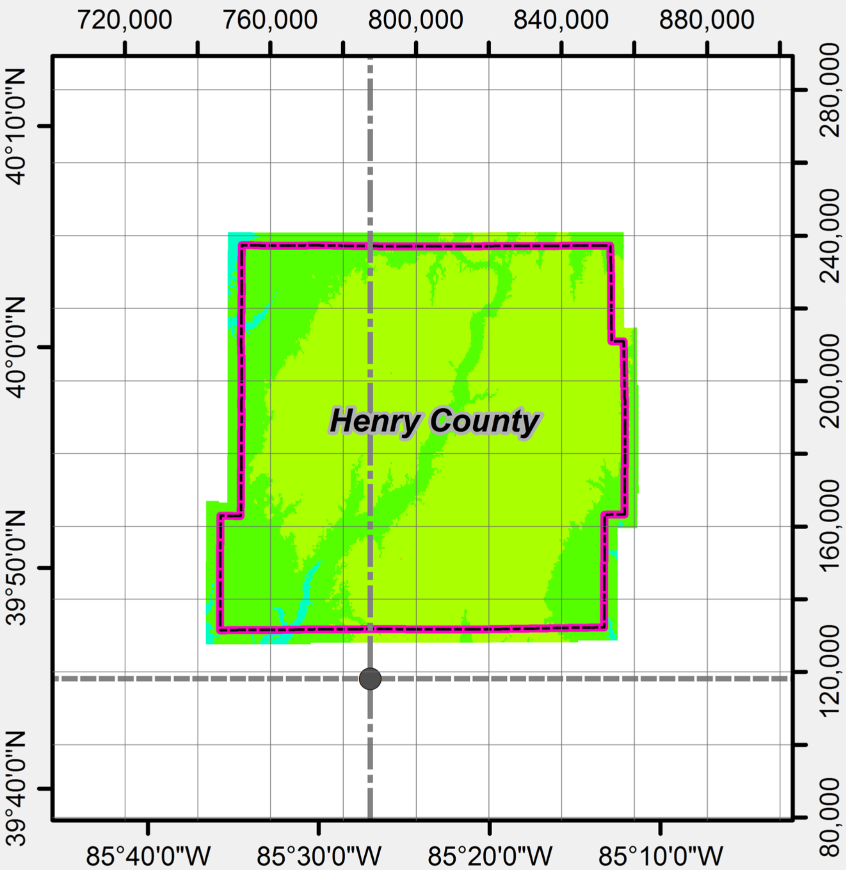
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HENRY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°45'00"N |
| Central Meridian: | 85°27'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 043 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Henry County | 2 | 4 | 5 |

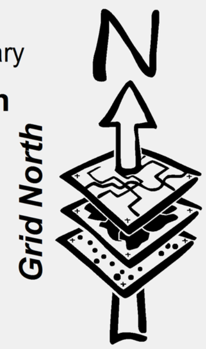
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

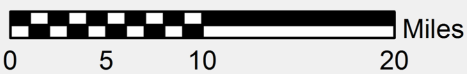
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

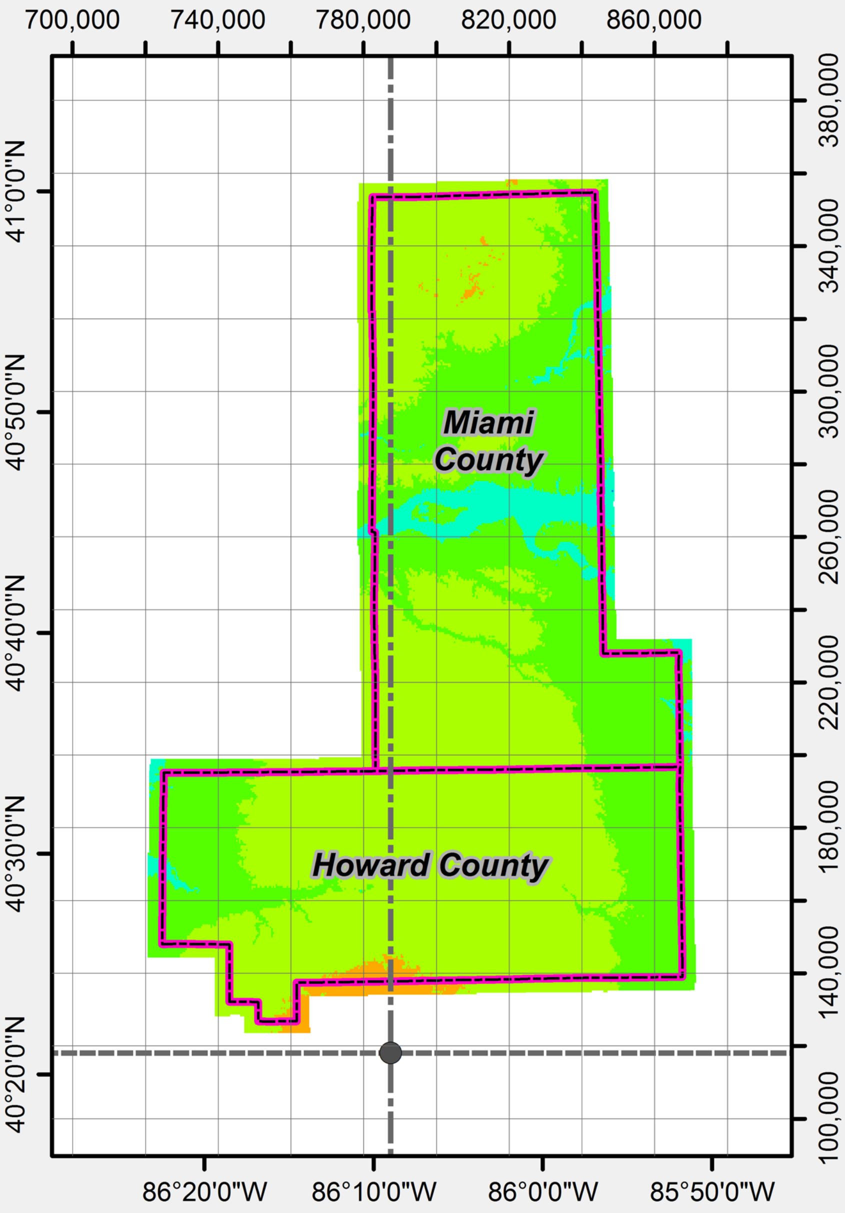
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HOWARD COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°21'00"N
Central Meridian: 86°09'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 031

*Note: Howard and Miami Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Howard County | 2 | 5 | 6 |
| Miami County | 2 | 6 | 8 |

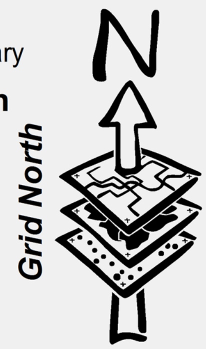
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

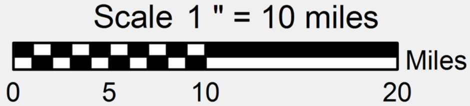
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

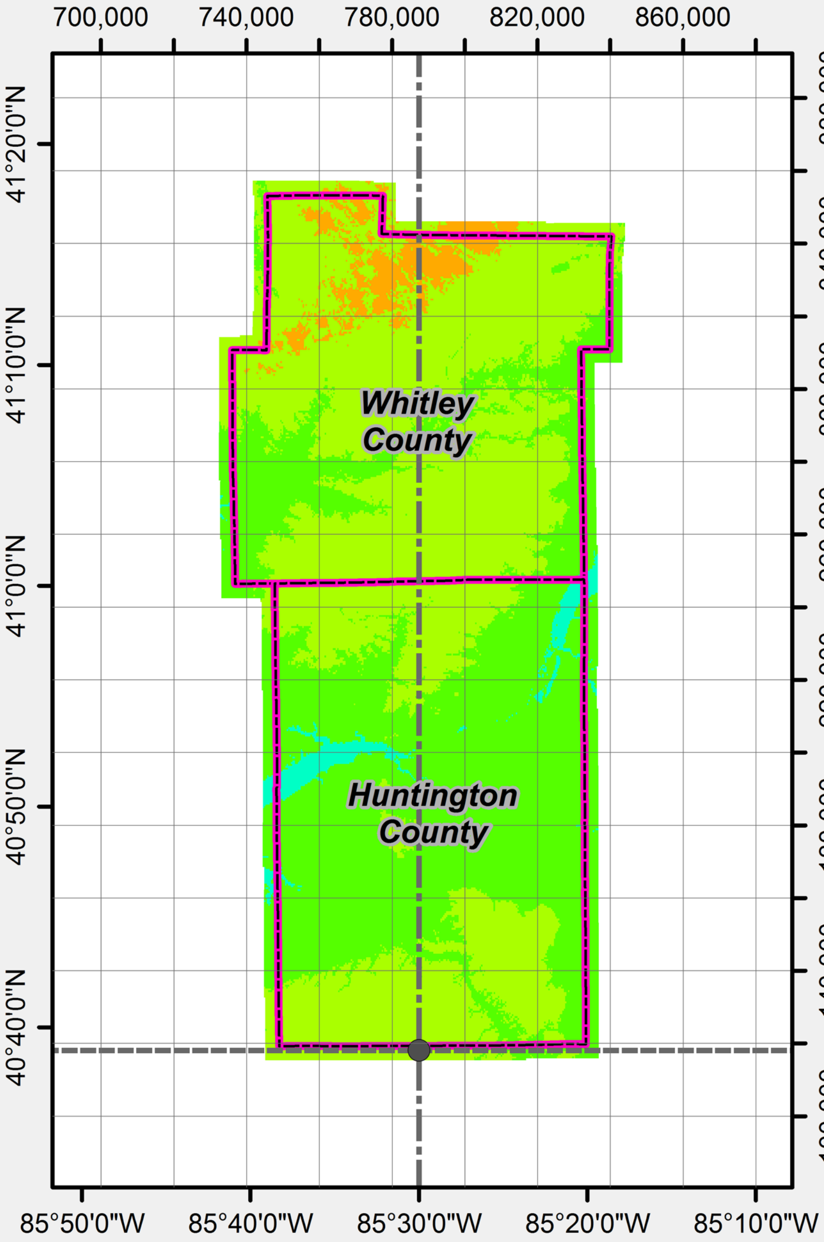
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# HUNTINGTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°39'00"N
Central Meridian: 85°30'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 034

*Note: Huntington and Whitley Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Huntington County | 2 | 5 | 6 |
| Whitley County | 2 | 5 | 7 |

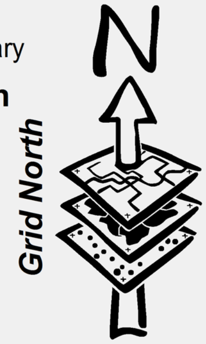
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

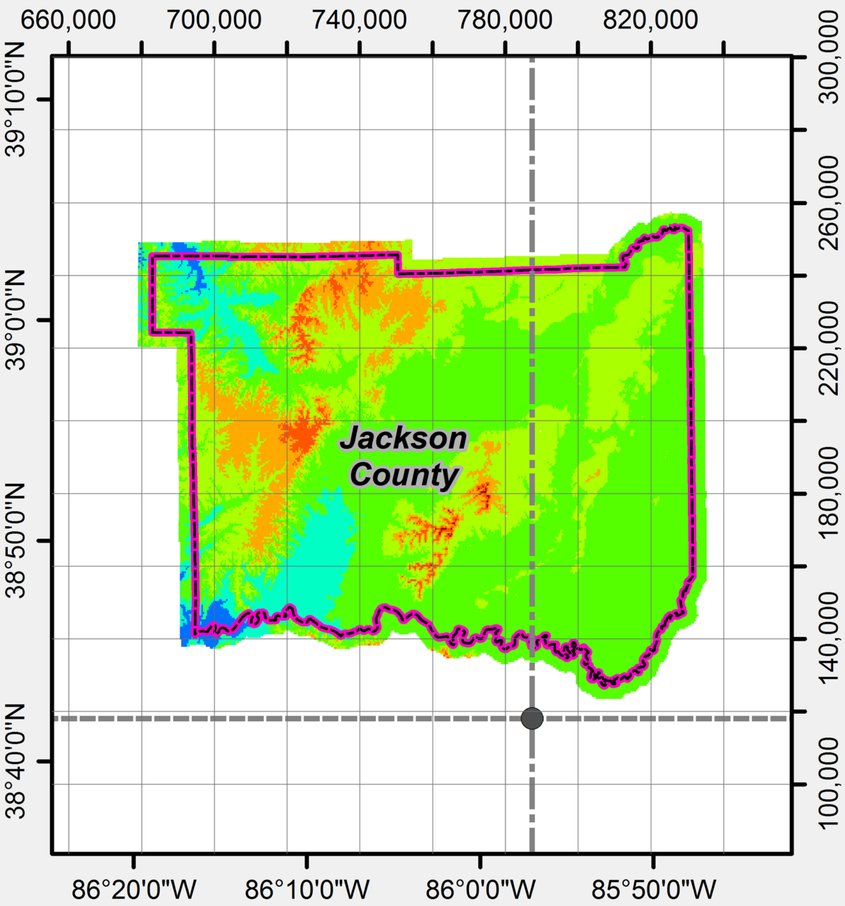
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# JACKSON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°42'00"N |
| Central Meridian: | 85°57'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 022 |

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Jackson County | 3 | 9 | 12 |

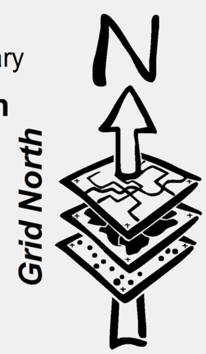
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm



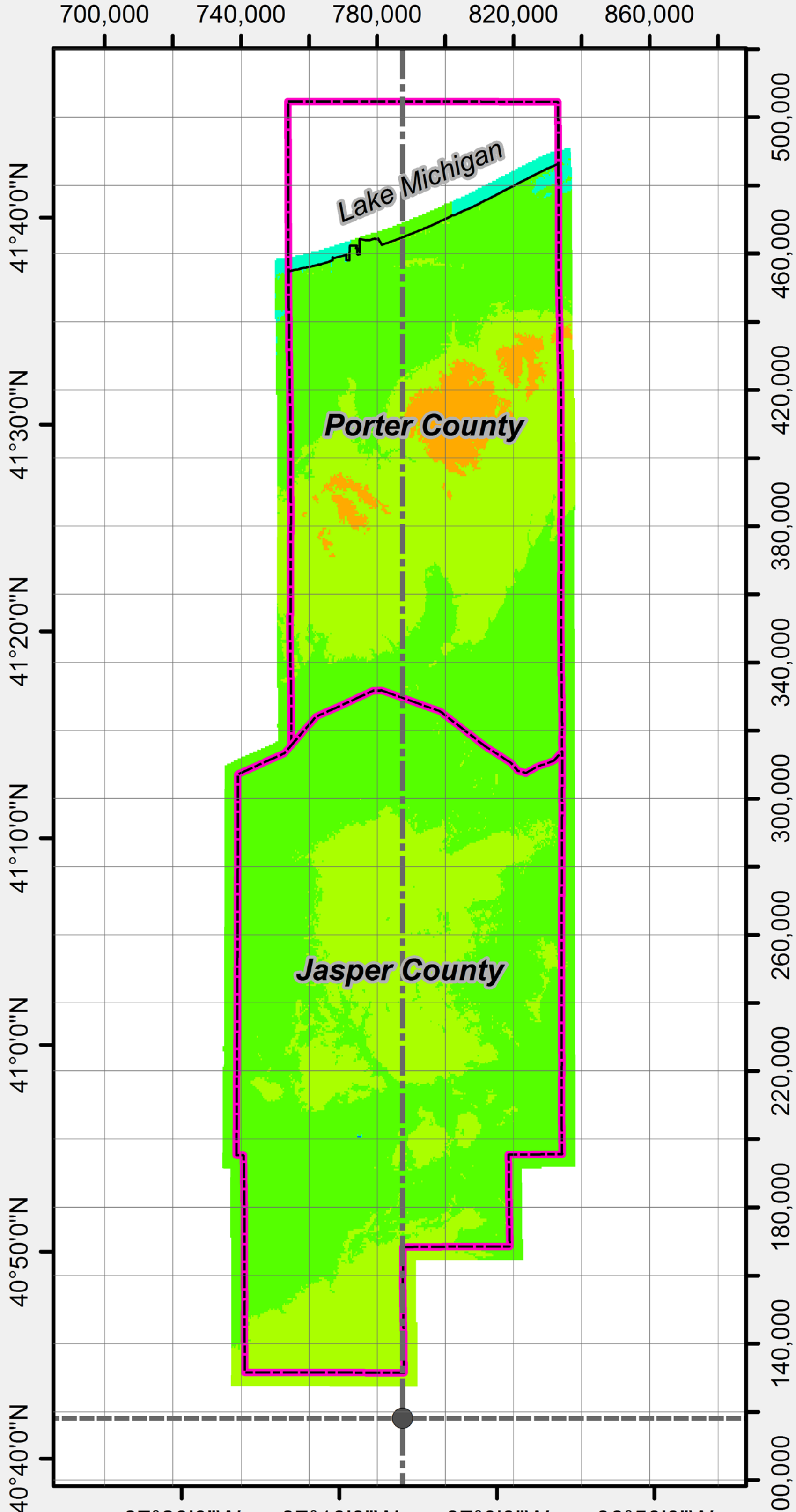

*Note: Map grid is shown in units of U.S. Survey feet.*

Scale 1 " = 10 miles


Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# JASPER COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°42'00"N |
| Central Meridian: | 87°06'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 027 |

*Note: Jasper and Porter Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Jasper County | 1 | 3 | 4 |
| Porter County | 2 | 6 | 7 |

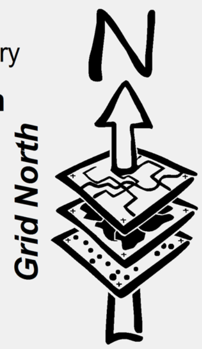
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

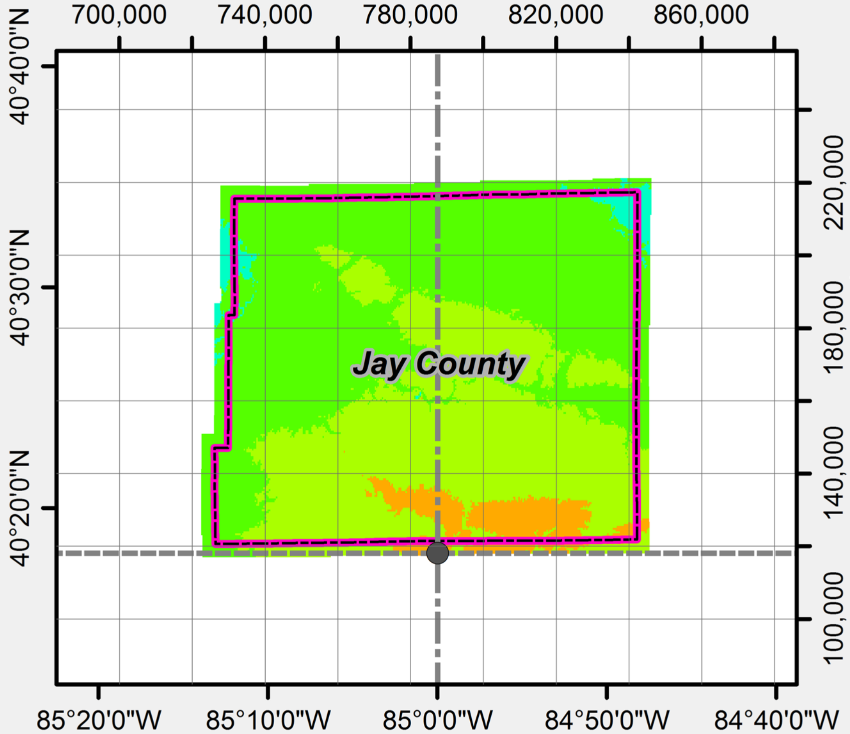
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# JAY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°18'00"N |
| Central Meridian: | 85°00'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 038 |

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Jay County | 2 | 6 | 6 |

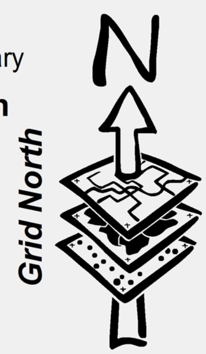
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

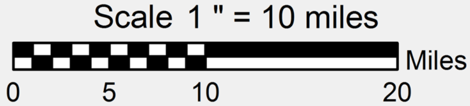
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

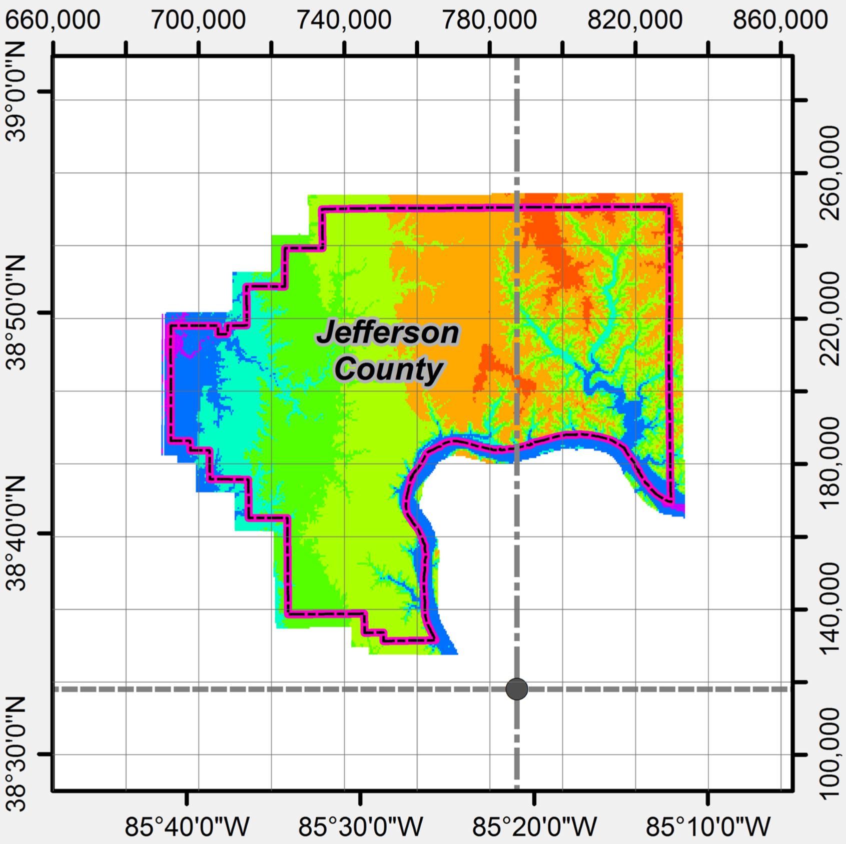
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# JEFFERSON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°33'00"N |
| Central Meridian: | 85°21'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 028 |

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Jefferson County | 6 | 13 | 15 |

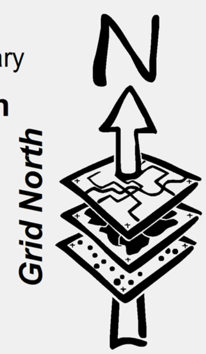
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm



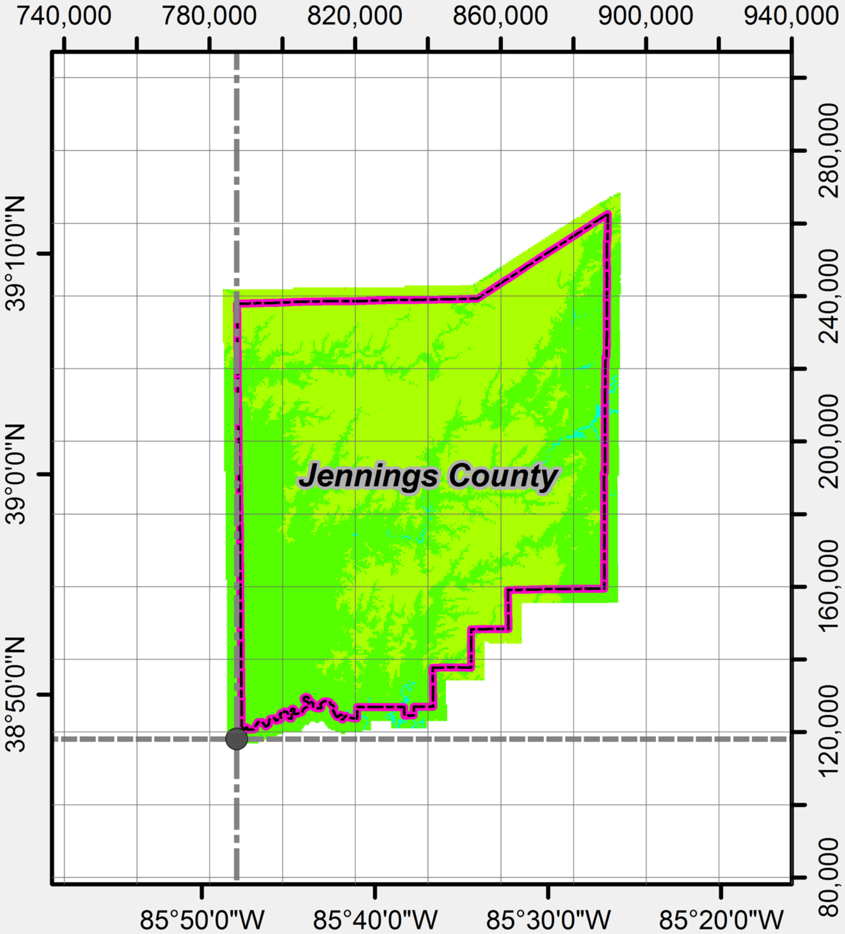

*Note: Map grid is shown in units of U.S. Survey feet.*

Scale 1 " = 10 miles


Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# JENNINGS COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°48'00"N |
| Central Meridian: | 85°48'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 025 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Jennings County | 2 | 4 | 5 |

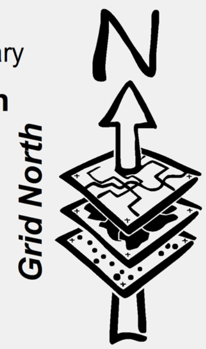
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

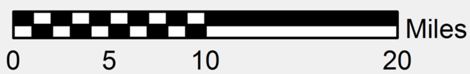
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

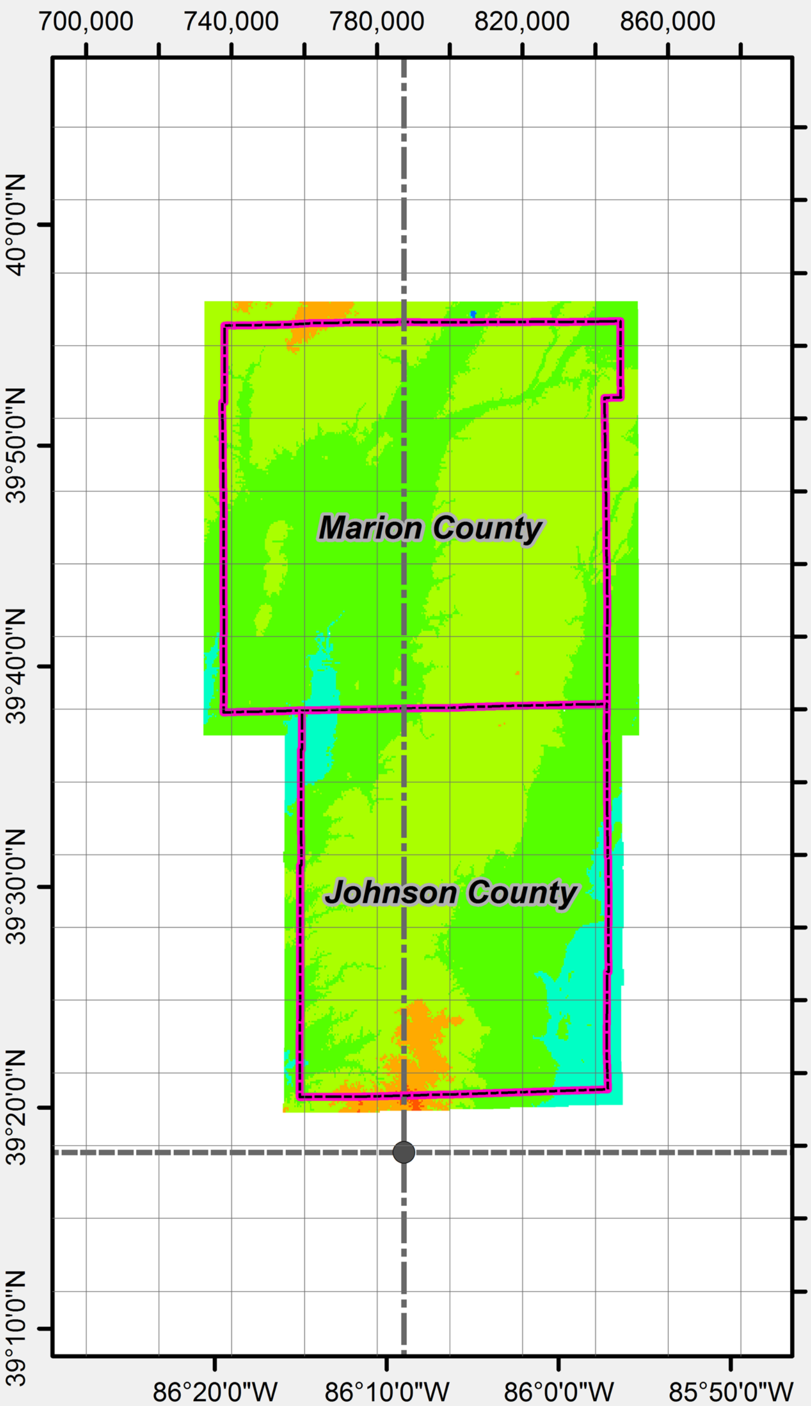
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# JOHNSON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°18'00"N |
| Central Meridian: | 86°09'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 031 |

*Note: Johnson and Marion Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Johnson County | 3 | 7 | 8 |
| Marion County | 3 | 6 | 8 |

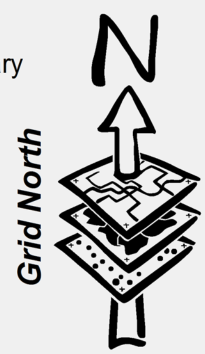
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

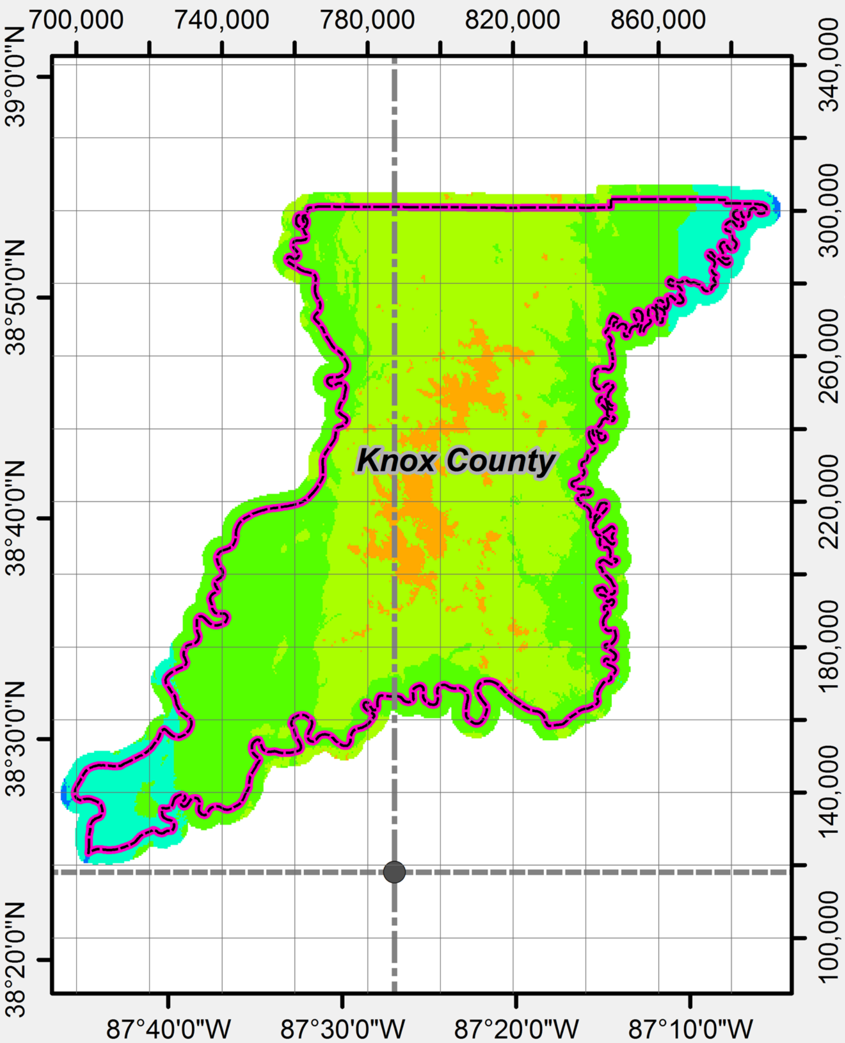
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# KNOX COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°24'00"N
Central Meridian: 87°27'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 015

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Knox County | 3 | 7 | 9 |

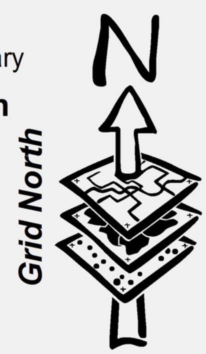
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

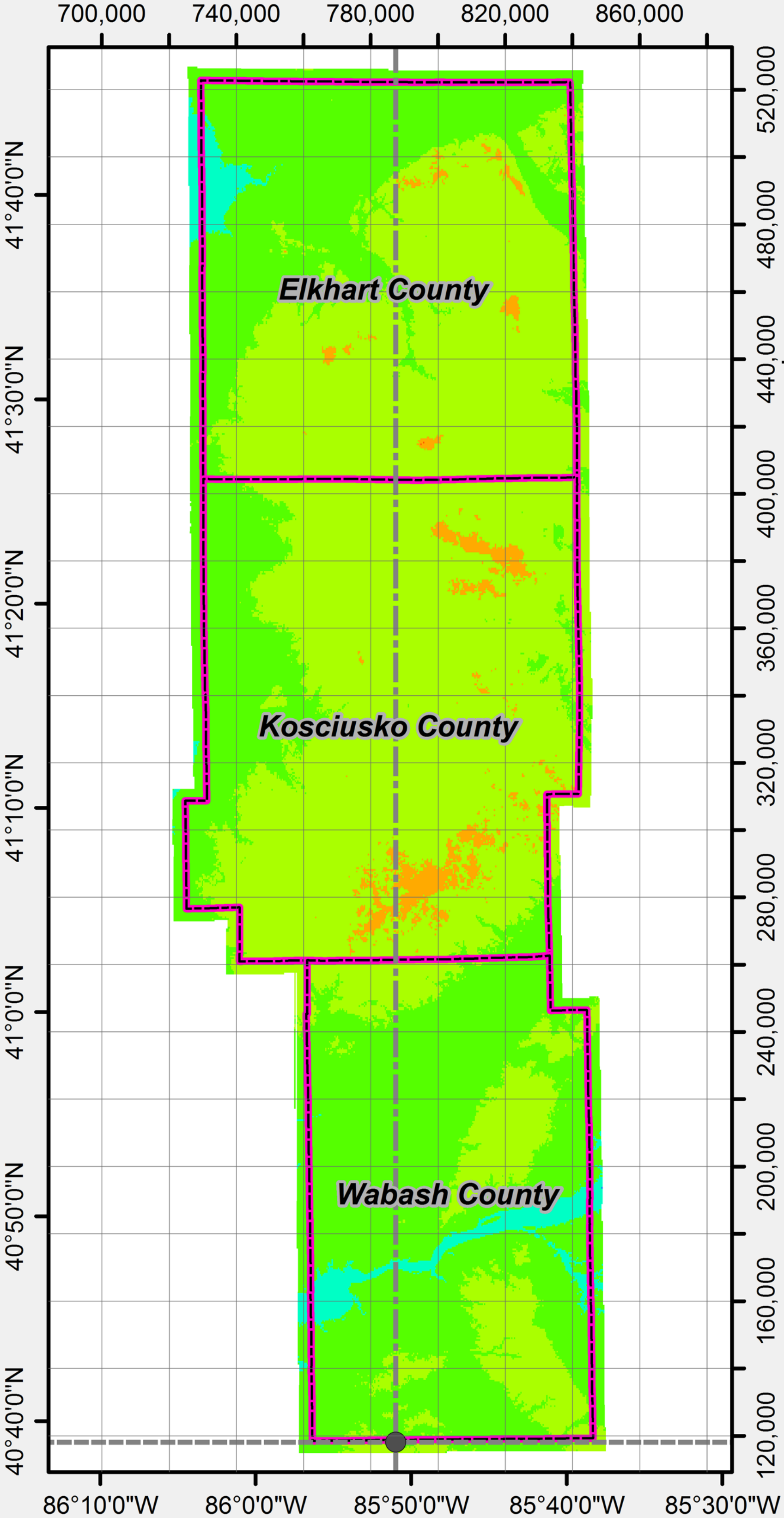
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# KOSCIUSKO COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°39'00"N |
| Central Meridian: | 85°51'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 033 |

*Note: Elkhart, Kosciusko, and Wabash Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Elkhart County | 2 | 5 | 6 |
| Koscisusko County | 2 | 5 | 6 |
| Wabash County | 2 | 5 | 8 |

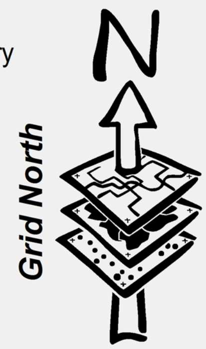
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

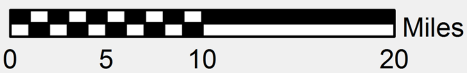
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

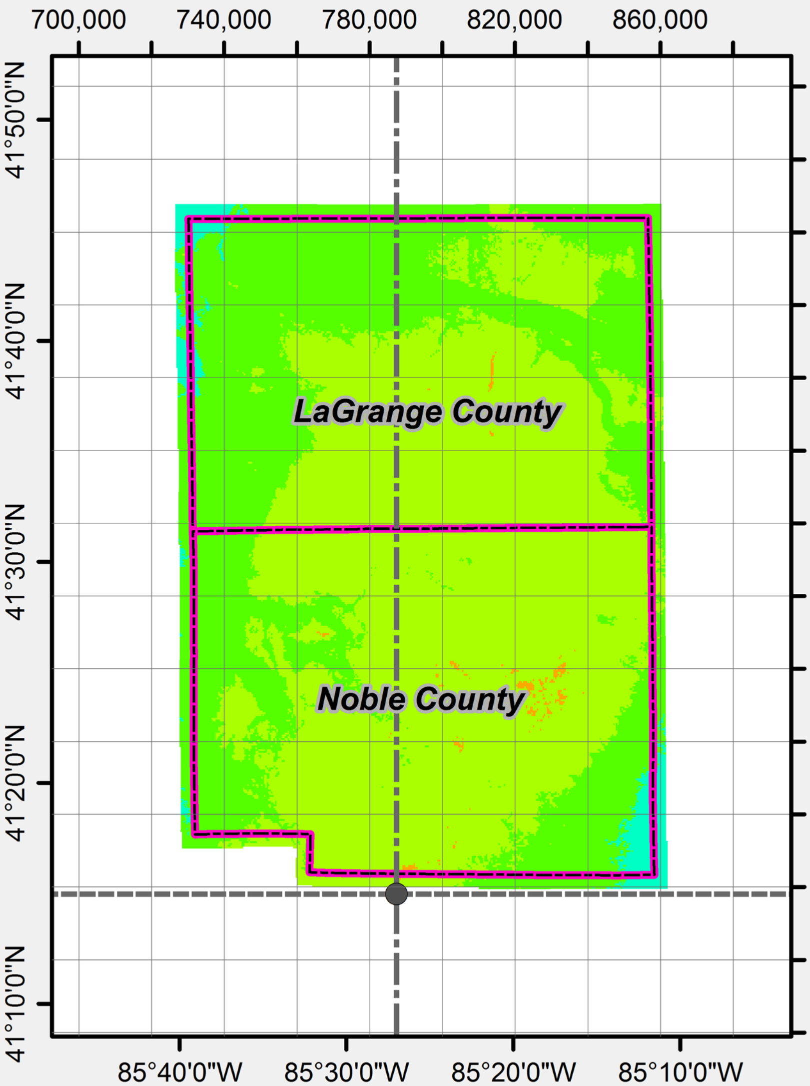
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# LAGRANGE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 41°15'00"N |
| Central Meridian: | 85°27'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 037 |

*Note: LaGrange and Noble Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| LaGrange County | 2 | 4 | 6 |
| Noble County | 2 | 5 | 7 |

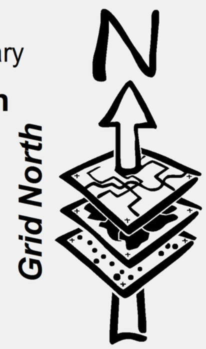
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

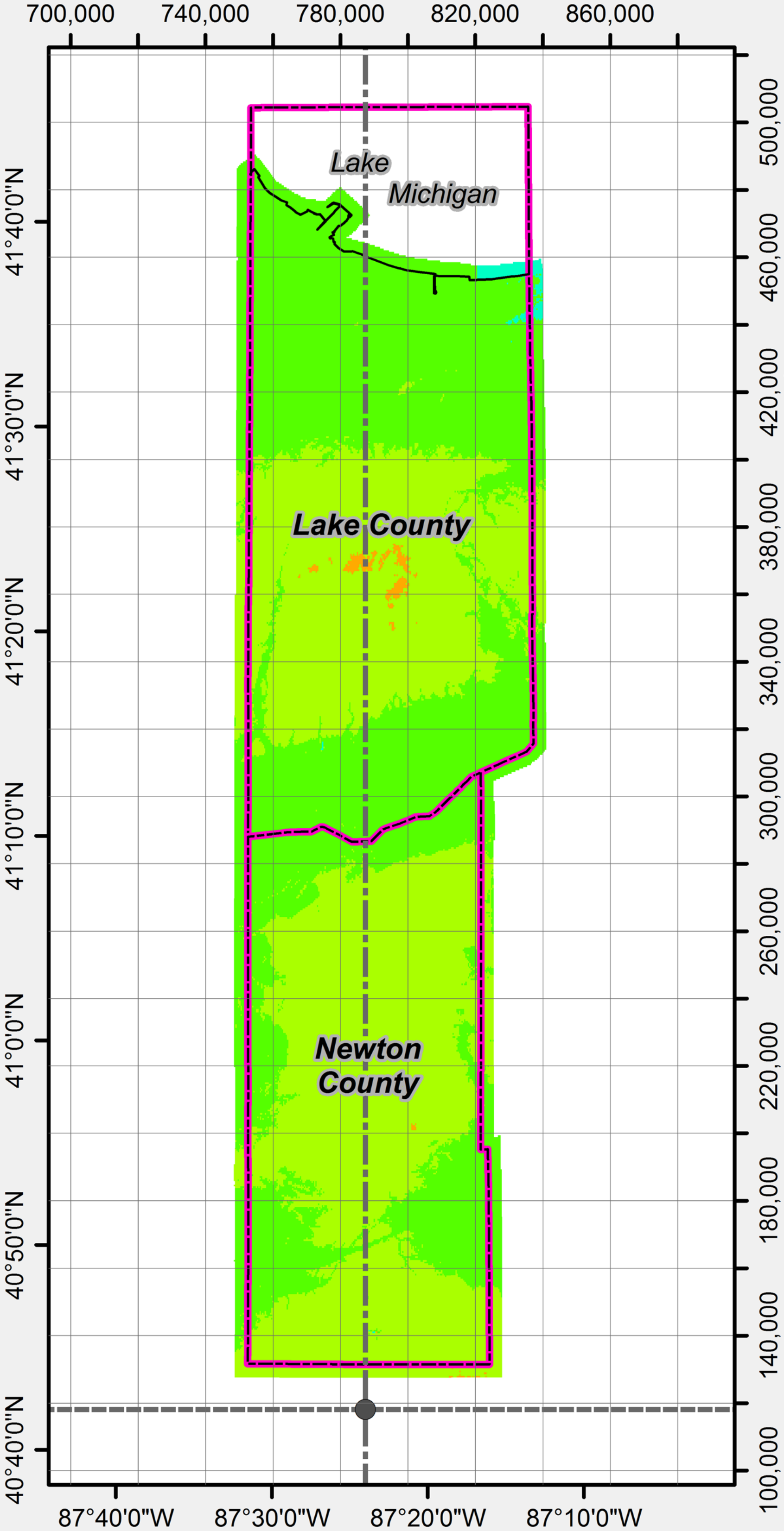
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# LAKE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°42'00"N
Central Meridian: 87°24'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 026

*Note: Lake and Newton Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Lake County | 2 | 4 | 5 |
| Newton County | 1 | 3 | 4 |

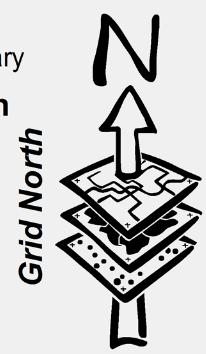
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

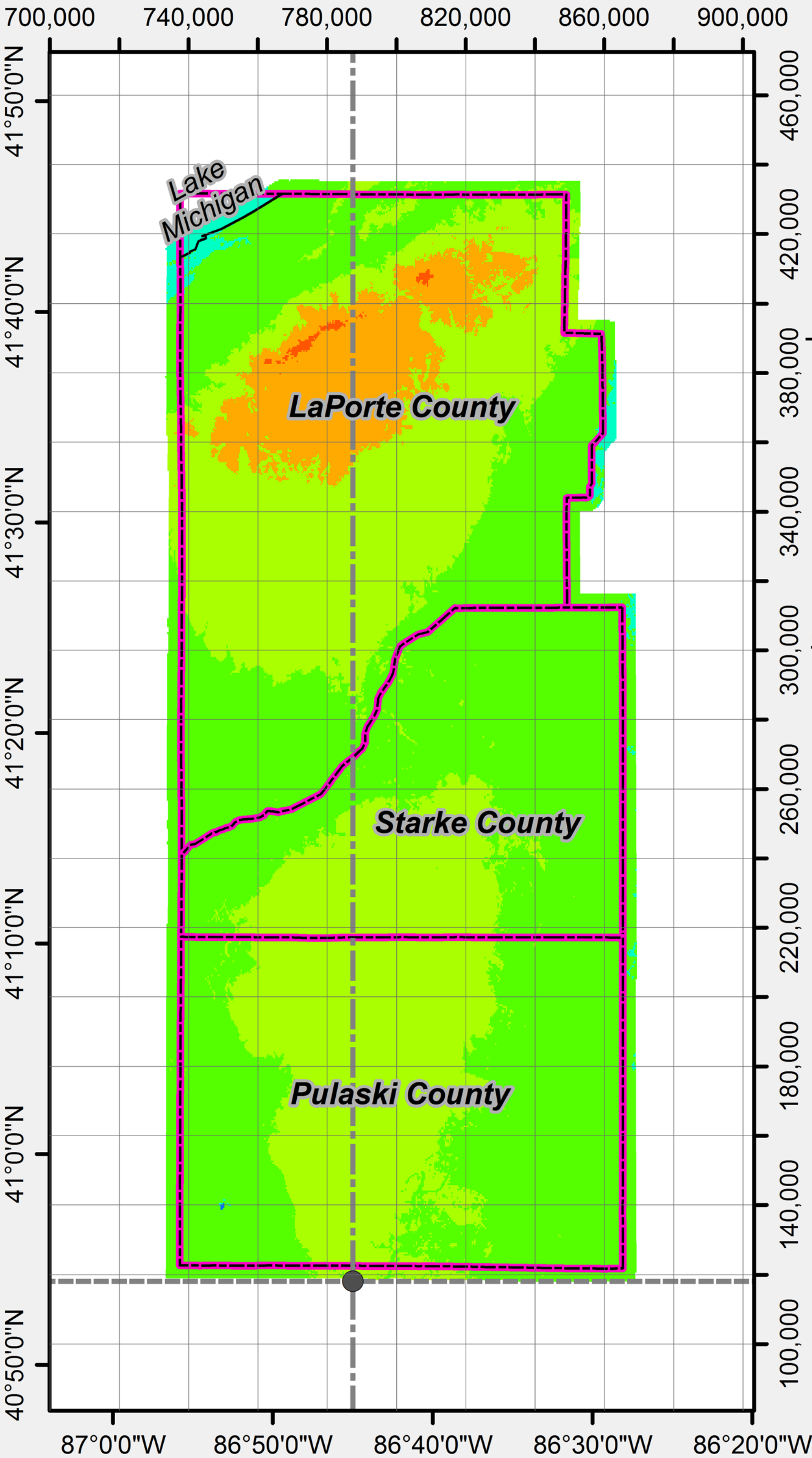
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# LAPORTE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°54'00"N
Central Meridian: 86°45'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 027

*Note: LaPorte, Pulaski, and Starke Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| LaPorte County | 3 | 7 | 9 |
| Pulaski County | 1 | 3 | 4 |
| Starke County | 2 | 4 | 5 |

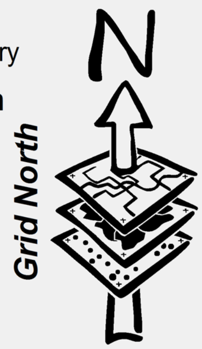
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

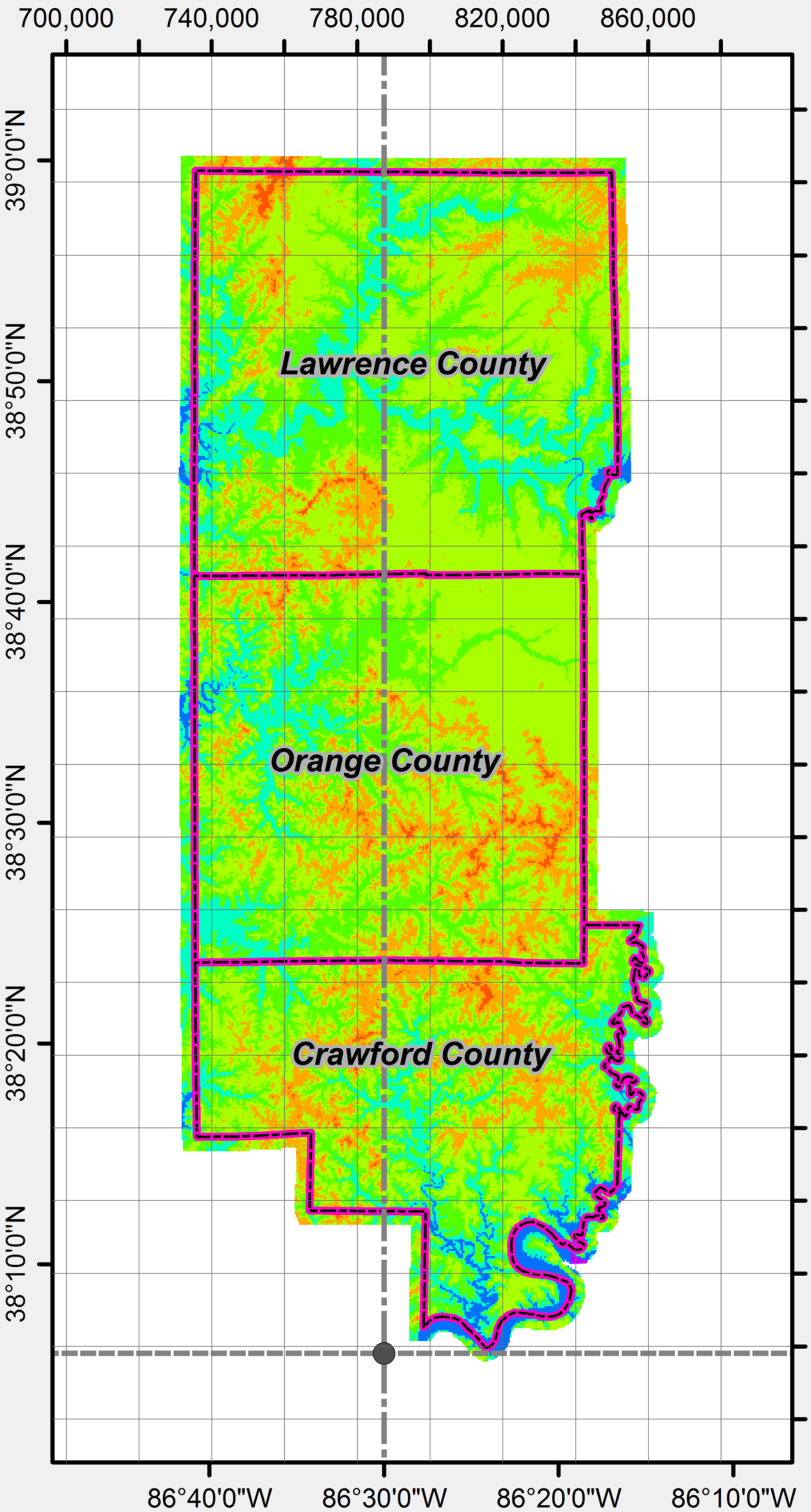
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# LAWRENCE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°06'00"N |
| Central Meridian: | 86°30'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 025 |

*Note: Crawford, Lawrence, and Orange Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Crawford County | 4 | 11 | 14 |
| Lawrence County | 4 | 8 | 11 |
| Orange County | 4 | 8 | 10 |

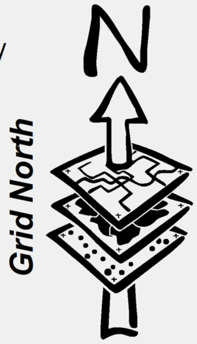
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

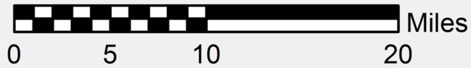
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

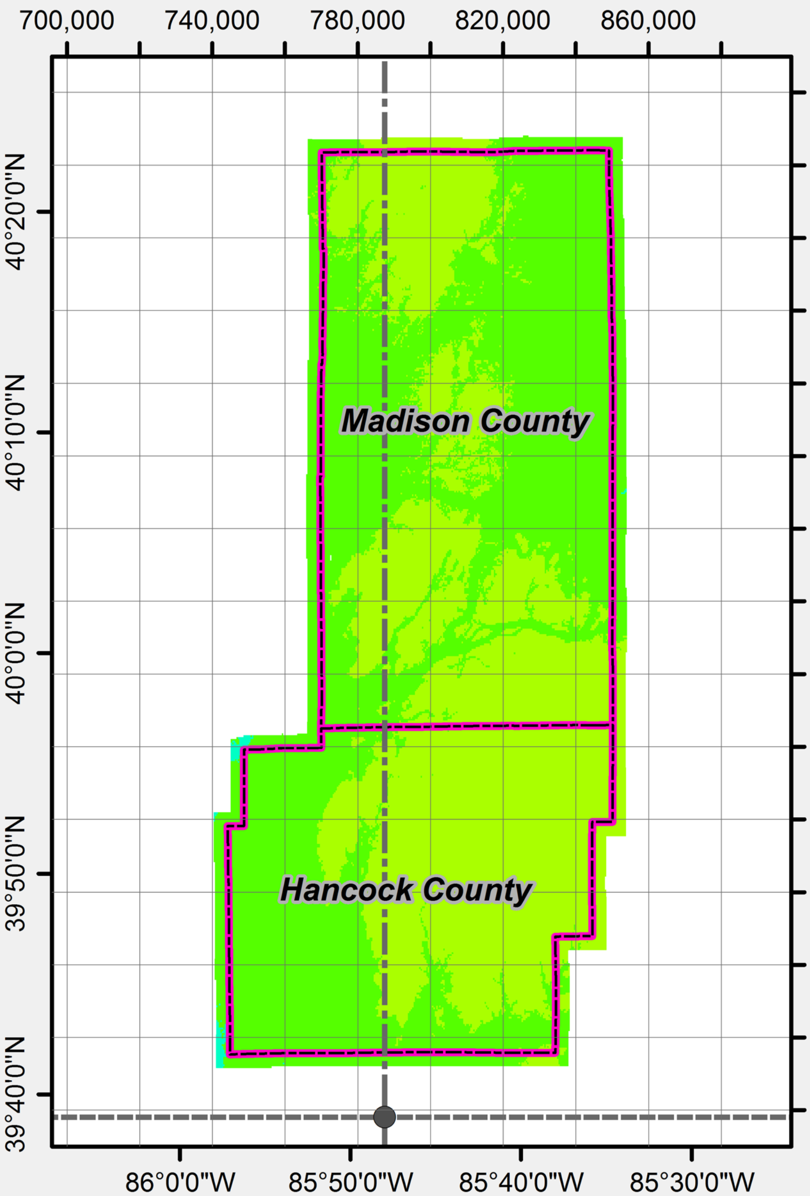
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MADISON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°39'00"N |
| Central Meridian: | 85°48'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 036 |

*Note: Hancock and Madison Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Hancock County | 2 | 3 | 5 |
| Madison County | 1 | 3 | 4 |

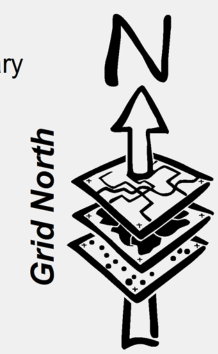
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

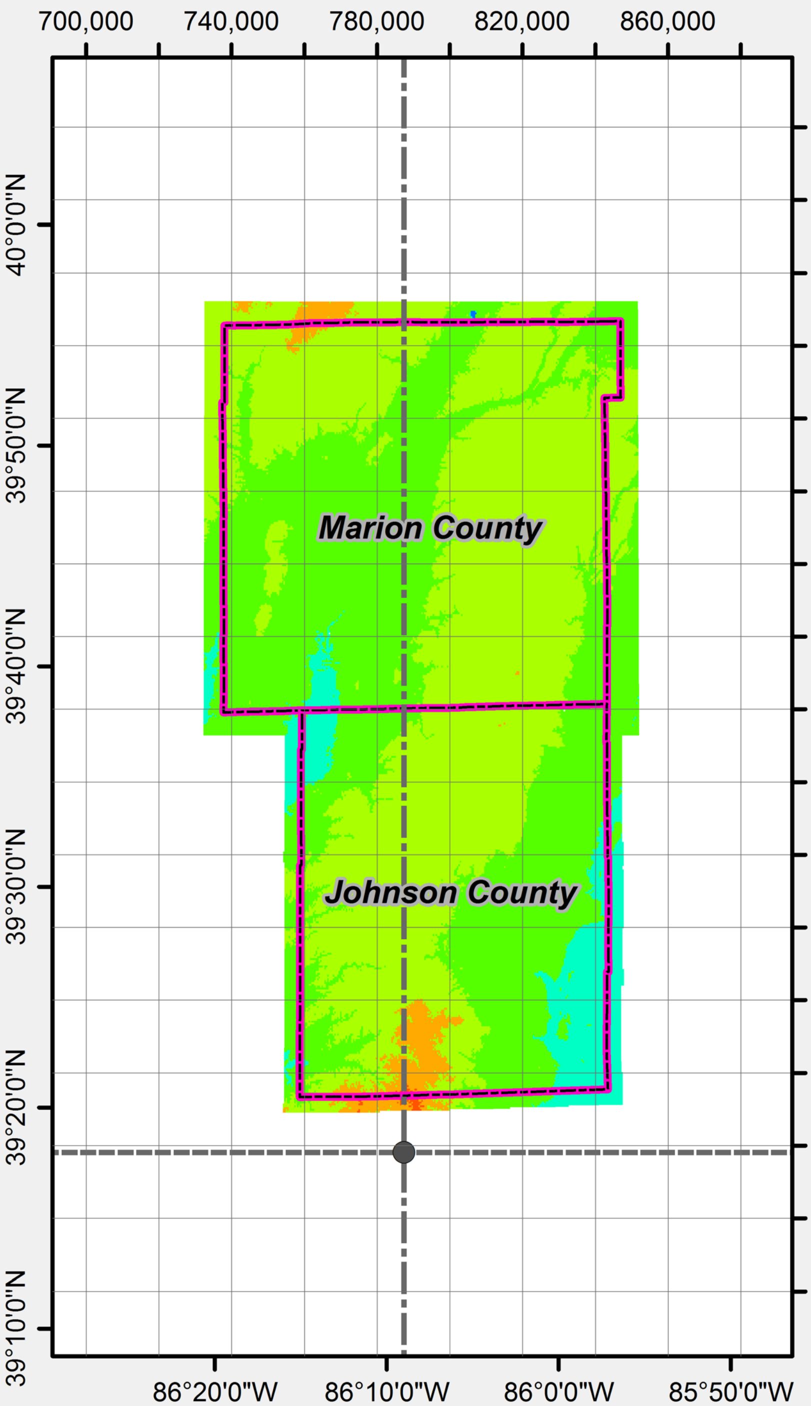
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MARION COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°18'00"N
Central Meridian: 86°09'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 031

*Note: Johnson and Marion Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Johnson County | 3 | 7 | 8 |
| Marion County | 3 | 6 | 8 |

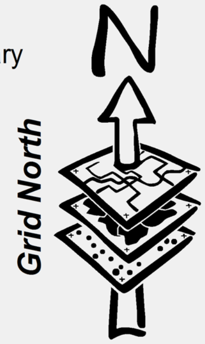
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

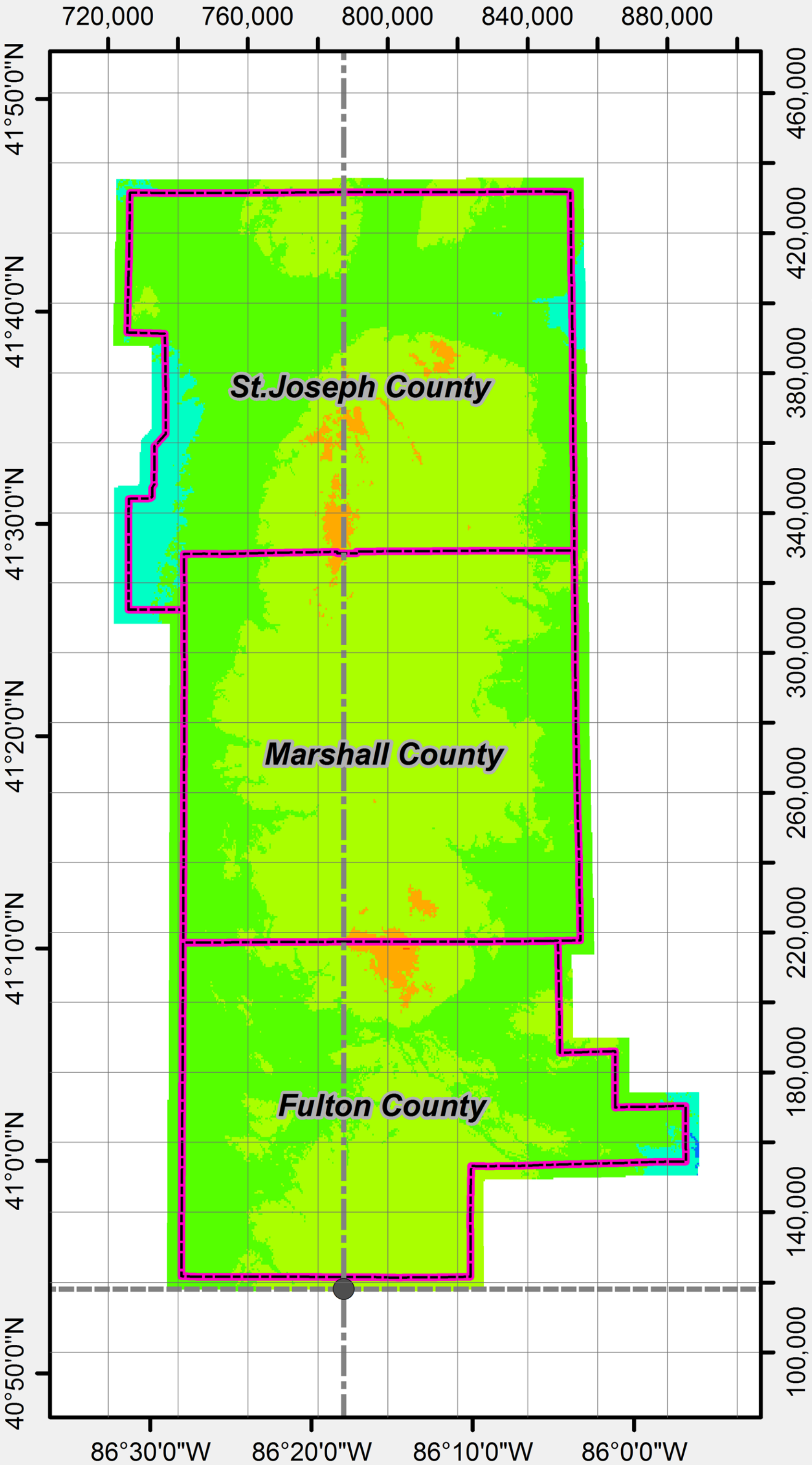
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MARSHALL COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°54'00"N |
| Central Meridian: | 86°18'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 031 |

*Note: Fulton, Marshall, and St.Joseph Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fulton County | 2 | 5 | 7 |
| Marshall County | 2 | 4 | 5 |
| St.Joseph County | 3 | 6 | 8 |

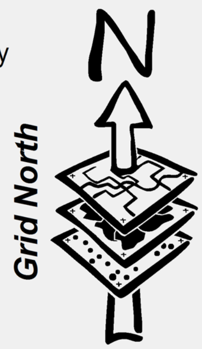
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

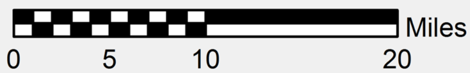
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

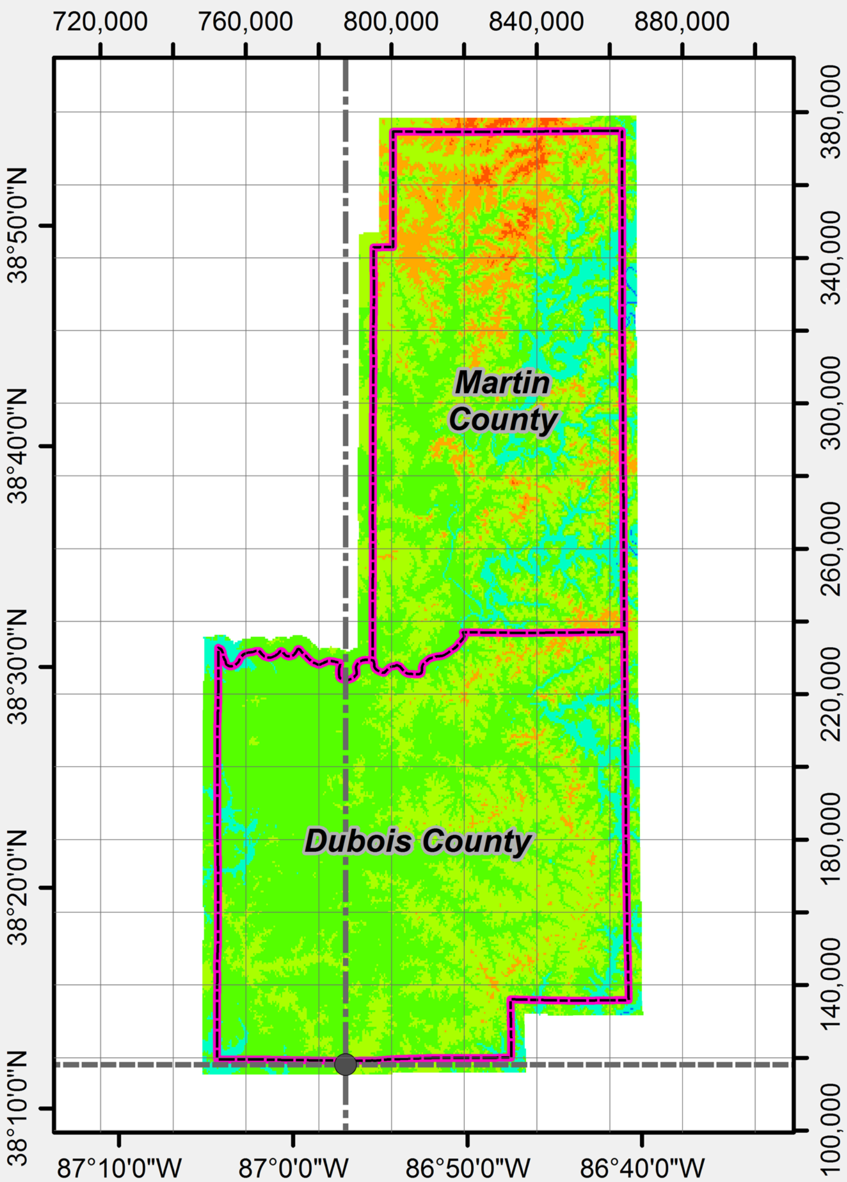
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MARTIN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°12'00"N
Central Meridian: 86°57'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 020

*Note: Dubois and Martin Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Dubois County | 3 | 6 | 7 |
| Martin County | 4 | 8 | 10 |

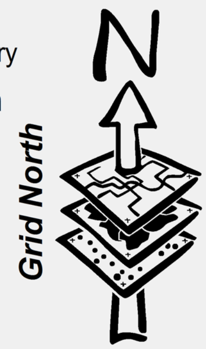
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

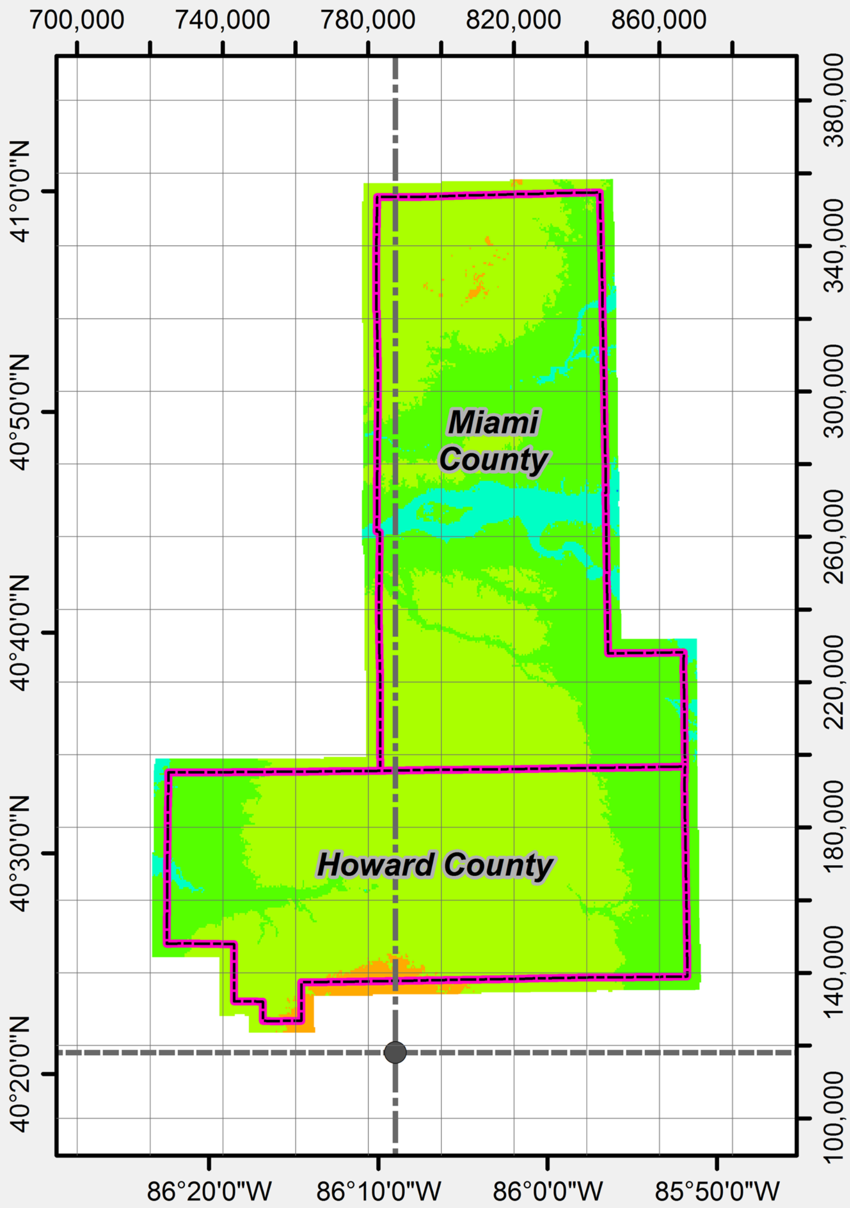
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MIAMI COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°21'00"N
Central Meridian: 86°09'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 031

*Note: Howard and Miami Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Howard County | 2 | 5 | 6 |
| Miami County | 2 | 6 | 8 |

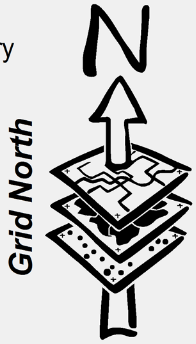
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

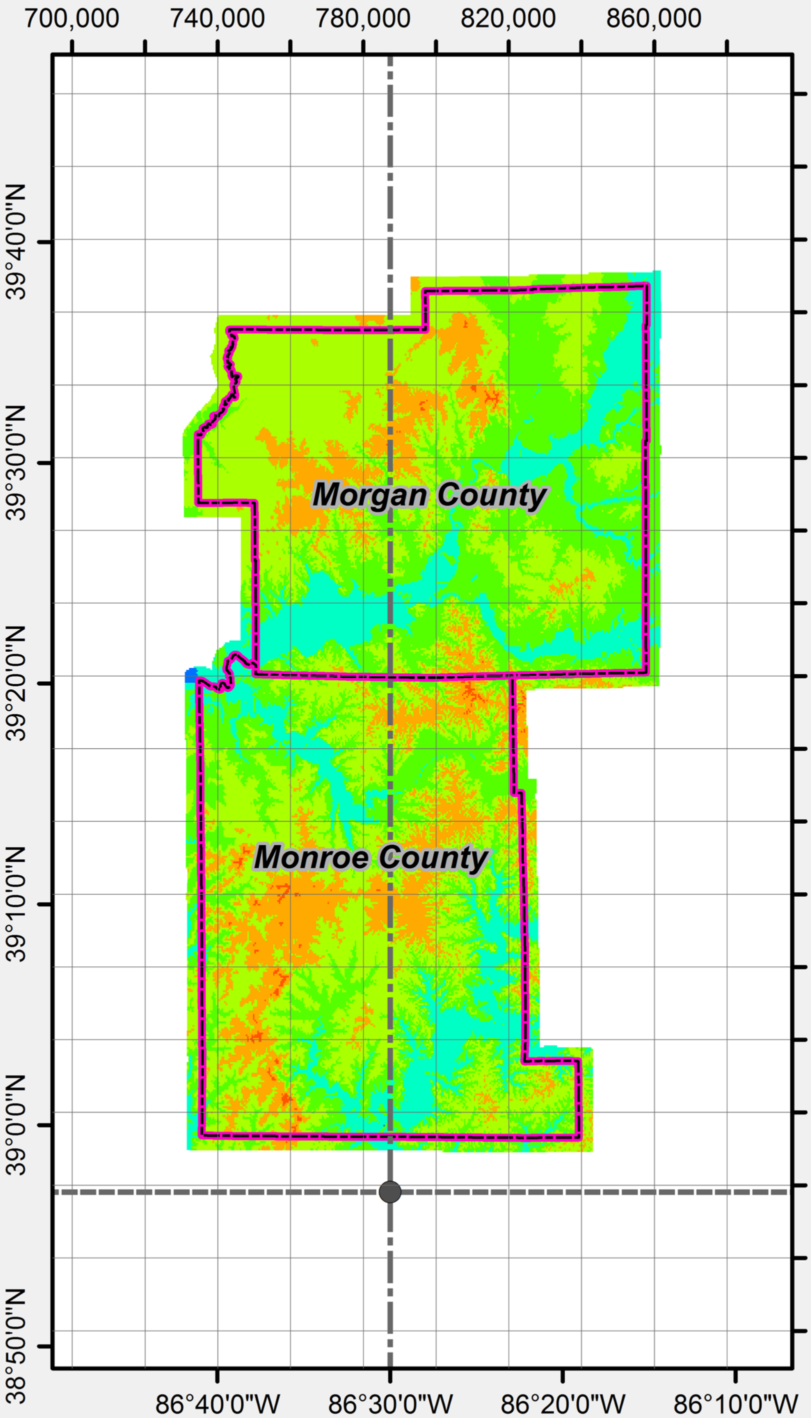
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MONROE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°57'00"N |
| Central Meridian: | 86°30'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 028 |

*Note: Monroe and Morgan Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Monroe County | 2 | 4 | 5 |
| Morgan County | 3 | 7 | 9 |

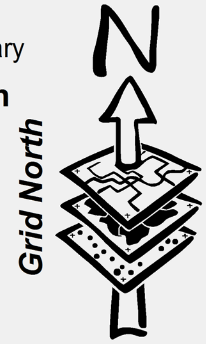
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

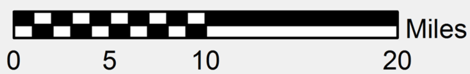
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

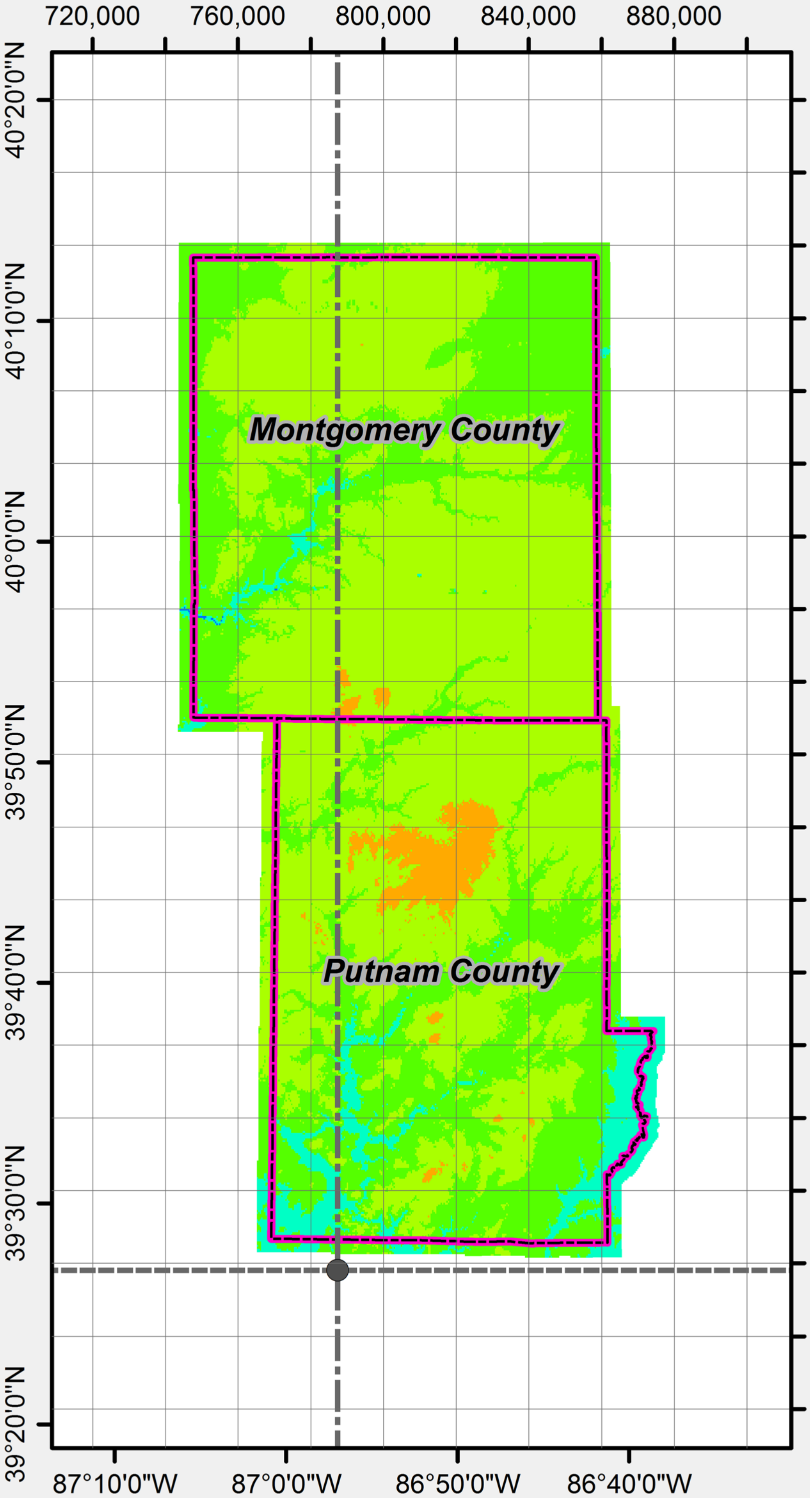
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MONTGOMERY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°27'00"N |
| Central Meridian: | 86°57'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 031 |

*Note: Montgomery and Putnam Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Montgomery County | 2 | 4 | 5 |
| Putnam County | 3 | 7 | 9 |

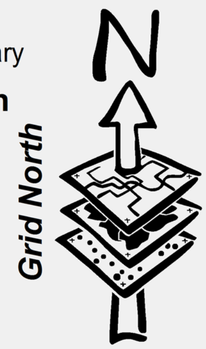
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

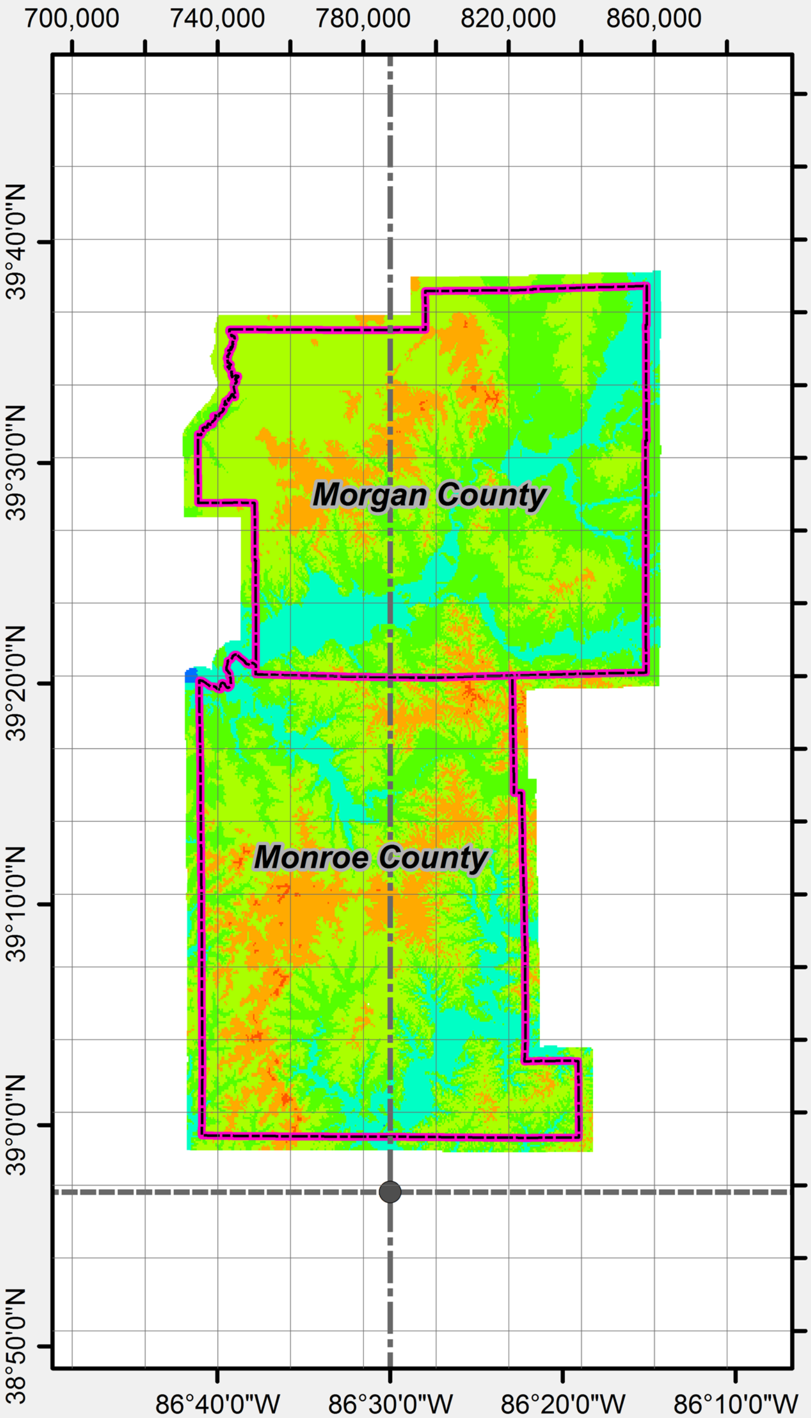
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# MORGAN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°57'00"N
Central Meridian: 86°30'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 028

*Note: Monroe and Morgan Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Monroe County | 2 | 4 | 5 |
| Morgan County | 3 | 7 | 9 |

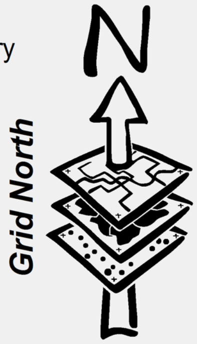
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

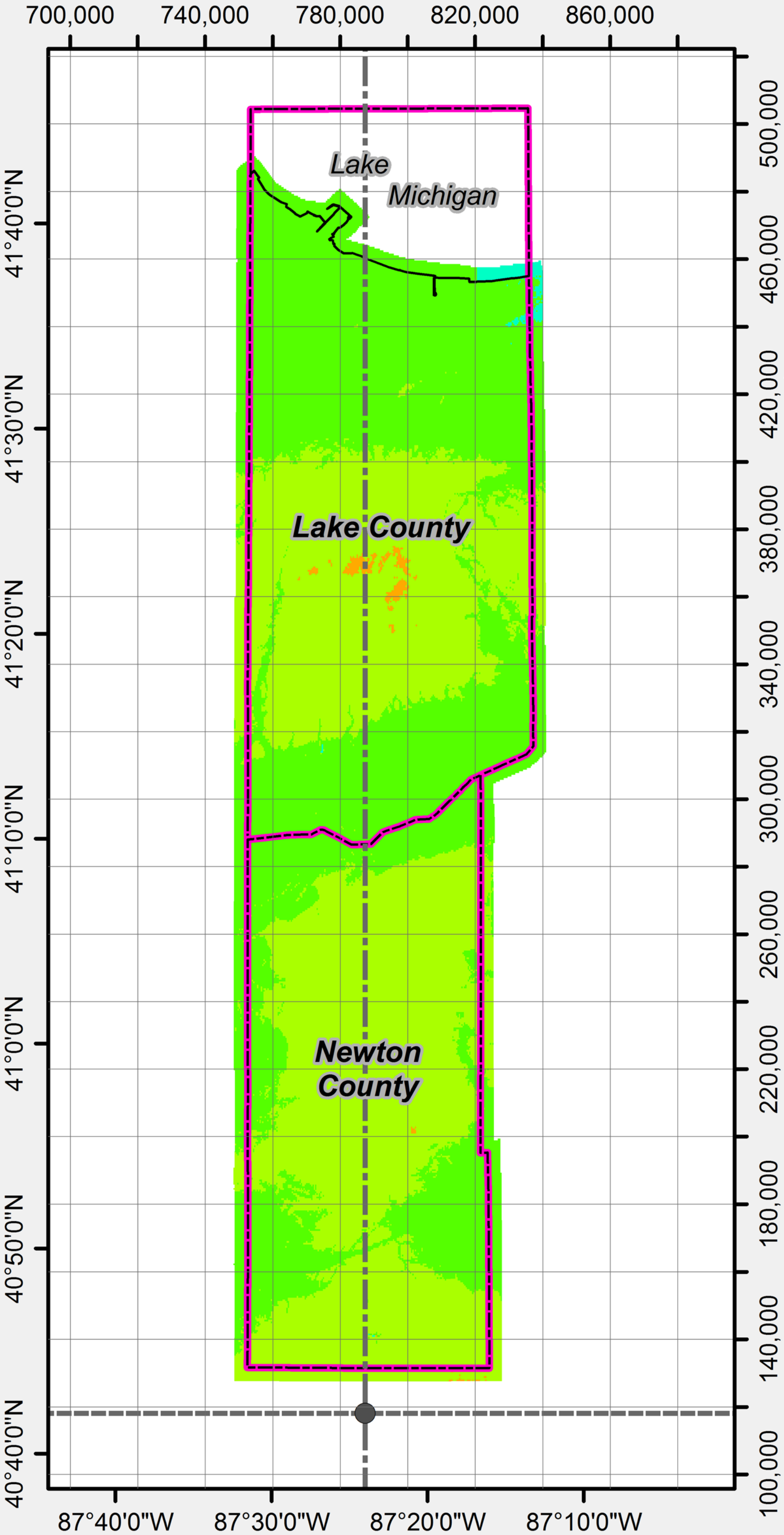
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# NEWTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°42'00"N |
| Central Meridian: | 87°24'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 026 |

*Note: Lake and Newton Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Lake County | 2 | 4 | 5 |
| Newton County | 1 | 3 | 4 |

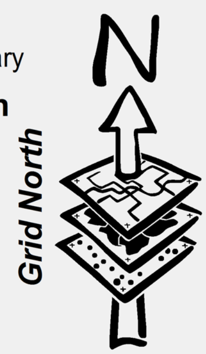
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

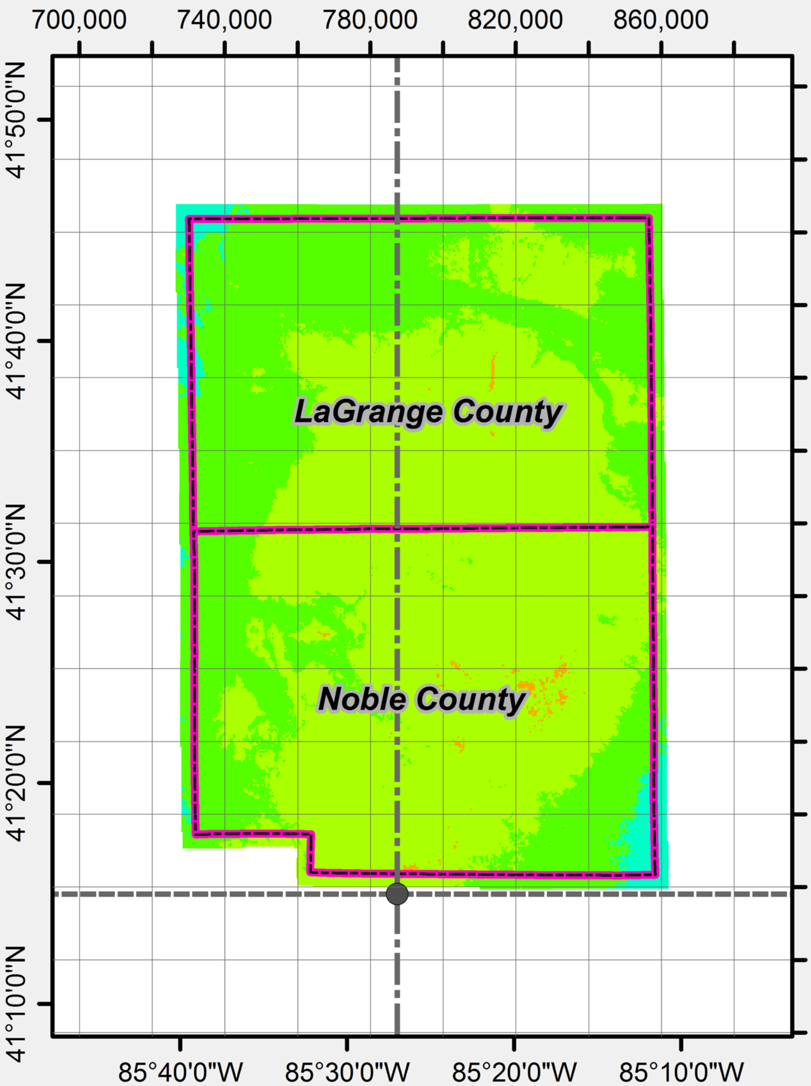
Scale 1 " = 10 miles

Miles
0 5 10 20

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# NOBLE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 41°15'00"N
Central Meridian: 85°27'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 037

*Note: LaGrange and Noble Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| LaGrange County | 2 | 4 | 6 |
| Noble County | 2 | 5 | 7 |

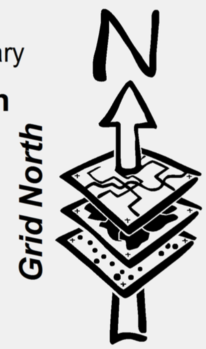
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

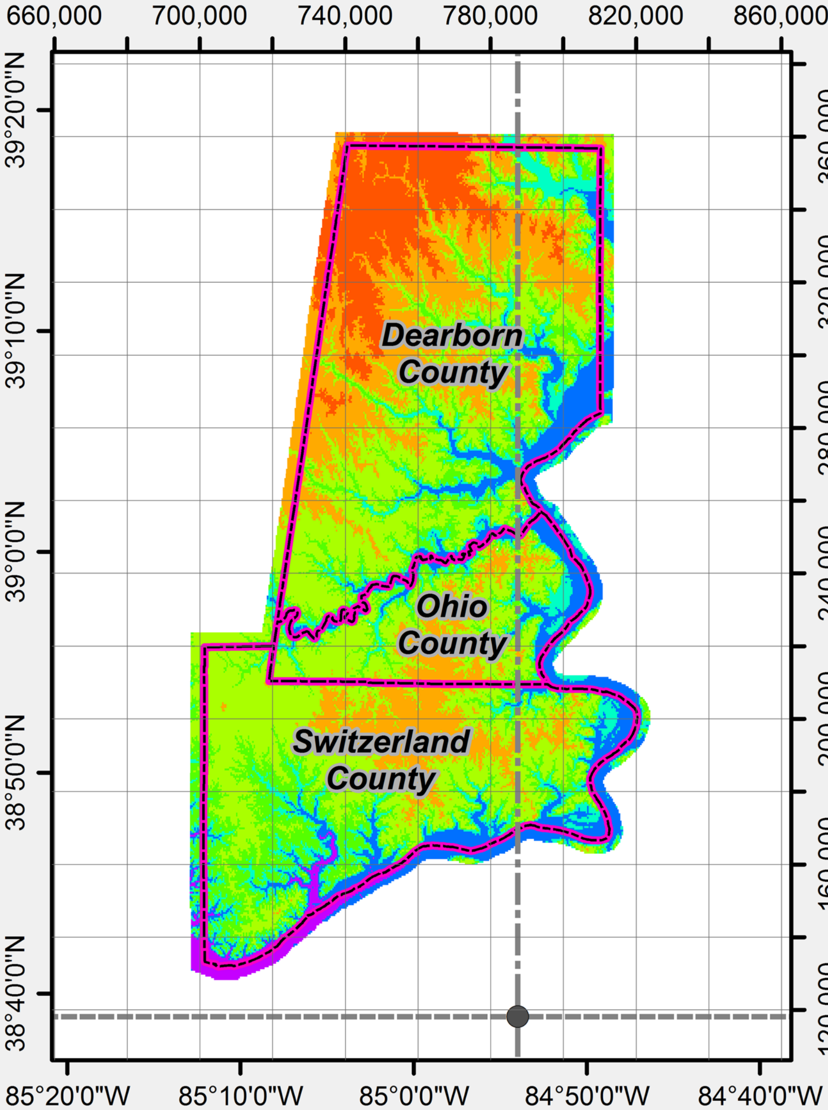
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# OHIO COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°39'00"N
Central Meridian: 84°54'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 029

*Note: Dearborn, Ohio, and Switzerland Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Dearborn County | 7 | 12 | 13 |
| Ohio County | 6 | 13 | 13 |
| Switzerland County | 6 | 15 | 20 |

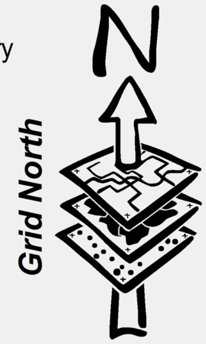
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

False Northing/Easting
Central Meridian
Origin Latitude
County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

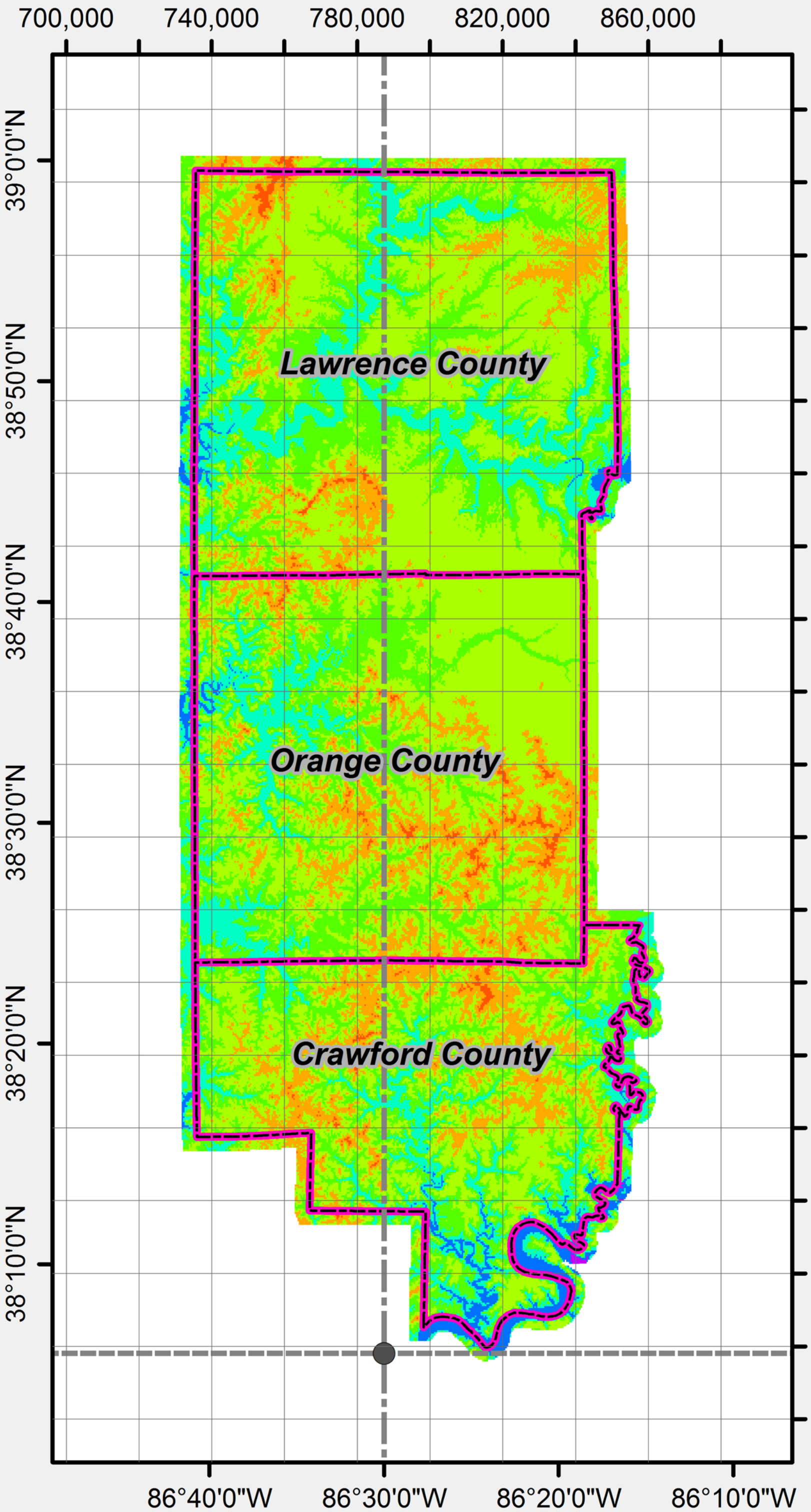
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# ORANGE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°06'00"N
Central Meridian: 86°30'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 025

*Note: Crawford, Lawrence, and Orange Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Crawford County | 4 | 11 | 14 |
| Lawrence County | 4 | 8 | 11 |
| Orange County | 4 | 8 | 10 |

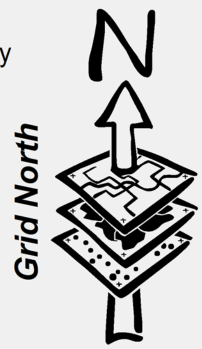
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

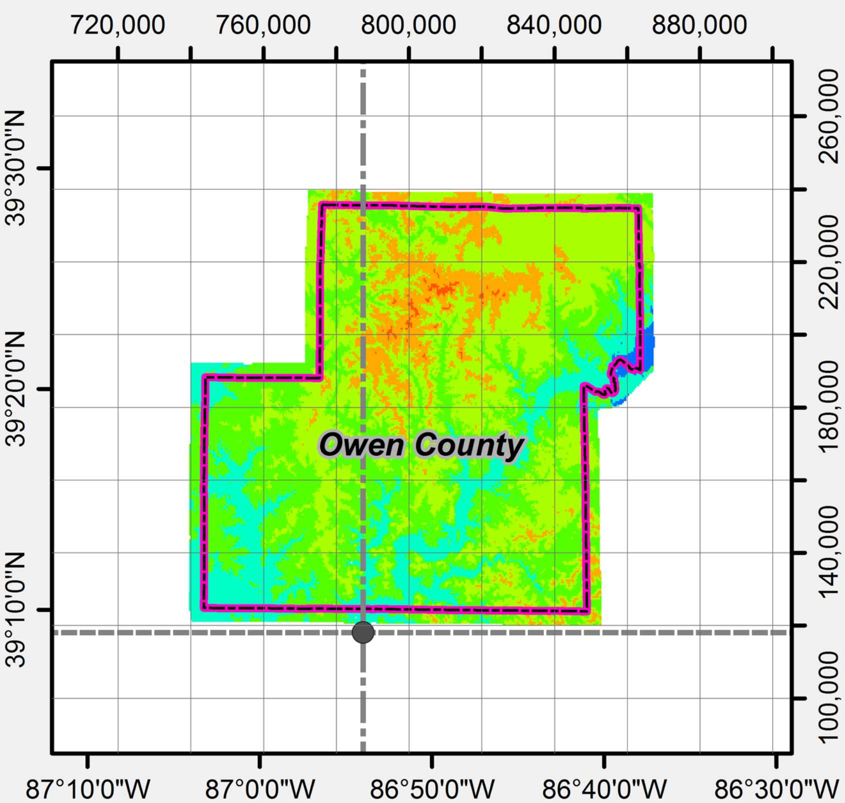
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# OWEN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°09'00"N |
| Central Meridian: | 86°54'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 026 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Owen County | 3 | 8 | 10 |

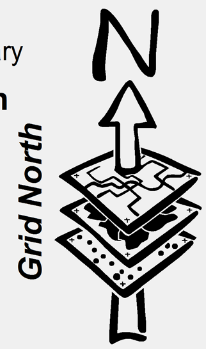
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

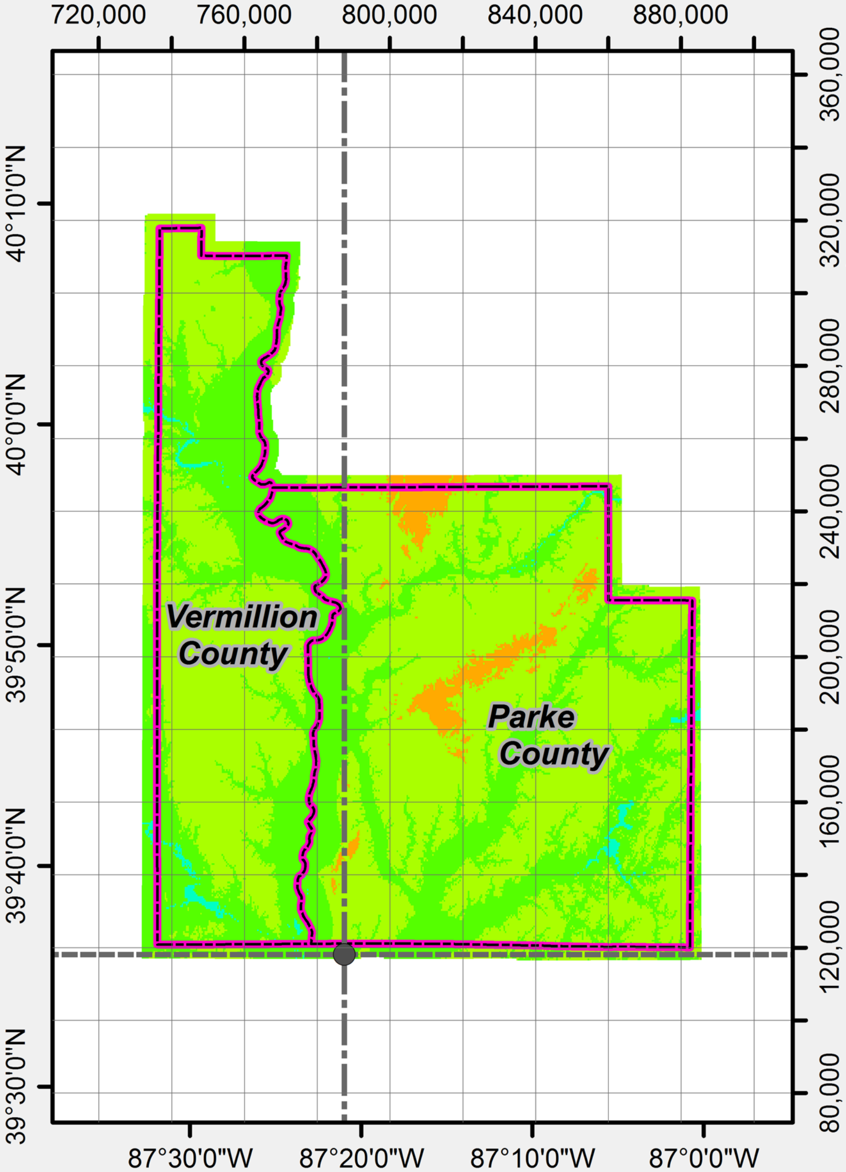
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# PARKE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°36'00"N |
| Central Meridian: | 87°21'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 022 |

*Note: Parke and Vermillion Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Parke County | 3 | 5 | 6 |
| Vermillion County | 2 | 5 | 5 |

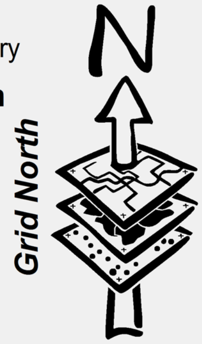
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

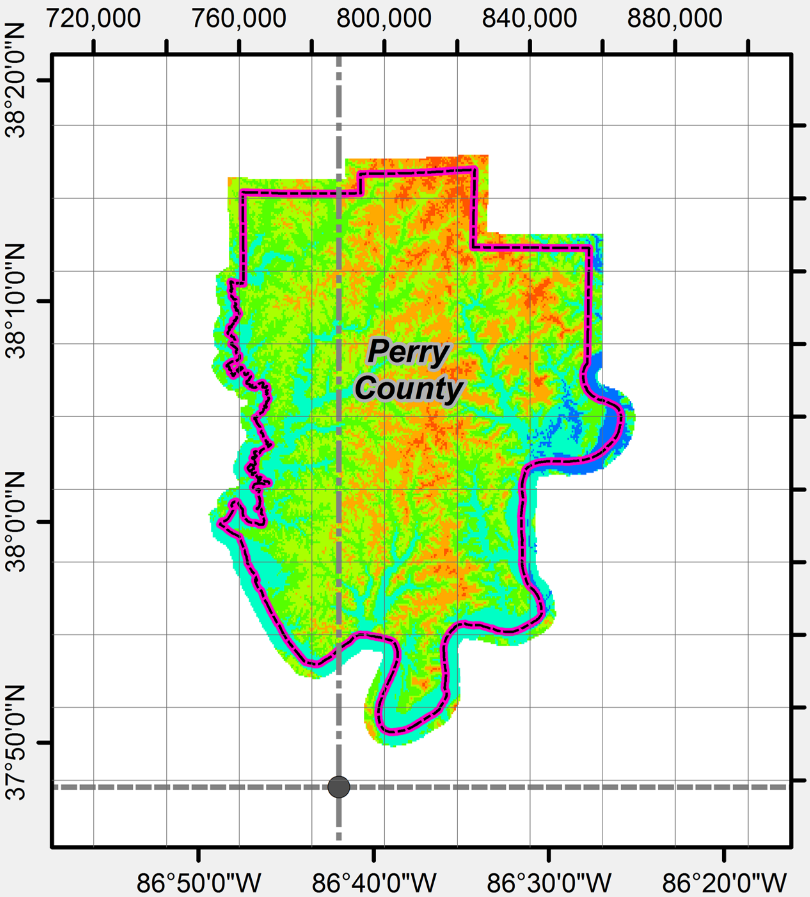
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# PERRY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 37°48'00"N |
| Central Meridian: | 86°42'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 020 |

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Perry County | 5 | 10 | 12 |

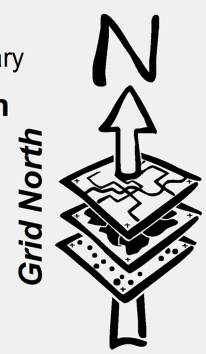
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

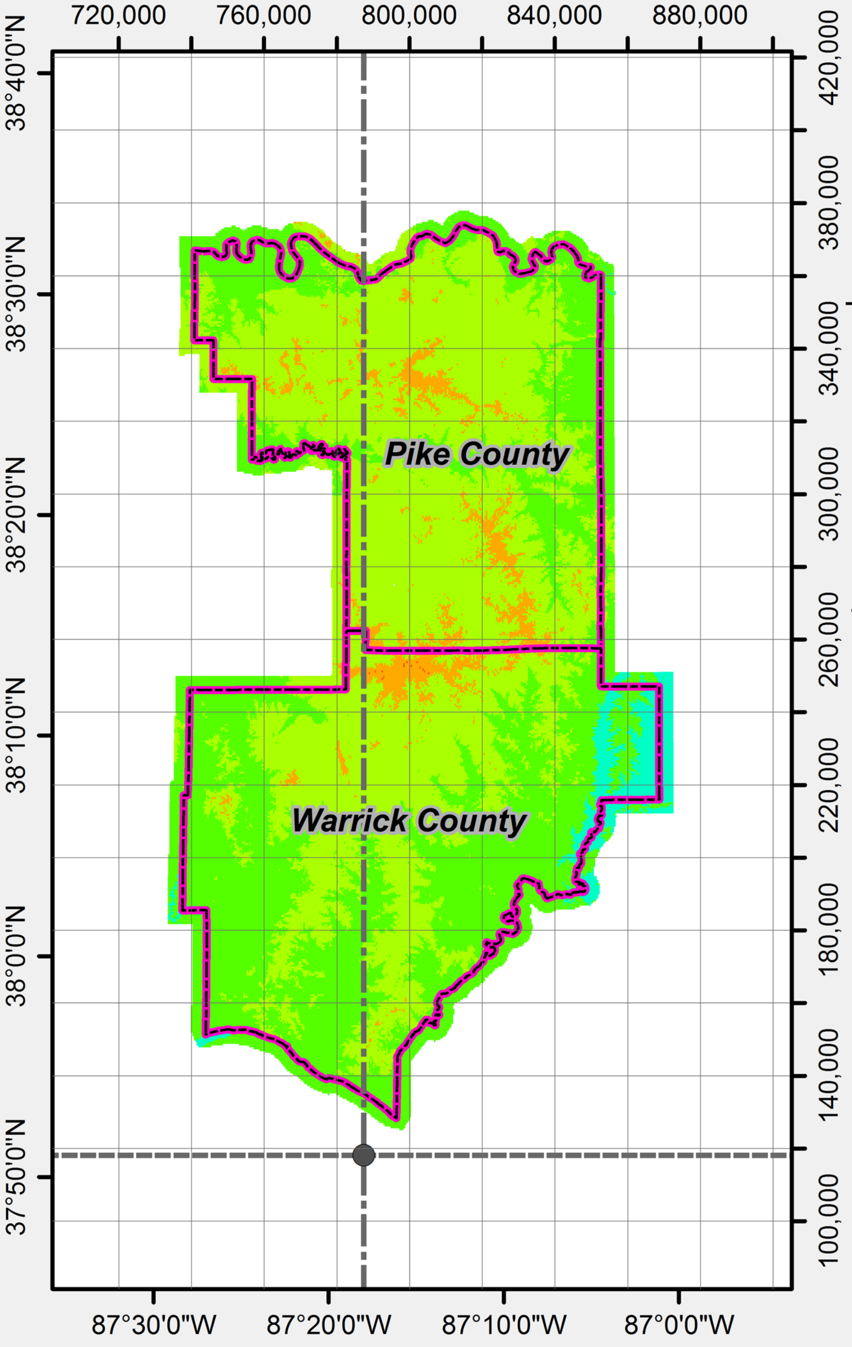
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# PIKE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 37°51'00"N
Central Meridian: 87°18'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 015

*Note: Pike and Warrick Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Pike County | 2 | 5 | 7 |
| Warrick County | 2 | 6 | 8 |

*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm

Grid North

*Note: Map grid is shown in units of U.S. Survey feet.*

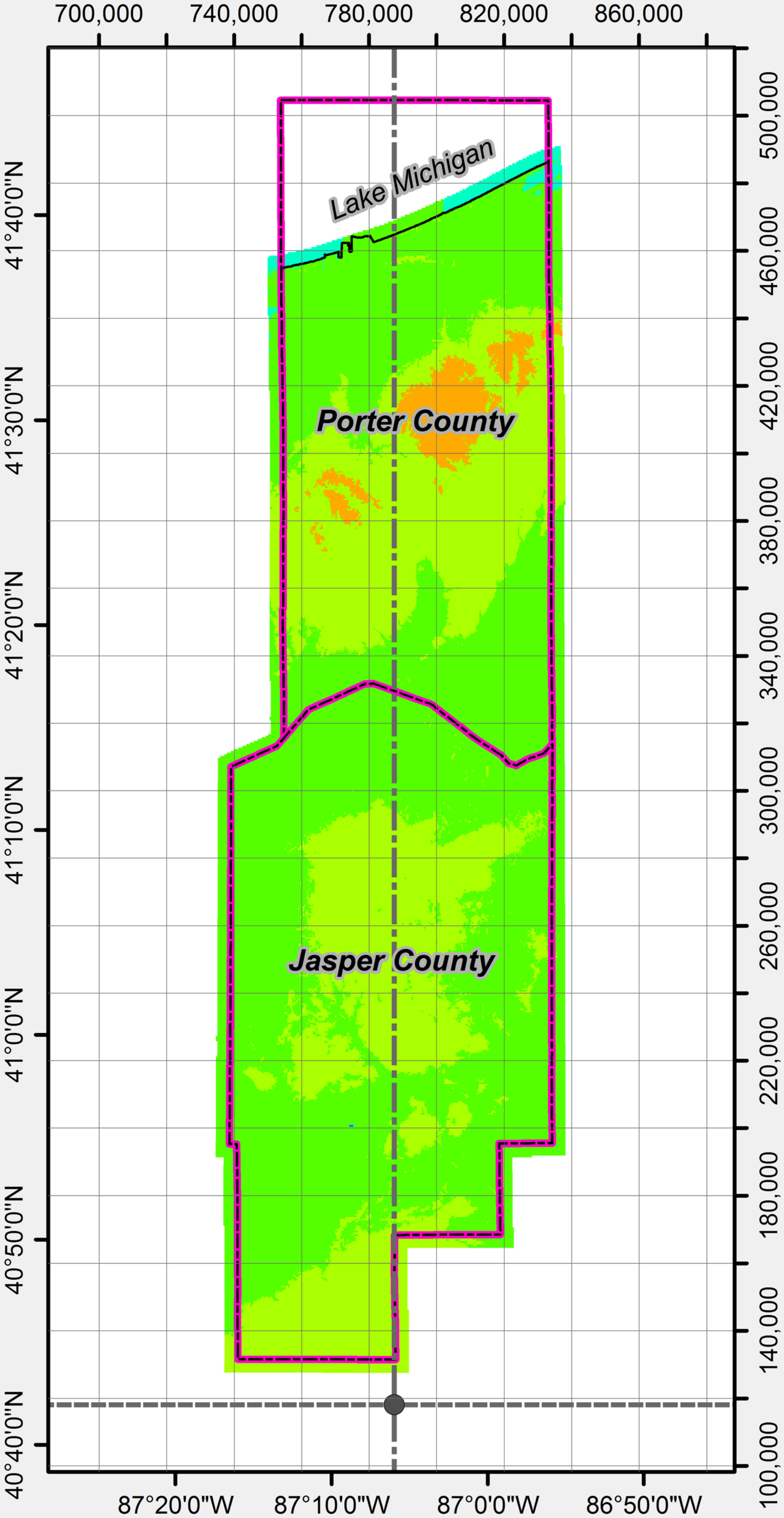
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# PORTER COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°42'00"N
Central Meridian: 87°06'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 027

*Note: Jasper and Porter Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Jasper County | 1 | 3 | 4 |
| Porter County | 2 | 6 | 7 |

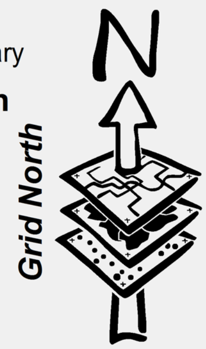
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

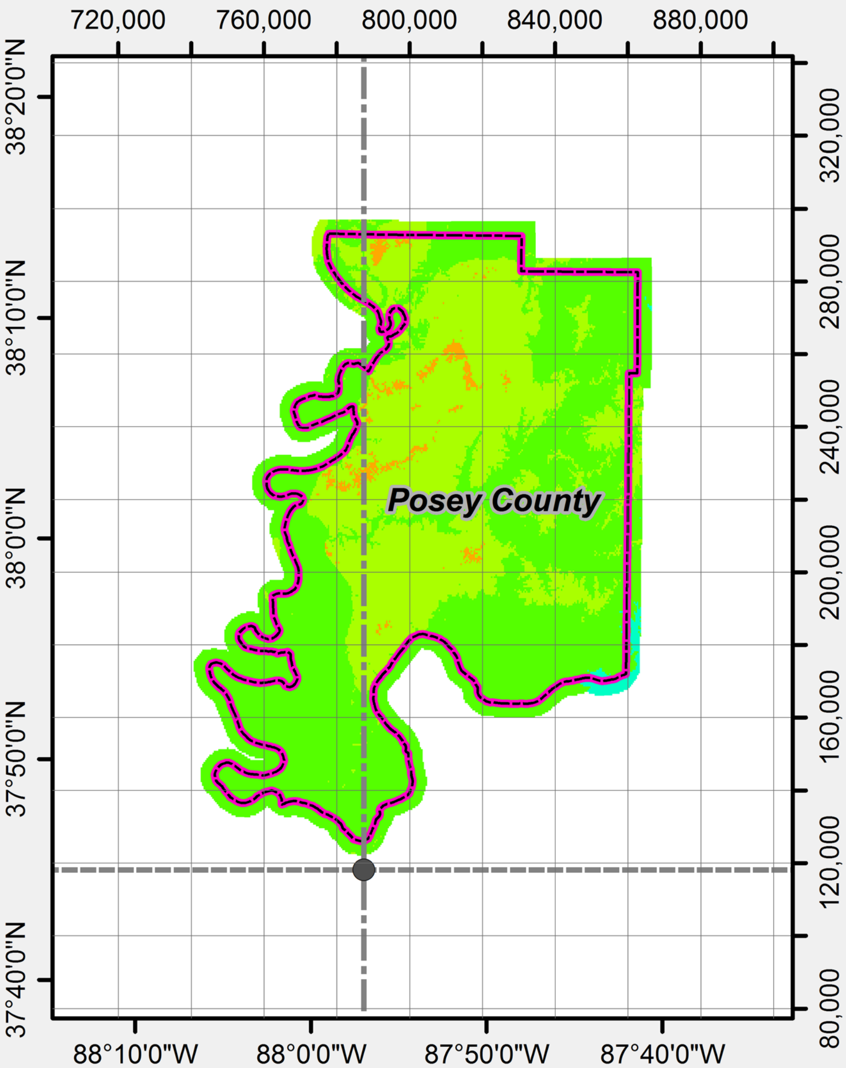
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# POSEY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 37°45'00"N
Central Meridian: 87°57'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 013

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Posey County | 2 | 4 | 6 |

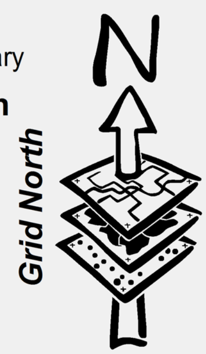
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

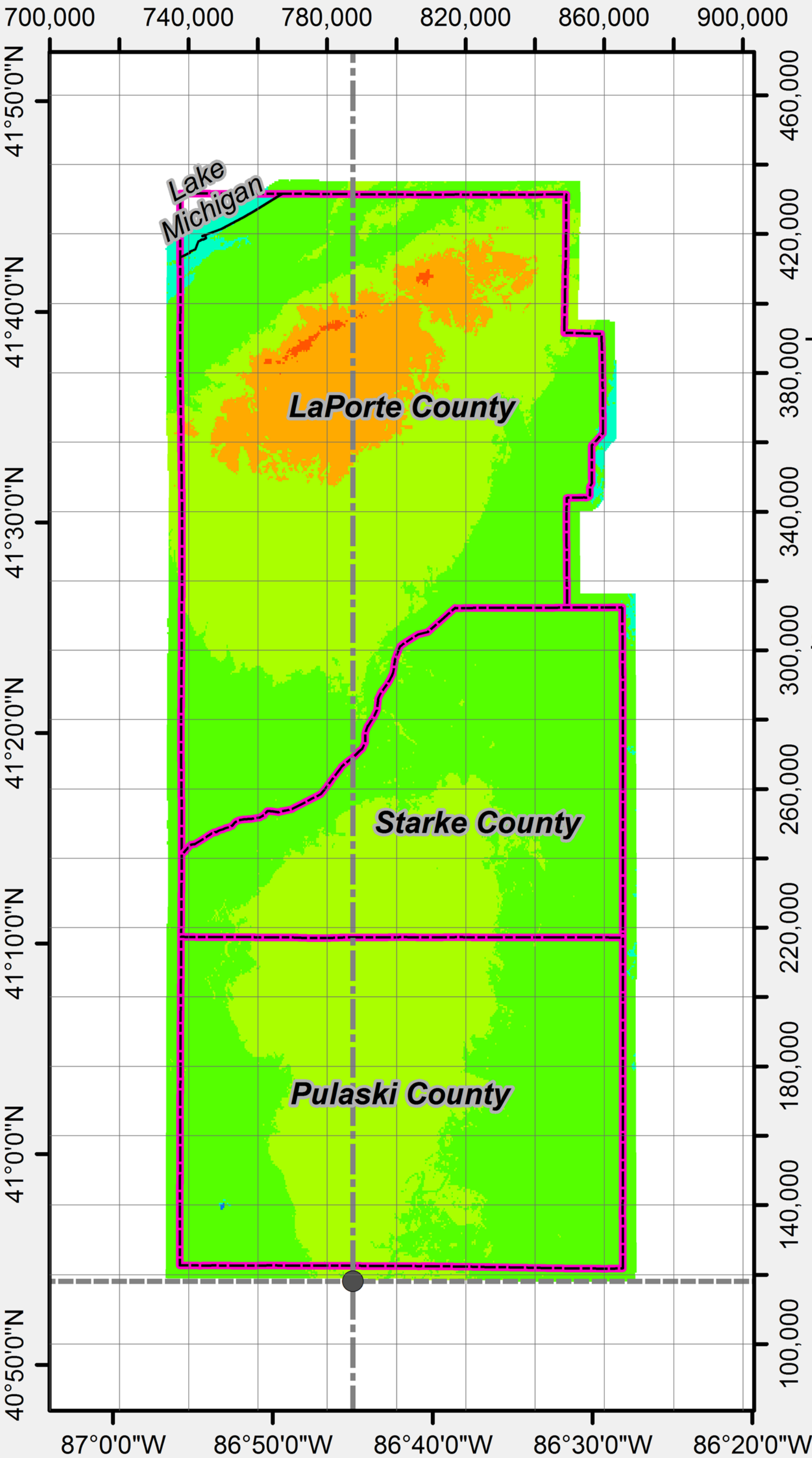
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# PULASKI COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°54'00"N
Central Meridian: 86°45'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 027

*Note: LaPorte, Pulaski, and Starke Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| LaPorte County | 3 | 7 | 9 |
| Pulaski County | 1 | 3 | 4 |
| Starke County | 2 | 4 | 5 |

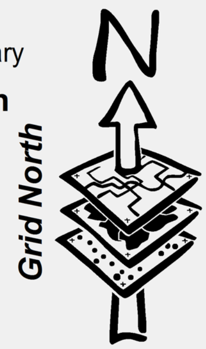
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

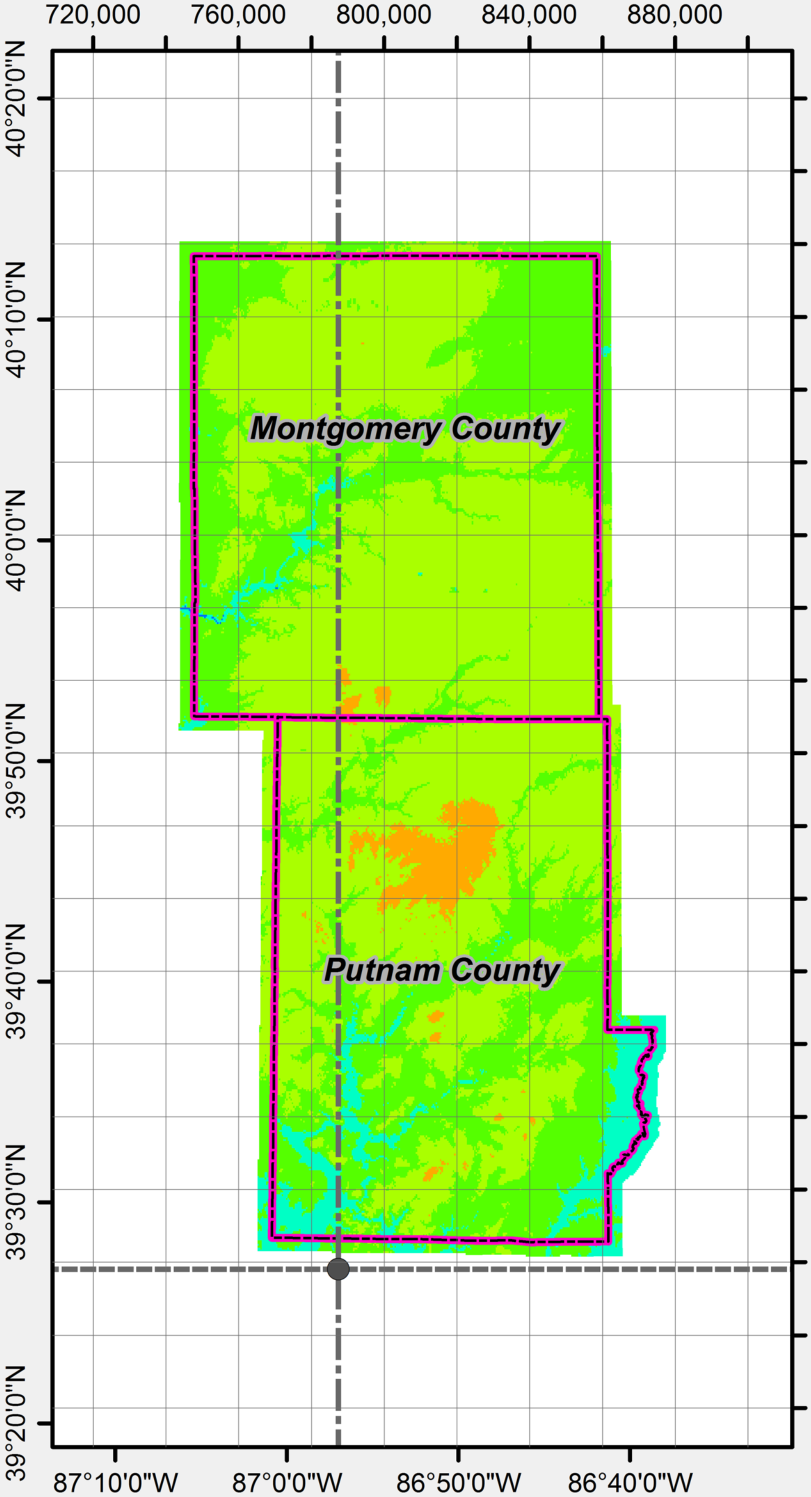
Scale 1 " = 10 miles

Miles 0 5 10 20

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# PUTNAM COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°27'00"N
Central Meridian: 86°57'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 031

*Note: Montgomery and Putnam Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Montgomery County | 2 | 4 | 5 |
| Putnam County | 3 | 7 | 9 |

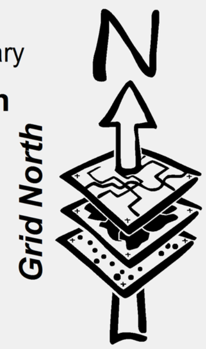
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

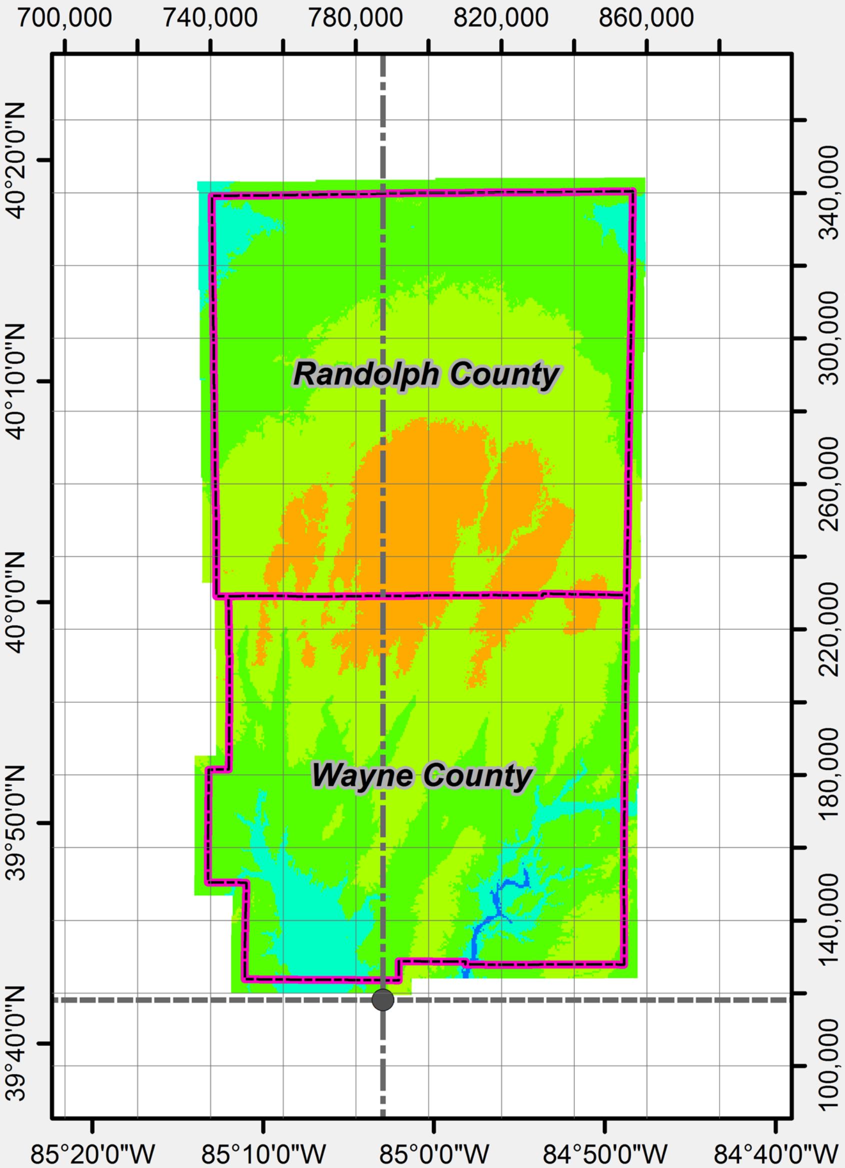
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# RANDOLPH COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°42'00"N |
| Central Meridian: | 85°03'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 044 |

*Note: Randolph and Wayne Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Randolph County | 3 | 7 | 8 |
| Wayne County | 3 | 7 | 9 |

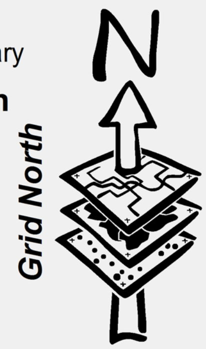
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

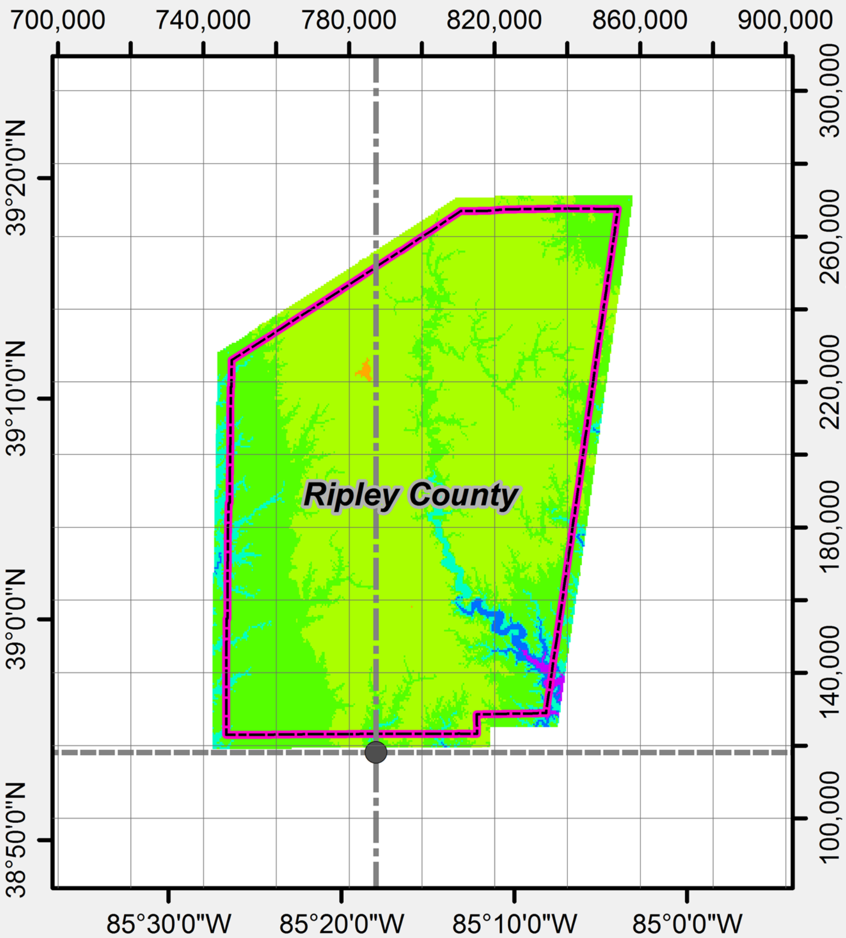
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# RIPLEY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 38°54'00"N
Central Meridian: 85°18'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 038

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Ripley County | 2 | 6 | 11 |

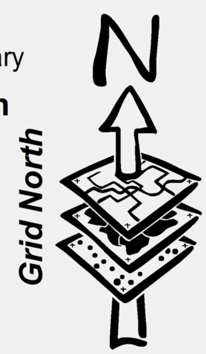
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

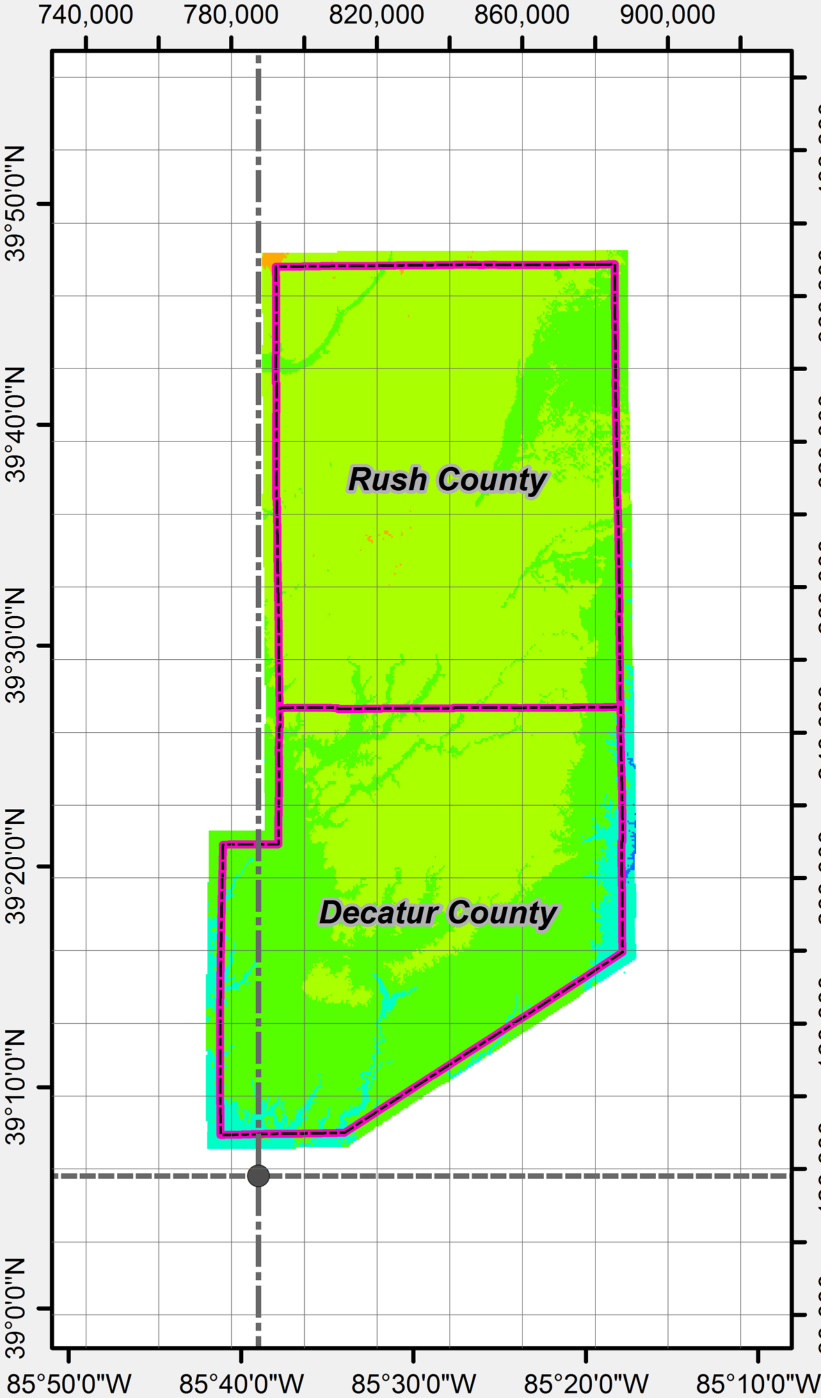
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# RUSH COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 39°06'00"N
Central Meridian: 85°39'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 036

*Note: Decatur and Rush Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Decatur County | 2 | 6 | 8 |
| Rush County | 2 | 4 | 5 |

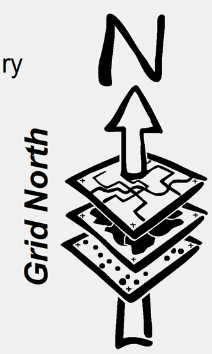
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

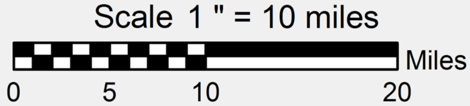
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

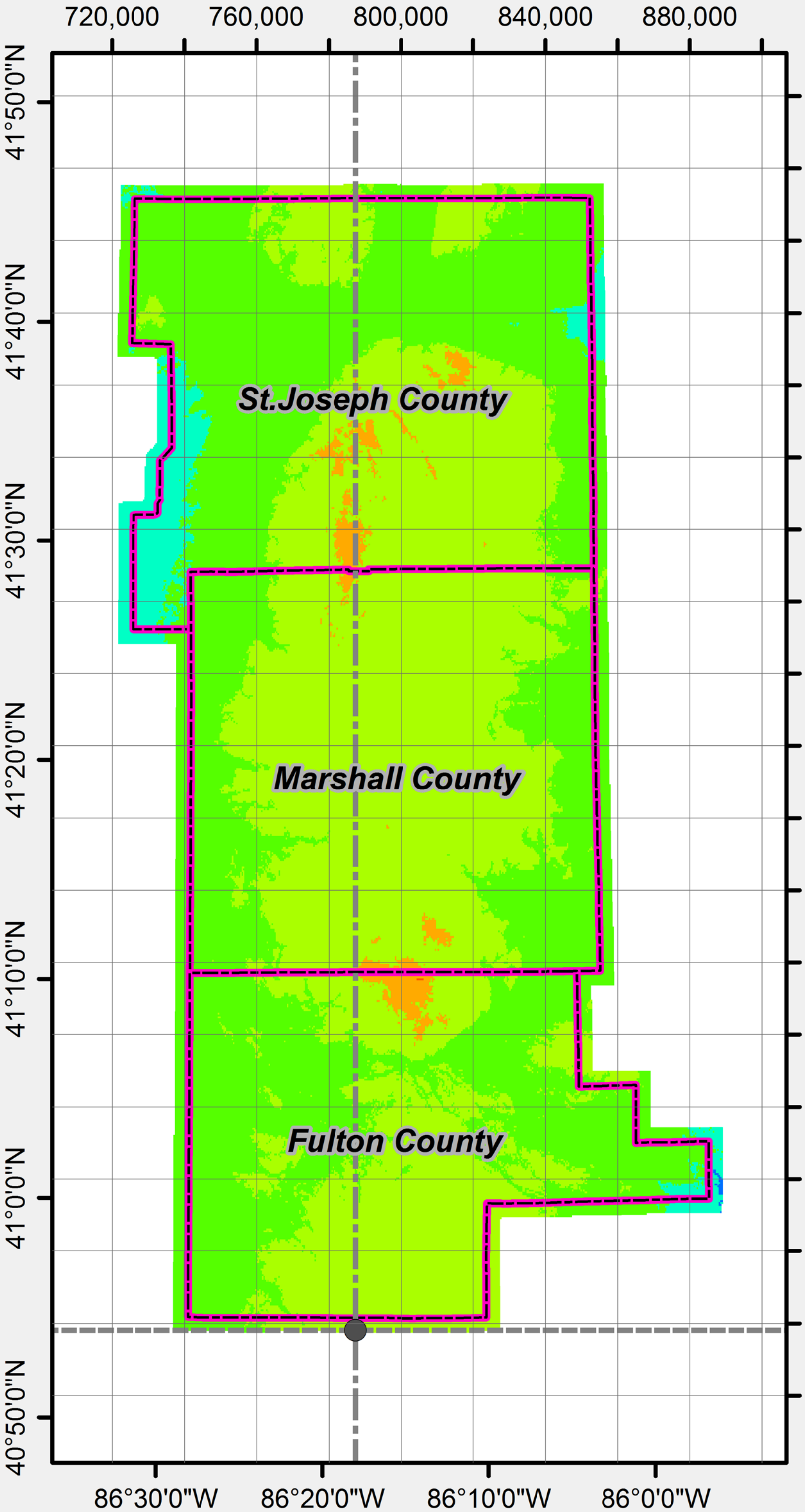
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# ST.JOSEPH COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°54'00"N
Central Meridian: 86°18'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 031

*Note: Fulton, Marshall, and St.Joseph Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fulton County | 2 | 5 | 7 |
| Marshall County | 2 | 4 | 5 |
| St.Joseph County | 3 | 6 | 8 |

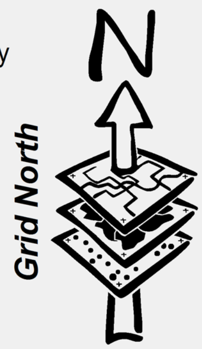
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

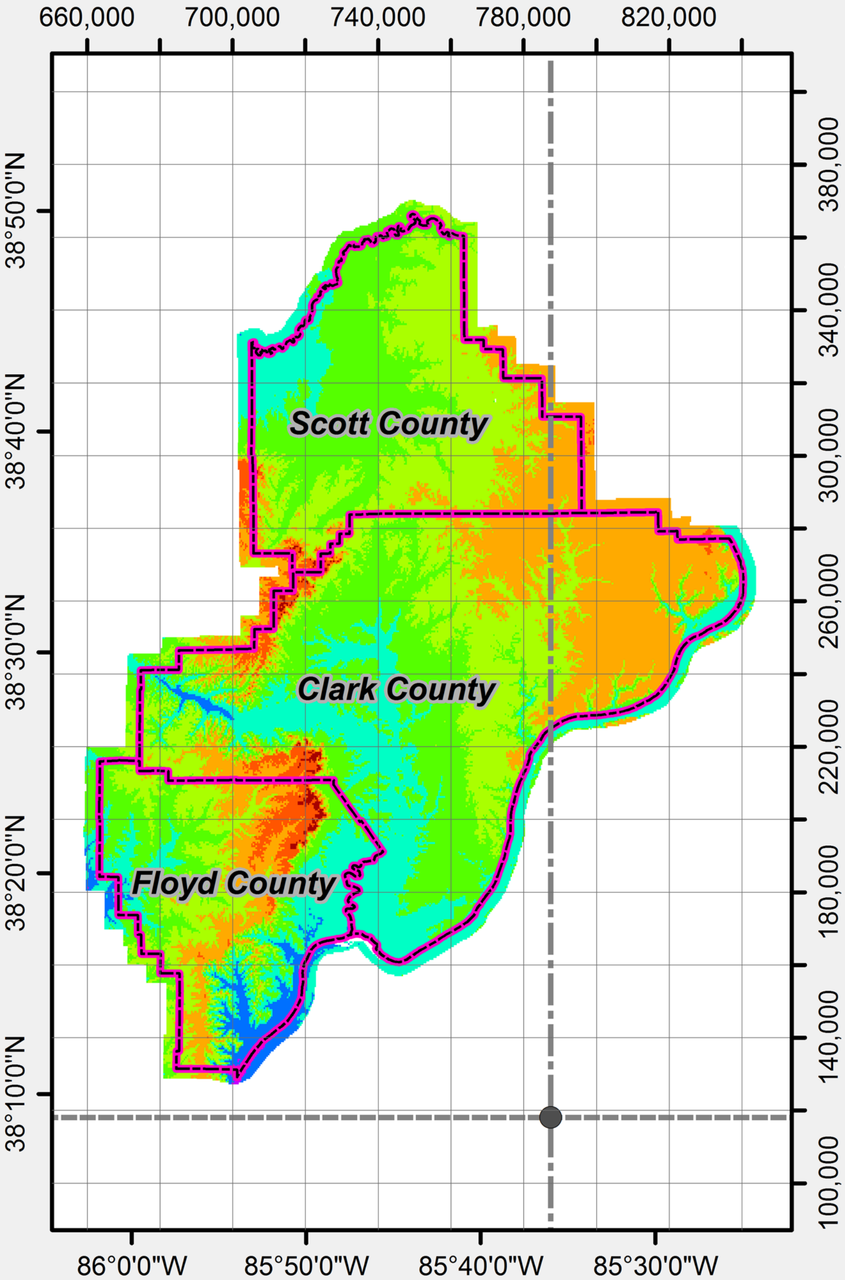
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# SCOTT COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°09'00"N |
| Central Meridian: | 85°36'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 021 |

*Note: Clark, Floyd, and Scott Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Clark County | 5 | 9 | 13 |
| Floyd County | 6 | 13 | 15 |
| Scott County | 4 | 9 | 13 |

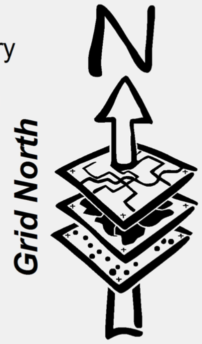
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

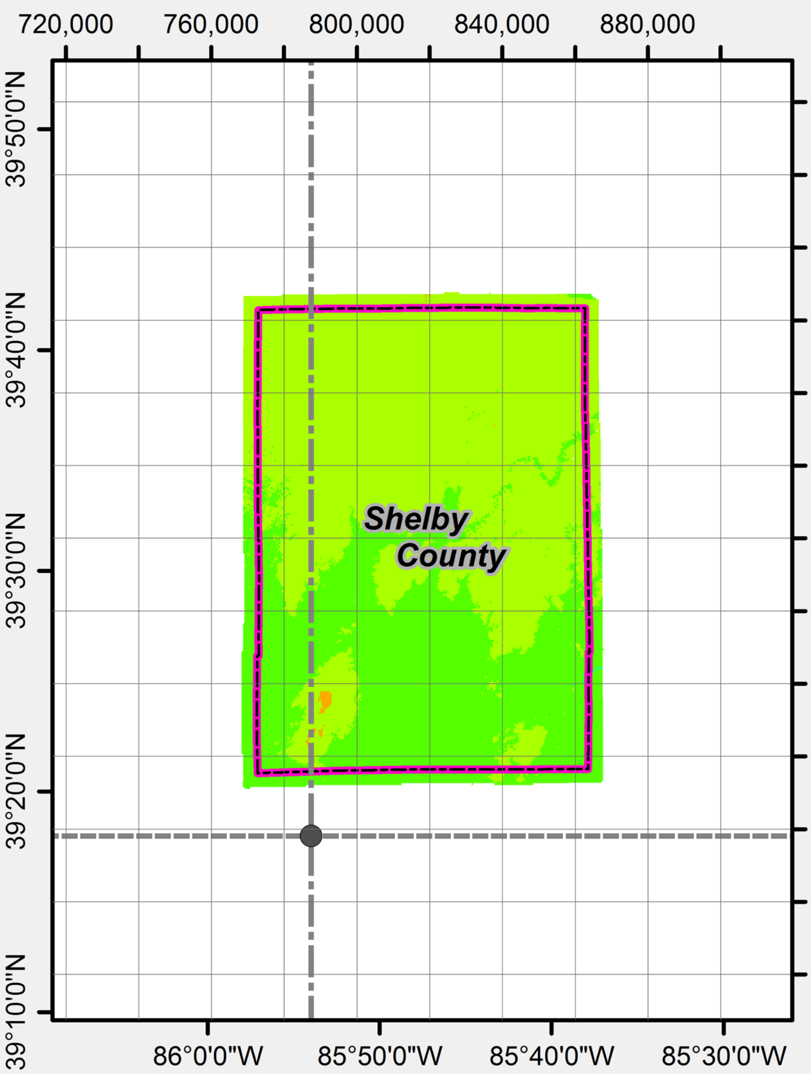
Scale 1 " = 10 miles

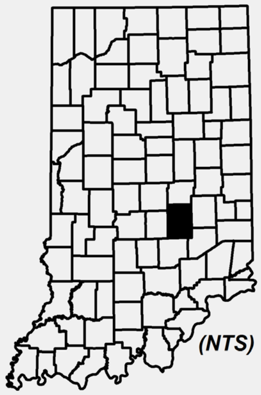
0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# SHELBY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°18'00"N |
| Central Meridian: | 85°54'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 030 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Shelby County | 2 | 4 | 4 |

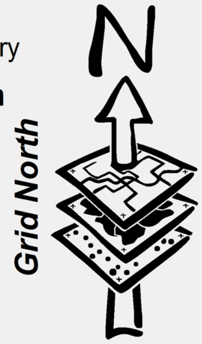
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

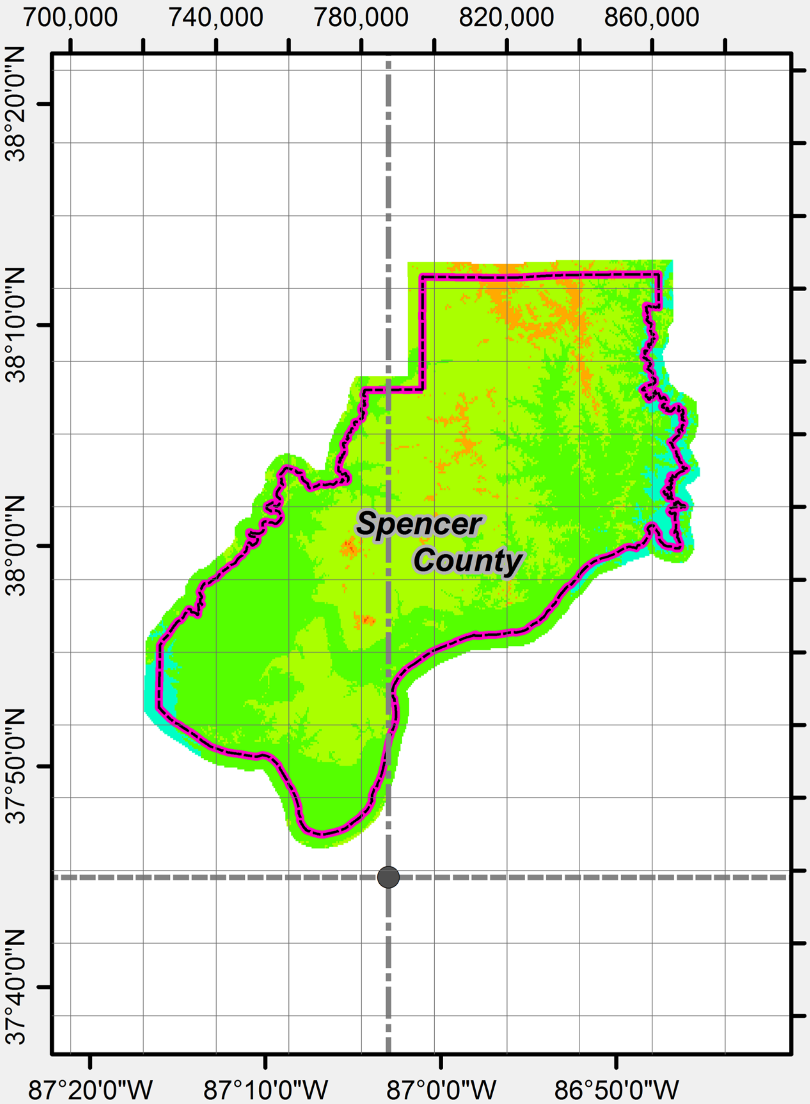
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# SPENCER COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 37°45'00"N
Central Meridian: 87°03'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 014

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Spencer County | 2 | 6 | 8 |

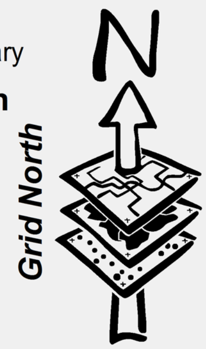
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

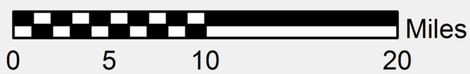
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

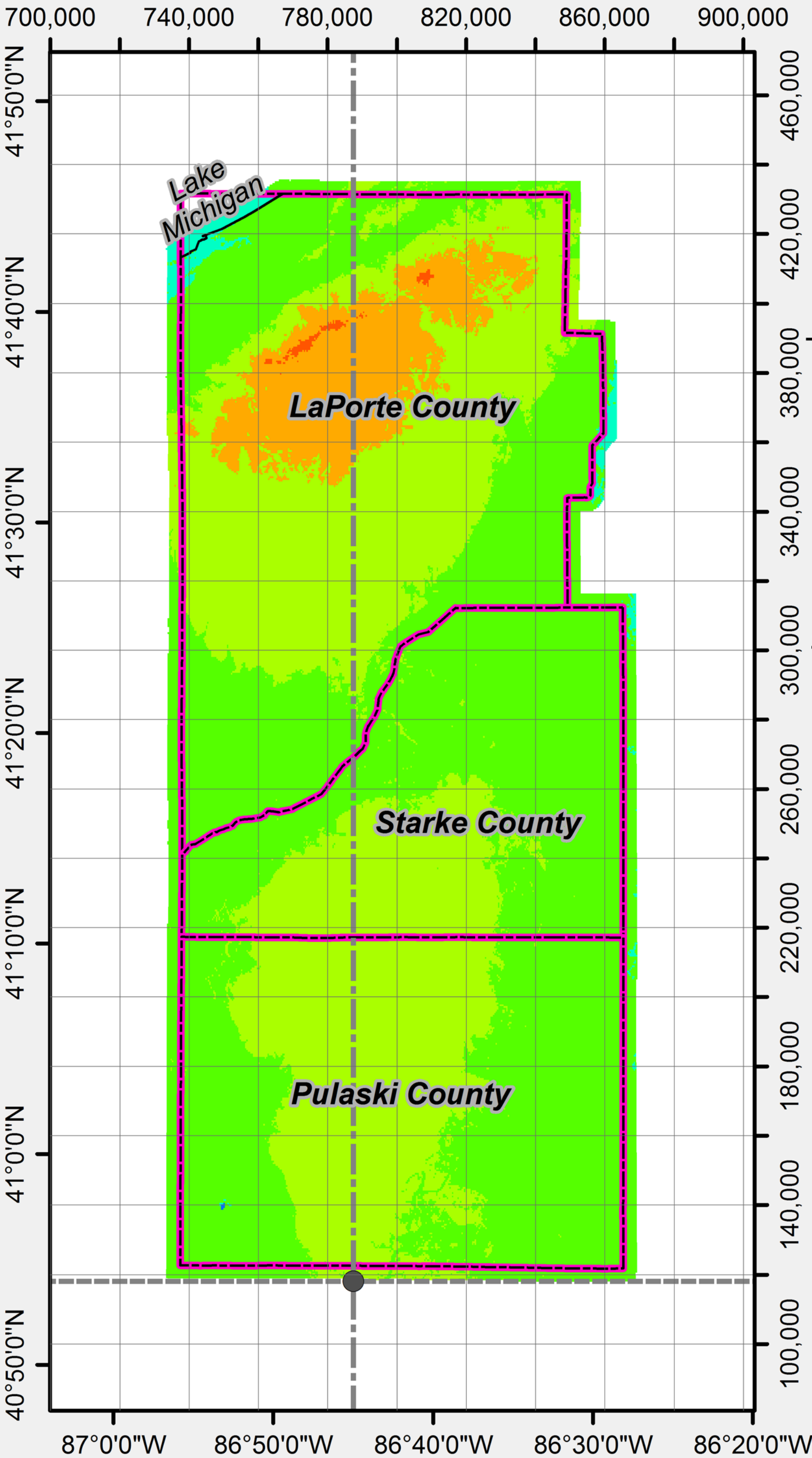
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# STARKE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°54'00"N |
| Central Meridian: | 86°45'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 027 |

*Note: LaPorte, Pulaski, and Starke Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| LaPorte County | 3 | 7 | 9 |
| Pulaski County | 1 | 3 | 4 |
| Starke County | 2 | 4 | 5 |

*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm

Grid North

*Note: Map grid is shown in units of U.S. Survey feet.*

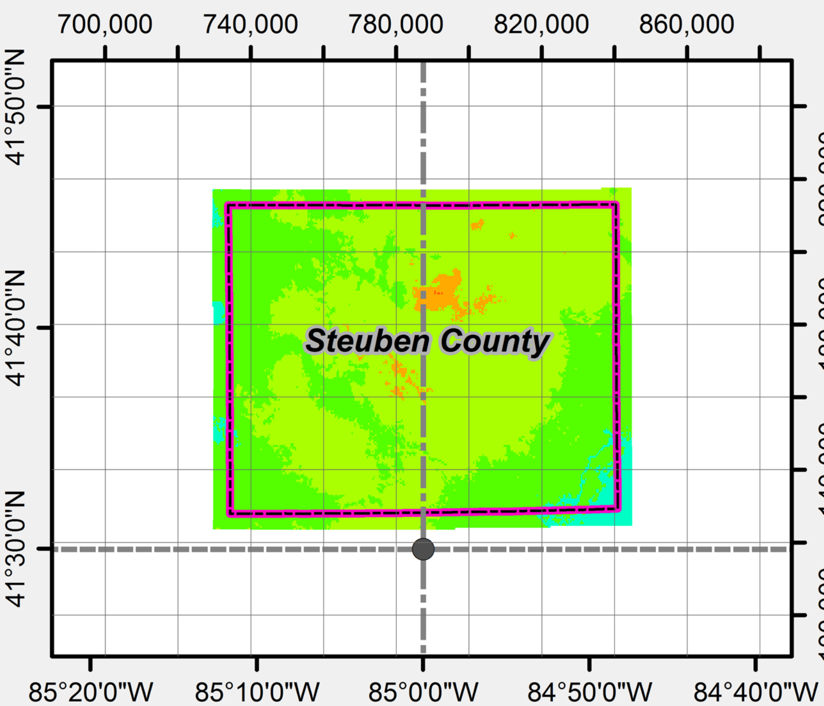
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# STEUBEN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 41°30'00"N |
| Central Meridian: | 85°00'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 041 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Steuben County | 2 | 5 | 7 |

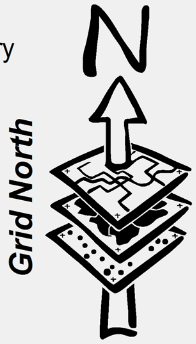
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm



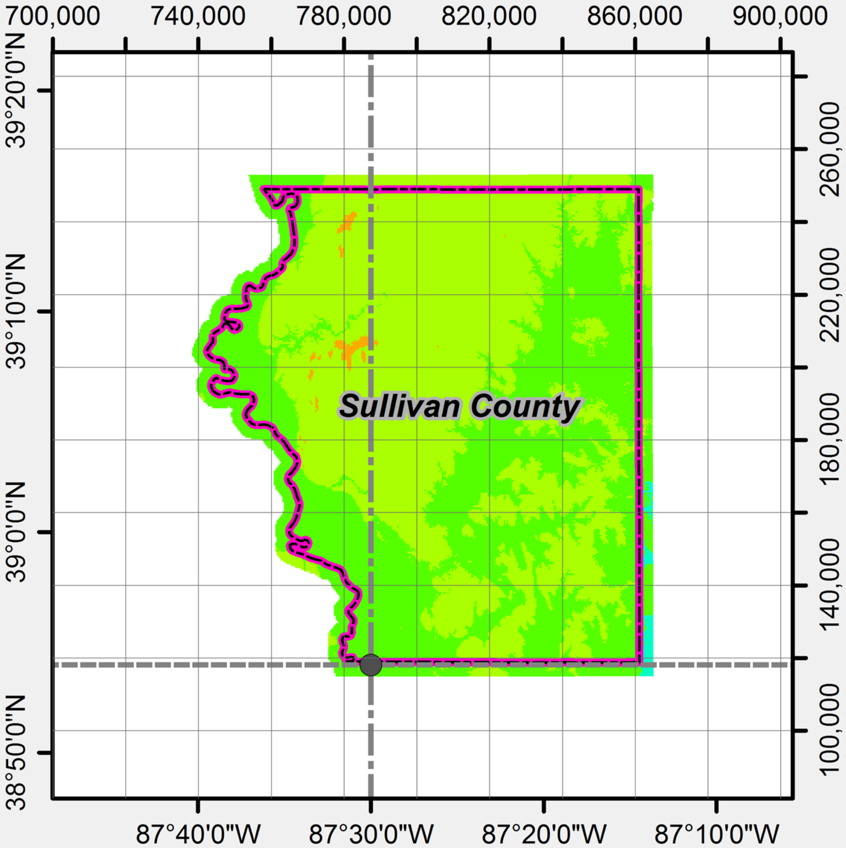

*Note: Map grid is shown in units of U.S. Survey feet.*

Scale 1 " = 10 miles


Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# SULLIVAN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°54'00"N |
| Central Meridian: | 87°30'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 017 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Sullivan County | 2 | 4 | 5 |

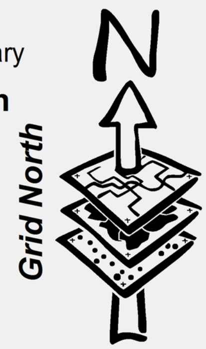
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

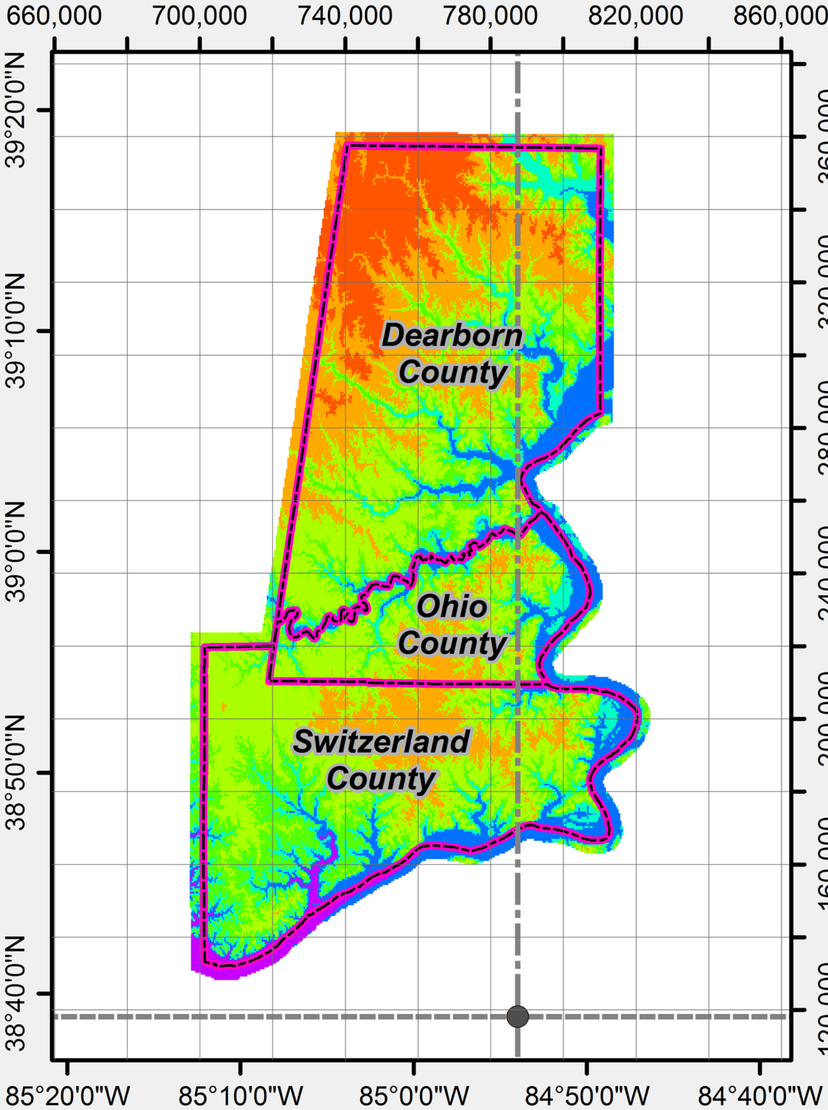
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# SWITZERLAND COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 38°39'00"N |
| Central Meridian: | 84°54'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 029 |

*Note: Dearborn, Ohio, and Switzerland Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Dearborn County | 7 | 12 | 13 |
| Ohio County | 6 | 13 | 13 |
| Switzerland County | 6 | 15 | 20 |

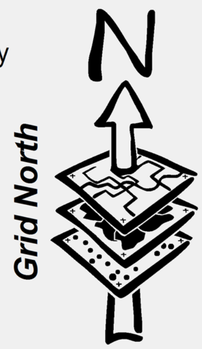
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

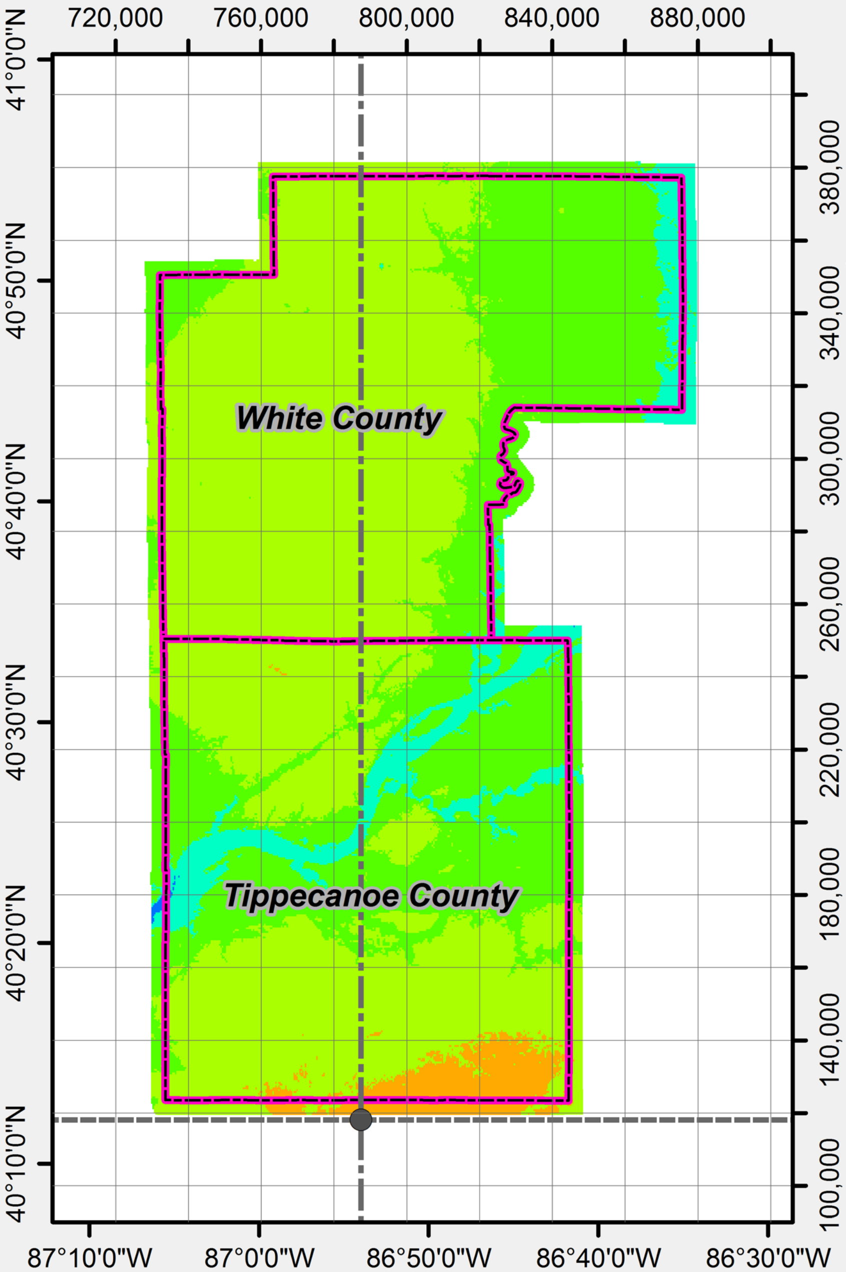
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# TIPPECANOE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°12'00"N
Central Meridian: 86°54'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 026

*Note: Tippecanoe and White Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Tippecanoe County | 3 | 6 | 9 |
| White County | 2 | 5 | 7 |

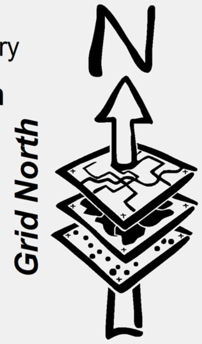
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

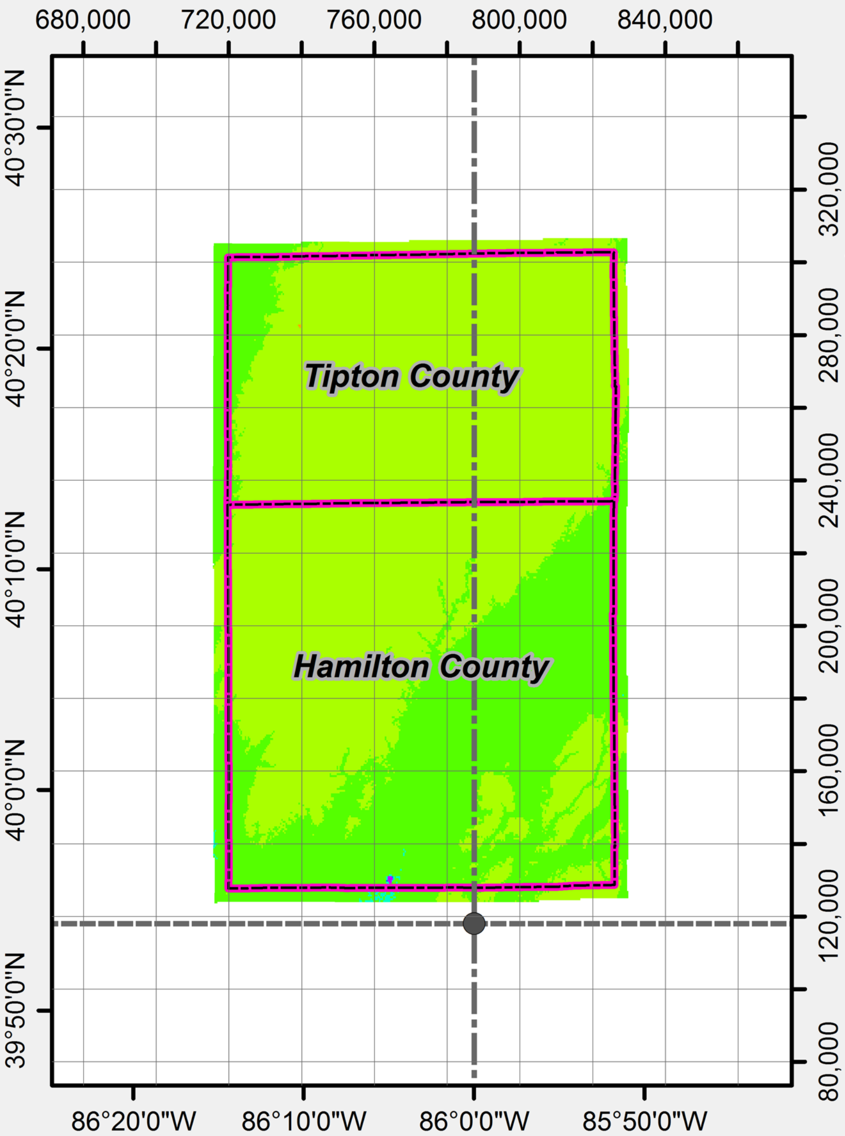
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# TIPTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°54'00"N |
| Central Meridian: | 86°00'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 034 |

*Note: Hamilton and Tipton Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Hamilton County | 1 | 3 | 4 |
| Tipton County | 1 | 2 | 3 |

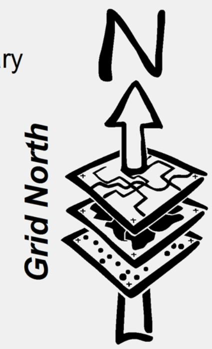
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

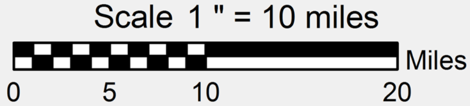
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

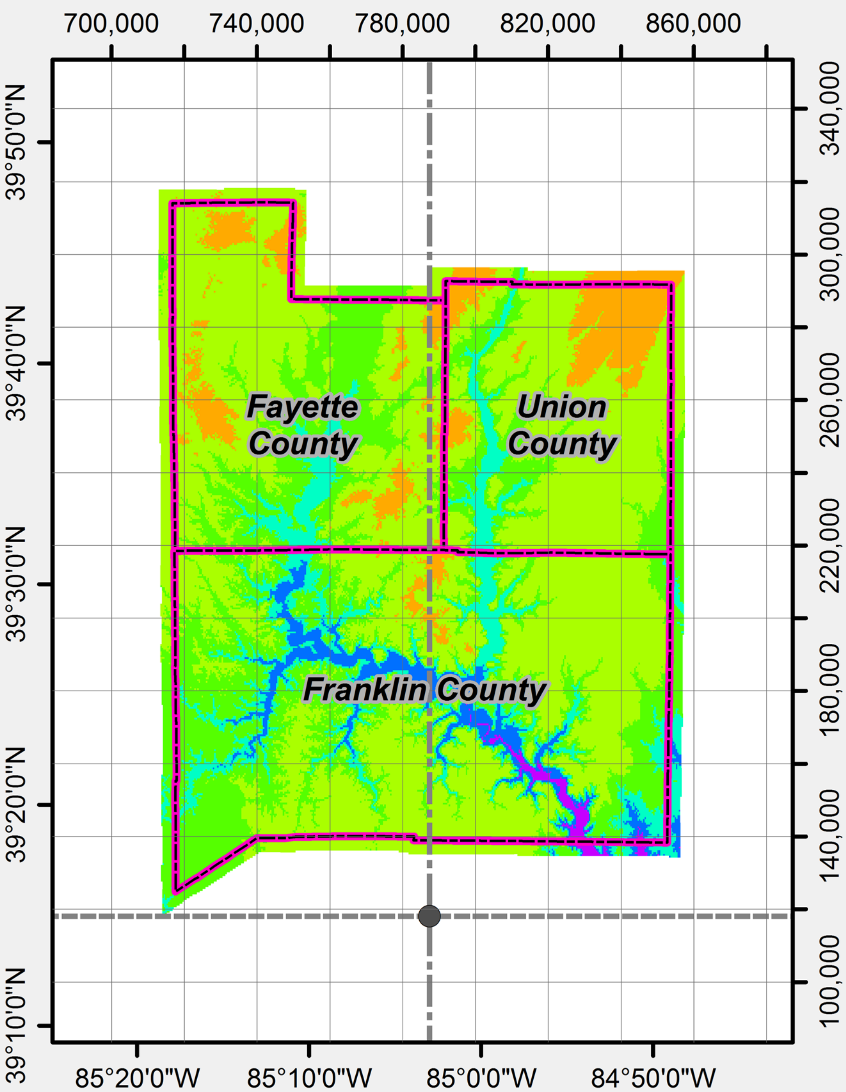
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# UNION COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°15'00"N |
| Central Meridian: | 85°03'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 038 |

*Note: Fayette, Franklin, and Union Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fayette County | 3 | 6 | 8 |
| Franklin County | 4 | 12 | 15 |
| Union County | 3 | 7 | 8 |

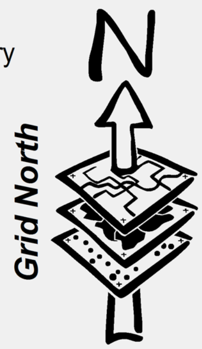
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

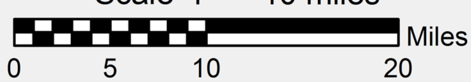
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

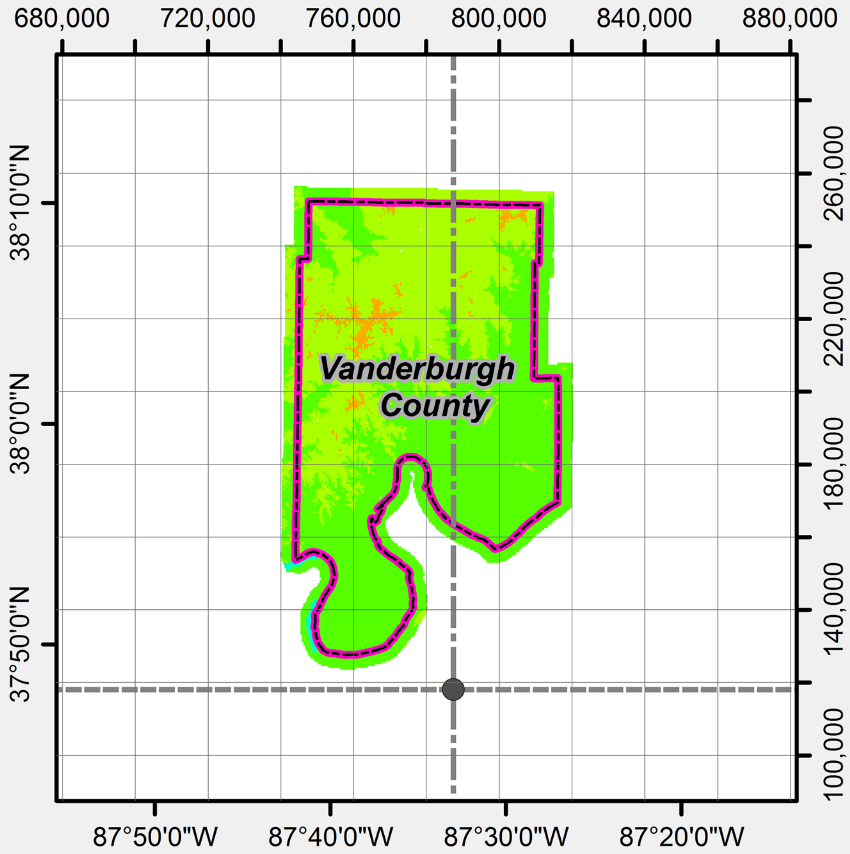
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# VANDERBURGH COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 37°48'00"N |
| Central Meridian: | 87°33'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 015 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Vanderburgh County | 2 | 4 | 6 |

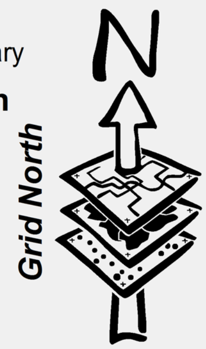
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

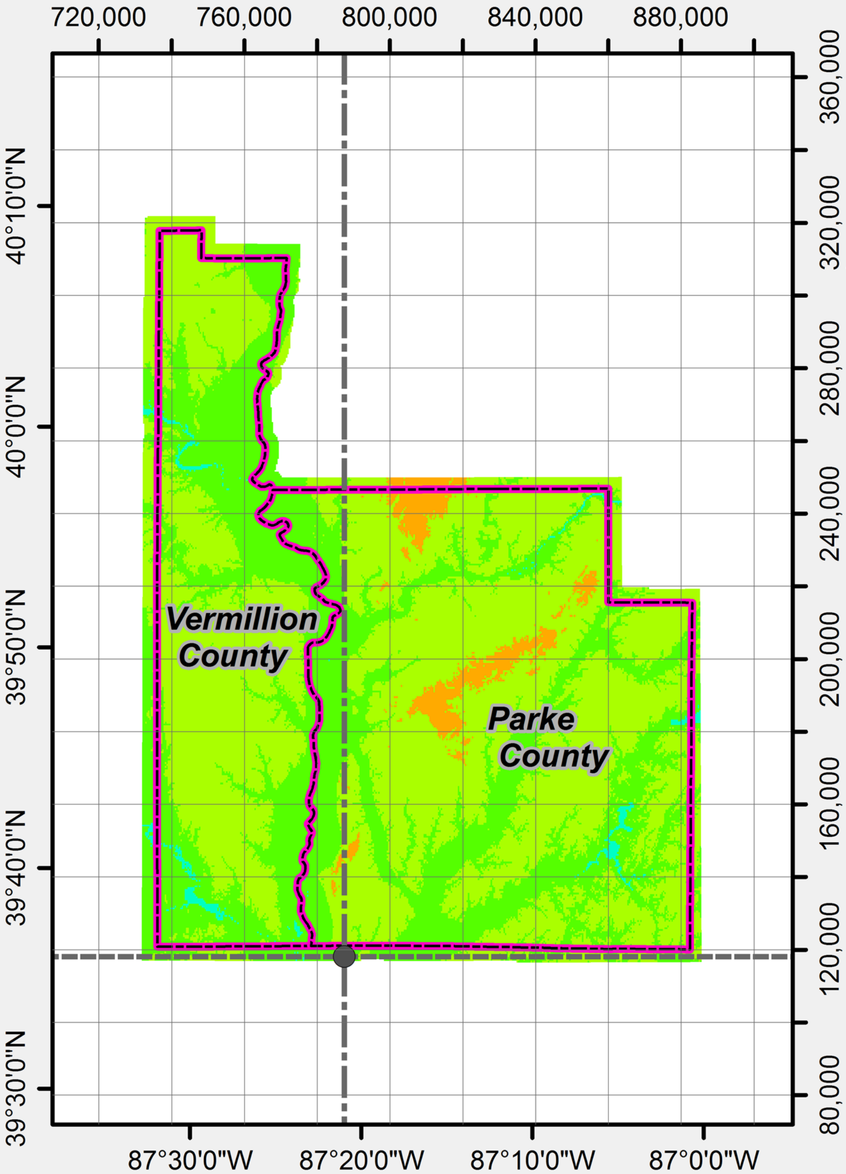
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# VERMILLION COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°36'00"N |
| Central Meridian: | 87°21'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 022 |

*Note: Parke and Vermillion Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Parke County | 3 | 5 | 6 |
| Vermillion County | 2 | 5 | 5 |

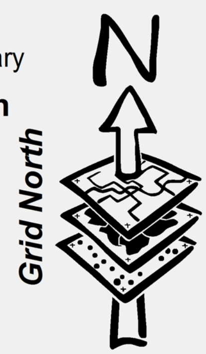
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

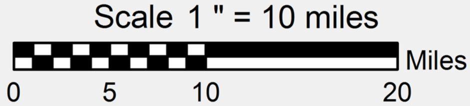
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

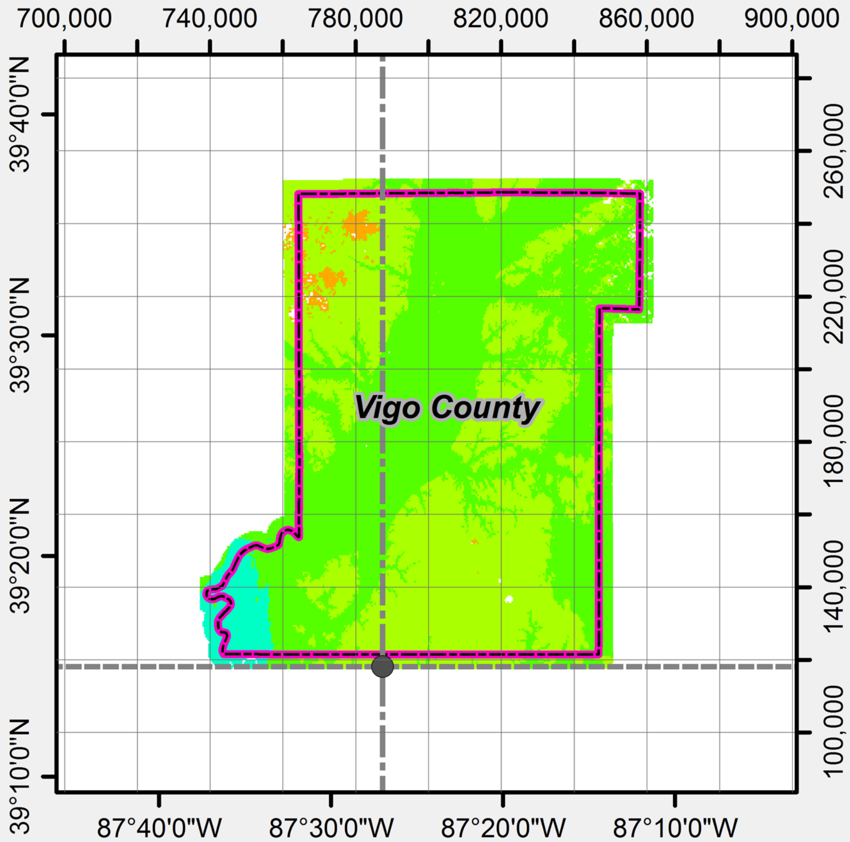
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# VIGO COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°15'00"N |
| Central Meridian: | 87°27'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 020 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Vigo County | 2 | 5 | 6 |

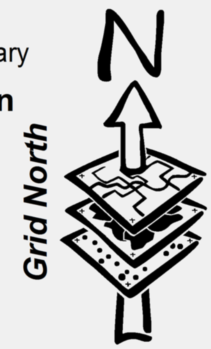
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

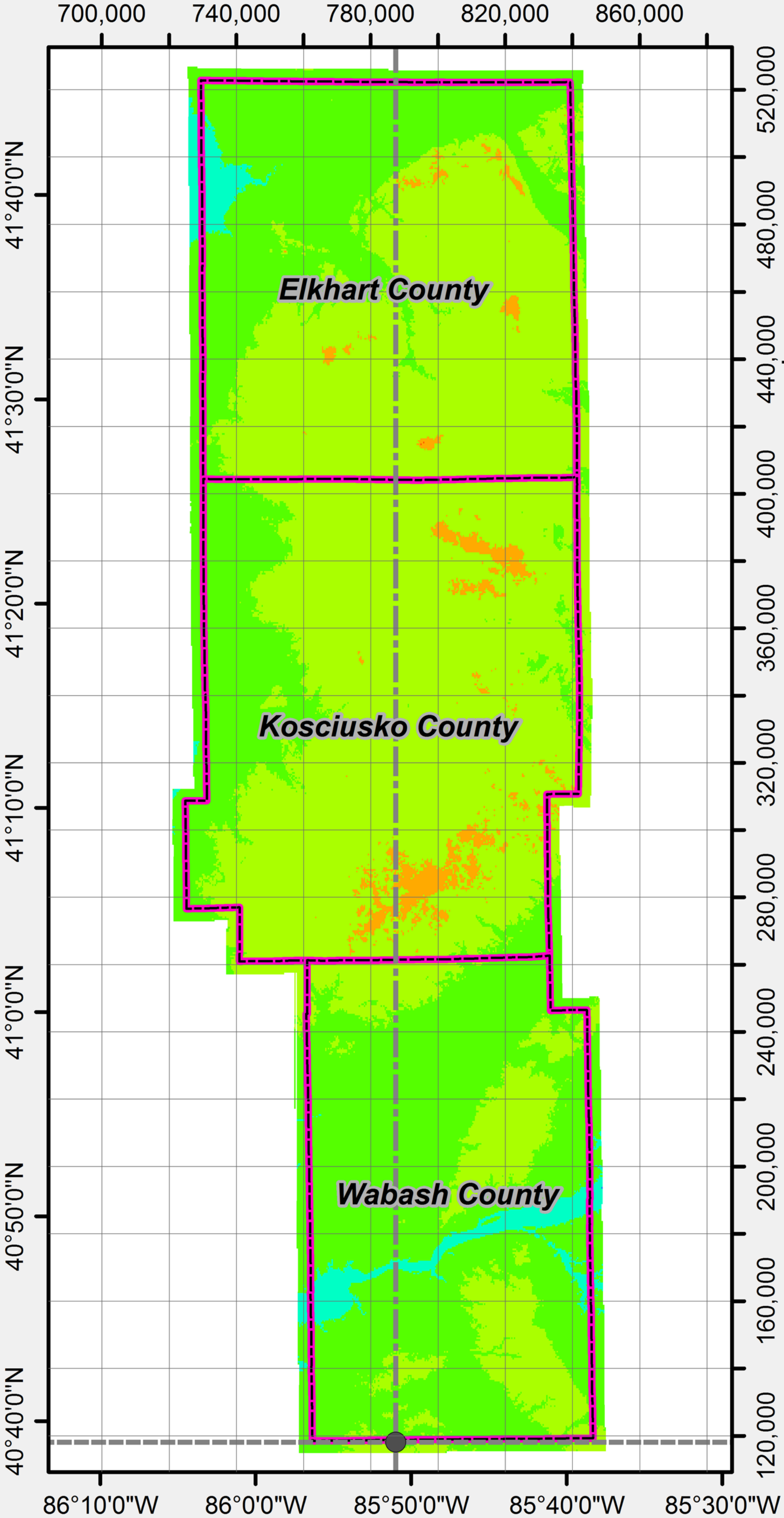
Scale 1 " = 10 miles

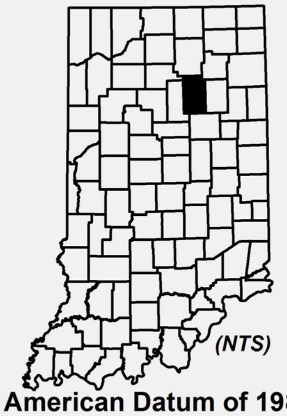
0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WABASH COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°39'00"N
Central Meridian: 85°51'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 033

*Note: Elkhart, Kosciusko, and Wabash Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Elkhart County | 2 | 5 | 6 |
| Koscisusko County | 2 | 5 | 6 |
| Wabash County | 2 | 5 | 8 |

*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

False Northing/Easting
Central Meridian
Origin Latitude
County Boundary

**Linear Distortion**

<-15 ppm
-15 to -10 ppm
-10 to -5 ppm
-5 to 0 ppm
0 to 5 ppm
5 to 10 ppm
10 to 15 ppm
>15 ppm

Grid North

*Note: Map grid is shown in units of U.S. Survey feet.*

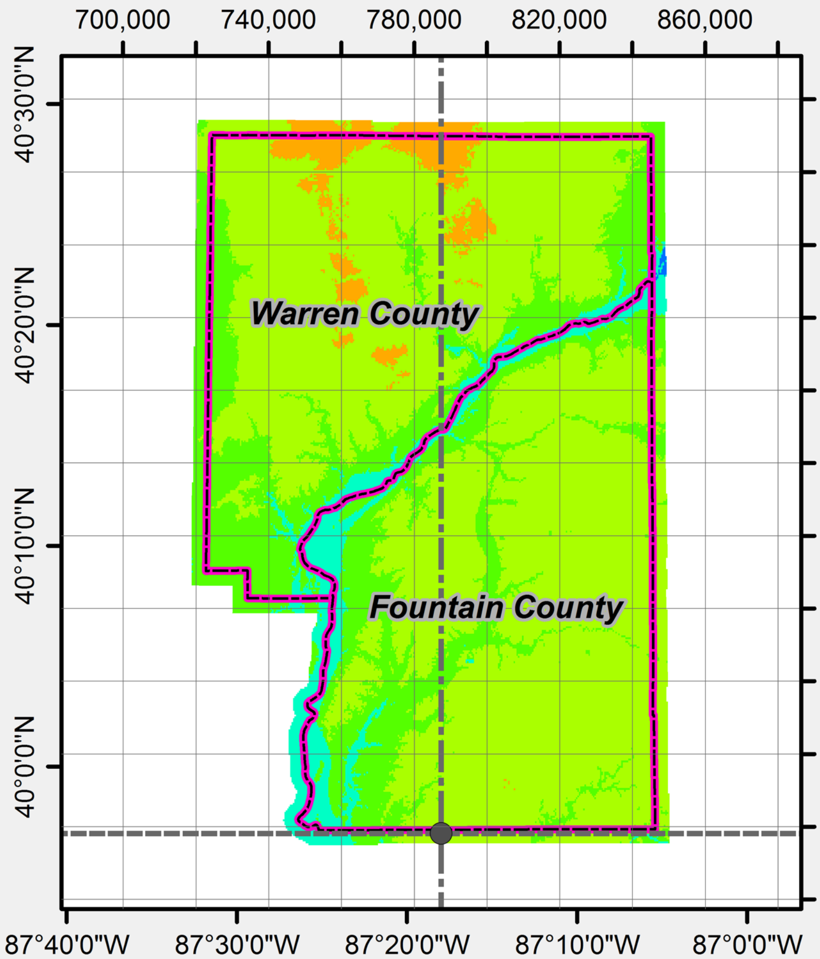
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WARREN COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°57'00"N |
| Central Meridian: | 87°18'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 025 |

*Note: Fountain and Warren Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Fountain County | 2 | 7 | 9 |
| Warren County | 3 | 7 | 8 |

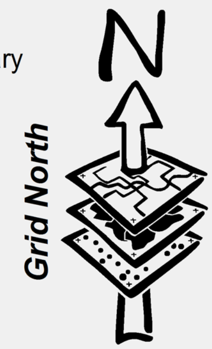
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

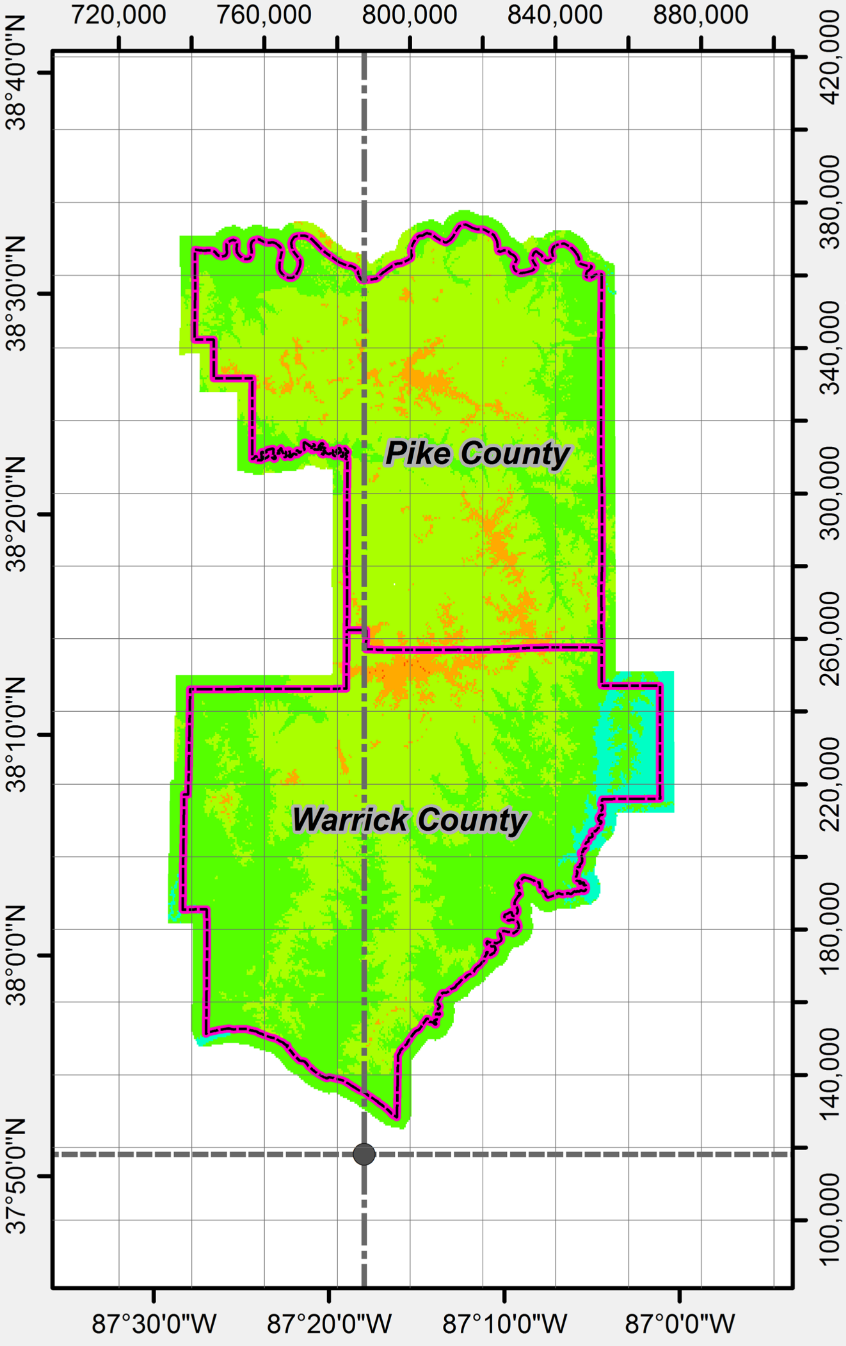
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WARRICK COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 37°51'00"N
Central Meridian: 87°18'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 015

*Note: Pike and Warrick Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Pike County | 2 | 5 | 7 |
| Warrick County | 2 | 6 | 8 |

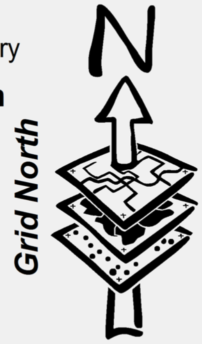
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

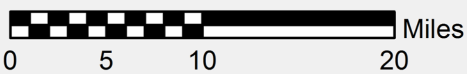
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

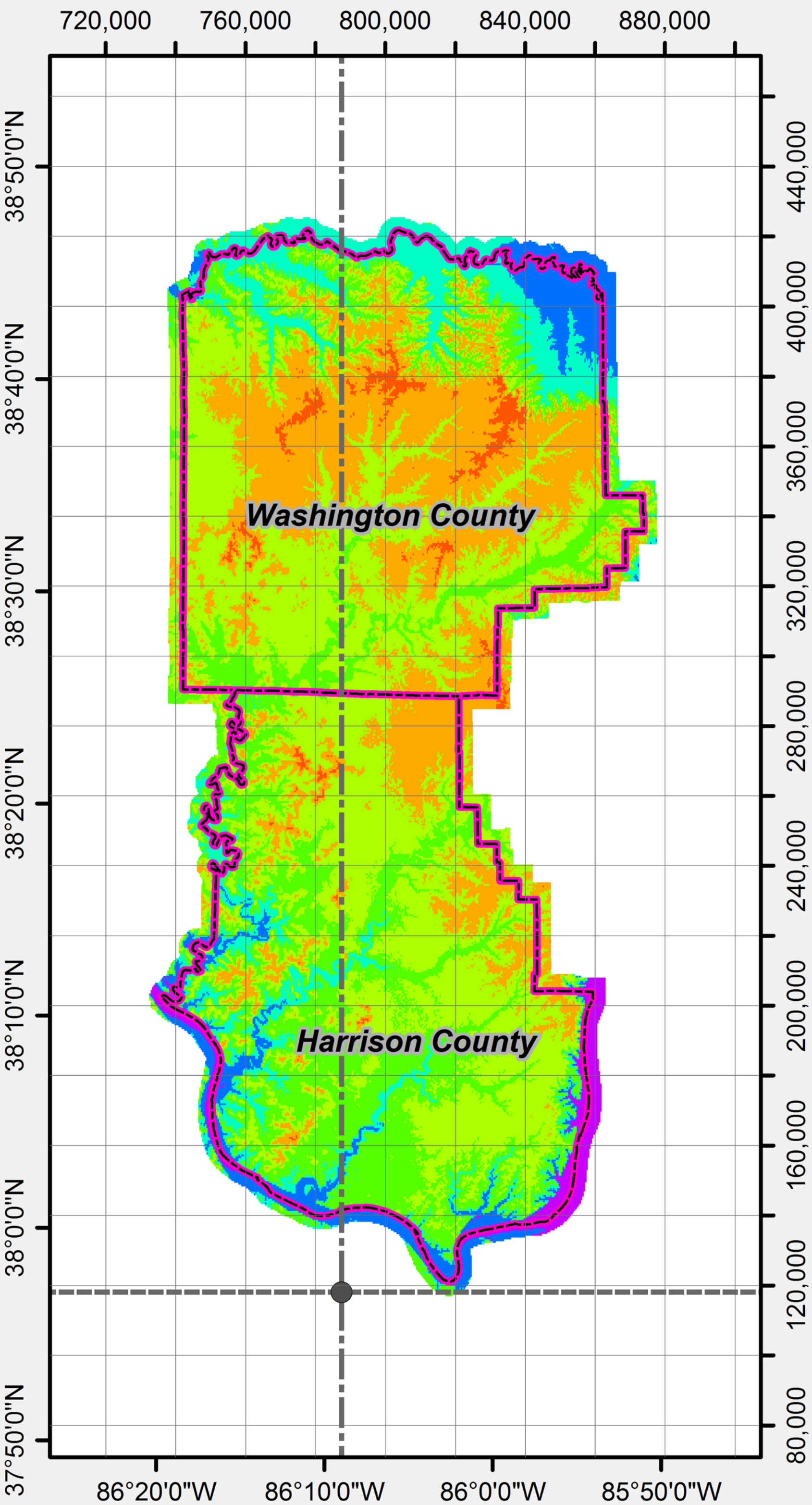
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WASHINGTON COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 37°57'00"N
Central Meridian: 86°09'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 027

*Note: Harrison and Washington Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Harrison County | 4 | 15 | 18 |
| Washington County | 5 | 11 | 13 |

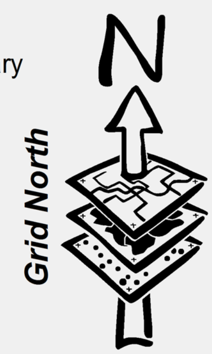
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

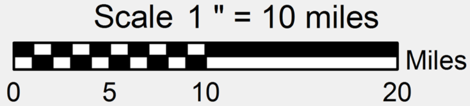
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

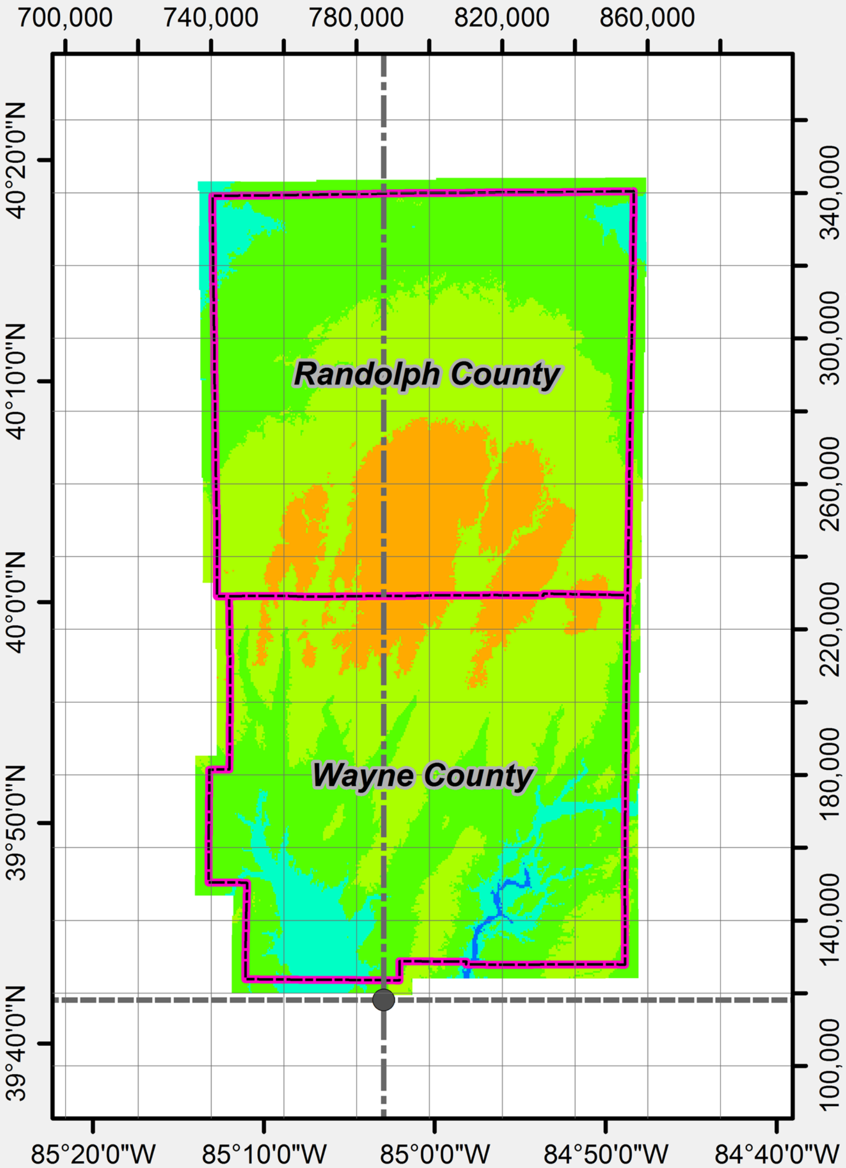
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WAYNE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 39°42'00"N |
| Central Meridian: | 85°03'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 044 |

*Note: Randolph and Wayne Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Randolph County | 3 | 7 | 8 |
| Wayne County | 3 | 7 | 9 |

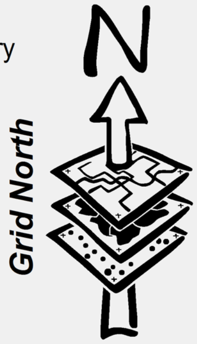
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

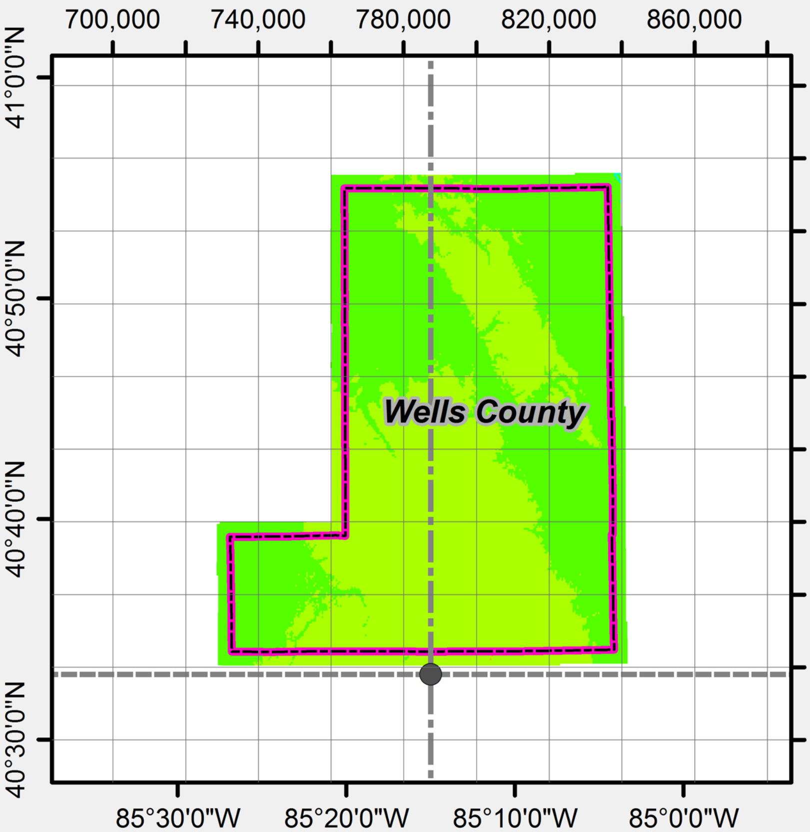
Scale 1 " = 10 miles

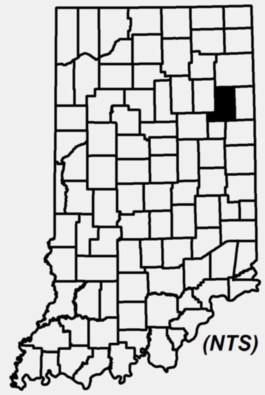
0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WELLS COUNTY

## INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)




**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°33'00"N |
| Central Meridian: | 85°15'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 034 |

**Sampled Linear Distortion Statistics**
**(absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Wells County | 1 | 3 | 4 |

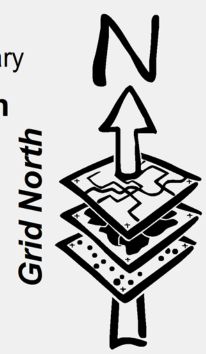
*(Note: 10 ppm = ± 0.053 feet/mile)*

## Legend

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

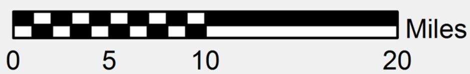
**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

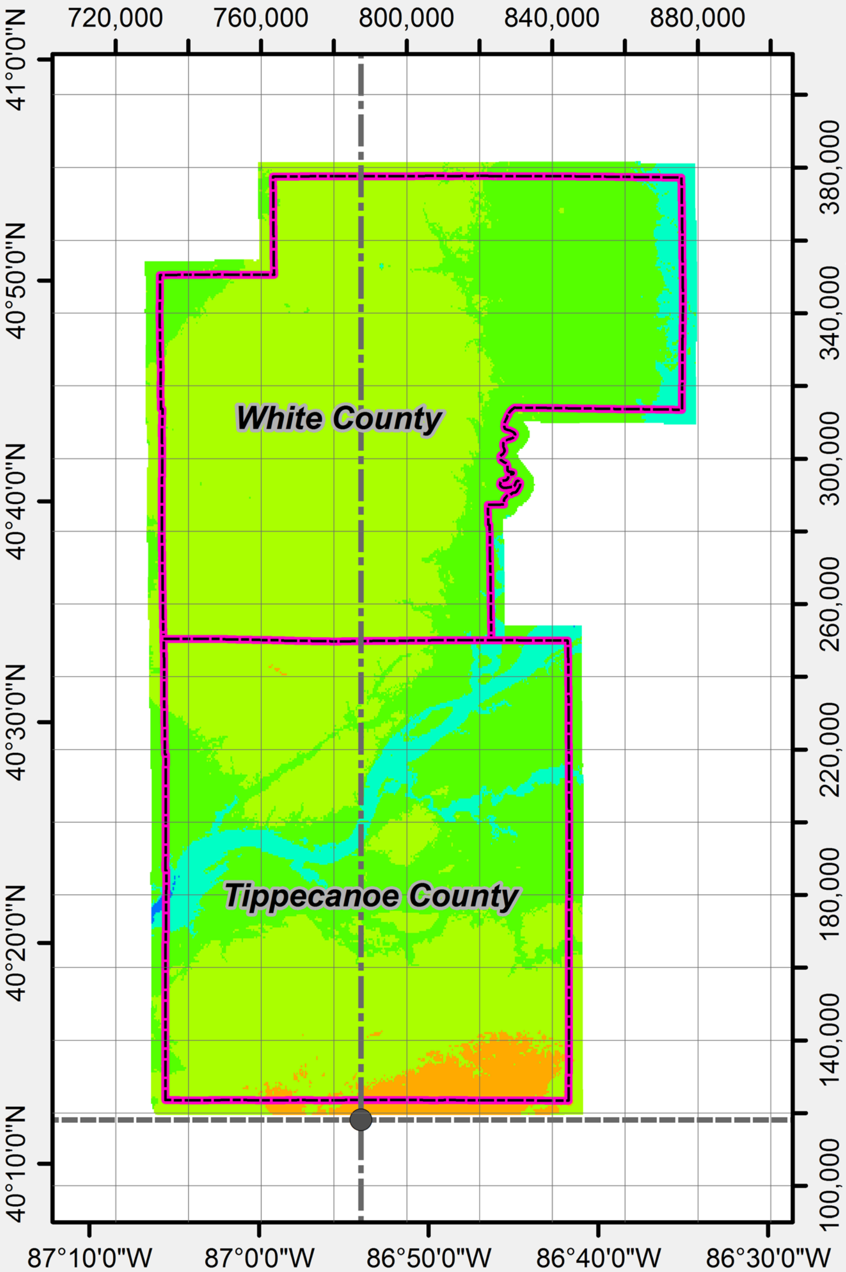
Scale 1 " = 10 miles




Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WHITE COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)





**North American Datum of 1983**
**Transverse Mercator Projection**

| | |
|---|---|
| Latitude of Grid Origin: | 40°12'00"N |
| Central Meridian: | 86°54'00"W |
| False Northing: | 36 000 m |
| False Easting: | 240 000 m |
| Central Meridian Scale: | 1.000 026 |

*Note: Tippecanoe and White Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Tippecanoe County | 3 | 6 | 9 |
| White County | 2 | 5 | 7 |

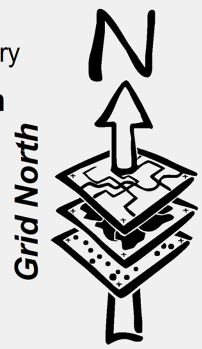
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

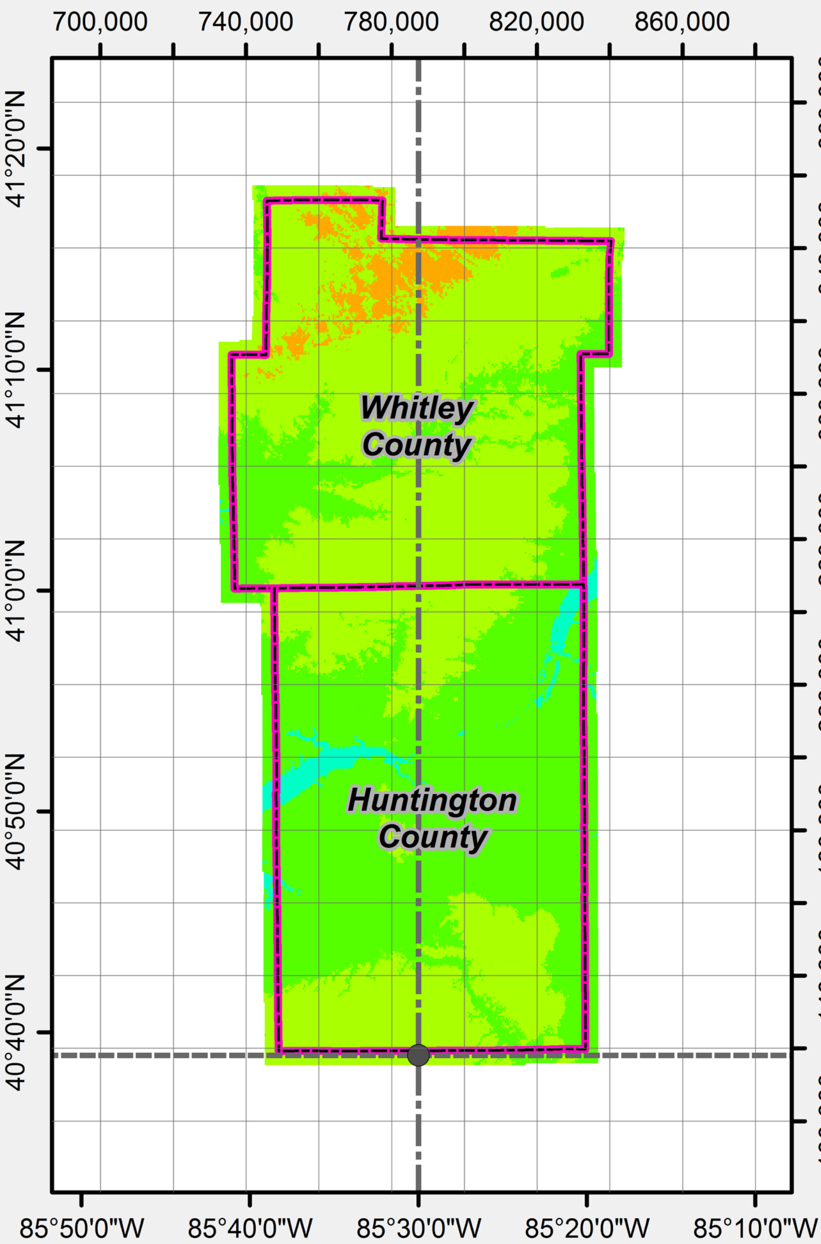
Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# WHITLEY COUNTY

INDIANA GEOSPATIAL COORDINATE SYSTEM (InGCS)


**North American Datum of 1983**
**Transverse Mercator Projection**

Latitude of Grid Origin: 40°39'00"N
Central Meridian: 85°30'00"W
False Northing: 36 000 m
False Easting: 240 000 m
Central Meridian Scale: 1.000 034

*Note: Huntington and Whitley Counties have identical projection parameters.*

**Sampled Linear Distortion Statistics (absolute values, in parts-per-million)**

| | Avg. | 95% | 99% |
|---|---|---|---|
| Huntington County | 2 | 5 | 6 |
| Whitley County | 2 | 5 | 7 |

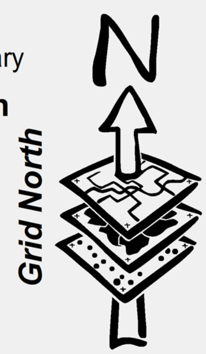
*(Note: 10 ppm = ± 0.053 feet/mile)*

## *Legend*

- False Northing/Easting
- Central Meridian
- Origin Latitude
- County Boundary

**Linear Distortion**

- <-15 ppm
- -15 to -10 ppm
- -10 to -5 ppm
- -5 to 0 ppm
- 0 to 5 ppm
- 5 to 10 ppm
- 10 to 15 ppm
- >15 ppm




*Note: Map grid is shown in units of U.S. Survey feet.*

Scale 1 " = 10 miles

0 5 10 20 Miles

Negative Linear Distortion: grid (map) length<horizontal ground length
Positive Linear Distortion: grid (map) length>horizontal ground length

# APPENDIX D

## InGCS Coordinates on NAD 83(2011) epoch 2010.00 NGS Control

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| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| ADAMS | LA0738 | X 224 | 40°44’44.98156” | 84°53’41.94969” | 705.261 | 189,462.7183 | 802,644.4057 |
| ADAMS | LA0737 | Y 224 | 40°44’42.72732” | 84°55’02.93787” | 712.522 | 189,231.4652 | 796,410.6363 |
| ALLEN | AJ8315 | 92 13 | 40°59’12.67351” | 85°11’35.68177” | 688.421 | 149,788.2051 | 747,850.5090 |
| ALLEN | AJ8314 | 92 16 | 40°58’07.89045” | 85°12’11.66679” | 680.638 | 143,236.1332 | 745,079.1875 |
| ALLEN | AJ8313 | FWA A | 40°58’28.70513” | 85°11’43.40097” | 686.898 | 145,339.0994 | 747,251.0901 |
| BARTHOLOMEW | DG9013 | 145 M | 39°04’54.41921” | 86°00’38.74966” | 492.407 | 147,938.6638 | 741,761.2831 |
| BARTHOLOMEW | AJ8289 | BAK A | 39°16’12.24902” | 85°53’13.22698” | 541.305 | 216,482.4668 | 776,922.0468 |
| BARTHOLOMEW | AJ8290 | BAK B | 39°15’45.70939” | 85°54’06.78414” | 539.041 | 213,799.2443 | 772,708.3771 |
| BARTHOLOMEW | AJ8291 | BAK C | 39°15’24.43476” | 85°53’20.50734” | 537.962 | 211,644.8434 | 776,347.3798 |
| BARTHOLOMEW | AE8493 | COL MUN AIRPORT | 39°15’09.53630” | 85°53’50.27784” | 539.999 | 210,138.5305 | 774,004.7785 |
| BARTHOLOMEW | JZ2219 | H 271 | 39°08’57.12398” | 85°55’13.44518” | 500.590 | 172,462.3724 | 767,433.0021 |
| BARTHOLOMEW | JZ2225 | K 268 | 39°13’26.47024” | 85°50’24.88052” | 526.173 | 199,706.9656 | 790,163.8620 |
| BARTHOLOMEW | JZ2181 | Q 268 | 39°19’13.66429” | 85°46’16.02783” | 625.596 | 234,845.8213 | 809,717.6642 |
| BENTON | LB1326 | D 124 | 40°38’06.38084” | 87°15’59.25056” | 700.963 | 185,551.5434 | 796,709.7233 |
| BLACKFORD | LA0940 | G 215 | 40°33’07.81901” | 85°21’08.16263” | 764.454 | 301,064.3602 | 800,665.0768 |
| BOONE | KA2086 | BOO 54 | 39°57’45.42818” | 86°14’34.31897” | 789.867 | 250,310.6941 | 859,481.2341 |
| BOONE | LB0881 | C 113 | 40°04’39.96137” | 86°37’11.38878” | 777.643 | 292,177.9001 | 753,864.9097 |
| BOONE | LB2708 | TERRY | 40°02’22.76753” | 86°15’06.33550” | 810.103 | 278,368.8268 | 856,909.9952 |
| BOONE | LB2709 | TERRY AZ MK | 40°01’50.98069” | 86°15’03.99353” | 808.227 | 275,152.6653 | 857,101.1443 |
| BOONE | DI4046 | TYQ A | 40°01’23.08135” | 86°15’11.21426” | 807.781 | 272,327.8322 | 856,547.2608 |
| BOONE | LB0624 | U 80 | 40°00’09.54551” | 86°28’48.44614” | 834.555 | 264,791.2272 | 792,968.5254 |
| BROWN | AE8502 | SC 13 | 39°10’09.72540” | 86°14’14.85535” | 892.944 | 179,806.6926 | 805,132.4241 |
| CARROLL | LB0972 | M 119 | 40°31’58.23235” | 86°38’20.33181” | 575.839 | 166,507.9756 | 790,463.0505 |
| CASS | LB2395 | ANCHOR | 40°43’05.74364” | 86°16’47.61258” | 613.431 | 179,436.7788 | 820,695.4346 |
| CLARK | DH2918 | CORPS OF DISCOVERY… | 38°16’33.70978” | 85°45’47.04281” | 335.570 | 164,049.2825 | 740,585.5667 |

| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| CLARK | AD8759 | JVY A | 38°21'24.92002" | 85°44'14.17576" | 348.769 | 193,497.0985 | 748,035.1252 |
| CLARK | AE8496 | JVY B | 38°22'03.18042" | 85°44'26.64563" | 348.441 | 197,369.1793 | 747,047.7048 |
| CLARK | AJ8294 | JVY C | 38°22'31.42165" | 85°44'12.78207" | 366.344 | 200,224.5267 | 748,156.1194 |
| CLARK | HZ1373 | V 49 | 38°19'06.92298" | 85°45'04.45027" | 360.780 | 179,543.0426 | 744,007.5168 |
| CLAY | KA1153 | B 70 | 39°29'59.19990" | 87°09'37.58135" | 565.685 | 245,517.5554 | 784,454.0046 |
| CLAY | KA1790 | PRAIRIE CITY | 39°26'45.83332" | 87°07'33.31767" | 514.946 | 225,952.7266 | 794,200.2397 |
| CLINTON | LB0534 | HILLISBURG | 40°17'18.65545" | 86°20'25.94181" | 807.574 | 168,678.7541 | 859,786.7645 |
| CRAWFORD | JA0279 | Y 312 | 38°20'38.43334" | 86°24'45.63071" | 471.721 | 206,986.0714 | 812,446.4598 |
| DAVIESS | JA1630 | DAVIESS | 38°41'43.34257" | 87°07'48.19058" | 361.738 | 207,477.0005 | 778,822.0929 |
| DEARBORN | JZ2060 | ALSACE | 39°15'30.32748" | 85°00'21.52064" | 916.219 | 339,734.5518 | 757,389.3420 |
| DEARBORN | JZ2794 | G 359 | 39°08'48.32143" | 84°51'30.19364" | 414.592 | 299,044.8839 | 799,202.5352 |
| DECATUR | JZ2825 | DECATUR AZ MK | 39°19'20.59324" | 85°31'20.25840" | 792.695 | 199,139.9039 | 823,530.9389 |
| DECATUR | JZ1981 | N 259 | 39°19'25.73802" | 85°19'32.64811" | 872.377 | 199,799.4596 | 879,140.0108 |
| DEKALB | AH8901 | DEKALB | 41°18'30.18388" | 85°03'58.08579" | 765.704 | 139,405.4701 | 755,491.5924 |
| DELEWARE | LA1263 | A 248 | 40°08'56.73001" | 85°29'58.24262" | 824.529 | 154,225.2912 | 759,580.1326 |
| DELEWARE | AD8773 | AP 1965 STA A2 | 40°14'44.99934" | 85°24'10.39114" | 816.875 | 189,453.8505 | 786,594.2065 |
| DELEWARE | AD8774 | AP 1965 STA B2 | 40°14'08.25075" | 85°23'24.28331" | 822.393 | 185,735.0844 | 790,170.1099 |
| DELEWARE | LA2450 | MIE ARP | 40°14'26.41783" | 85°23'43.04207" | 822.157 | 187,573.4477 | 788,715.1231 |
| DELEWARE | LA1231 | P 217 | 40°19'15.88582" | 85°27'37.93829" | 781.130 | 216,873.1586 | 770,518.4392 |
| DELEWARE | LA1200 | P 220 | 40°19'34.80995" | 85°17'08.86440" | 824.792 | 218,803.0498 | 819,244.2108 |
| DUBOIS | CG8225 | JASPER N BASE RM 1 | 38°26'40.39435" | 86°56'14.26291" | 387.217 | 207,173.9421 | 791,038.9084 |
| DUBOIS | JA2135 | STINSON 2 | 38°14'54.24208" | 86°57'05.11491" | 421.879 | 135,736.6300 | 786,991.9514 |
| ELKHART | AJ8274 | EKM A | 41°43'23.94321" | 85°59'31.36194" | 665.366 | 509,230.1930 | 748,621.3078 |
| ELKHART | AJ8275 | EKM B | 41°43'19.22803" | 86°00'52.80536" | 660.622 | 508,763.9043 | 742,444.2015 |
| ELKHART | AJ8276 | EKM C | 41°42'36.45541" | 85°59'31.27019" | 658.381 | 504,423.2679 | 748,620.3368 |

| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| ELKHART | DI3637 | GSH A | 41°31'26.27333" | 85°47'35.13390" | 710.501 | 436,558.9927 | 802,983.7683 |
| ELKHART | DI3694 | GSH B | 41°31'27.39022" | 85°47'00.31300" | 713.686 | 436,673.9374 | 805,632.4399 |
| ELKHART | DI3695 | GSH C | 41°31'26.18389" | 85°48'19.84349" | 706.705 | 436,547.9446 | 799,582.8008 |
| ELKHART | MD1344 | J 160 | 41°31'47.29418" | 85°49'30.65634" | 700.094 | 438,682.5851 | 794,195.5884 |
| ELKHART | MD1356 | W 8 RESET | 41°37'32.59827" | 85°54'13.73596" | 671.925 | 473,638.4626 | 772,685.9916 |
| FAYETTE | JZ1782 | J 263 | 39°38'15.00253" | 85°03'14.02500" | 901.294 | 259,262.9527 | 786,302.7403 |
| FAYETTE | JZ1759 | MARSHALL | 39°37'12.65400" | 85°15'54.15168" | 1,059.522 | 253,026.5075 | 726,818.3506 |
| FLOYD | HZ1322 | E 278 | 38°21'40.63431" | 85°49'00.93101" | 434.448 | 195,130.6380 | 725,196.5932 |
| FLOYD | HZ1348 | EDWARD 2 | 38°17'01.83100" | 85°54'22.99645" | 807.905 | 166,998.5300 | 699,449.5783 |
| FOUNTAIN | LB1704 | W 96 | 40°13'09.98834" | 87°10'20.00968" | 577.650 | 216,293.2788 | 823,083.8961 |
| FRANKLIN | JZ1991 | CH 29 | 39°19'23.78774" | 85°12'29.66838" | 864.542 | 144,839.7405 | 742,630.4244 |
| FULTON | LB0165 | 106 | 40°58'52.47936" | 86°14'40.11175" | 692.046 | 147,716.7804 | 802,731.4465 |
| FULTON | DH9108 | RCR A | 41°03'53.11468" | 86°10'52.51710" | 674.014 | 178,162.0114 | 820,146.5876 |
| FULTON | DH9110 | RCR B | 41°03'59.51569" | 86°11'26.56342" | 674.083 | 178,806.4642 | 817,537.7159 |
| FULTON | DH9109 | RCR C | 41°03'46.58935" | 86°10'23.19179" | 675.478 | 177,504.7301 | 822,393.9635 |
| GIBSON | JA1598 | L 356 | 38°10'20.88585" | 87°28'08.49727" | 354.104 | 126,343.1877 | 839,428.1639 |
| GRANT | LA1380 | G 204 | 40°28'43.49567" | 85°49'29.63111" | 751.468 | 165,040.9485 | 752,652.7406 |
| GRANT | DM4009 | MZZ A | 40°29'31.11999" | 85°40'36.98576" | 743.909 | 169,836.9036 | 793,814.0373 |
| GRANT | DM4045 | MZZ B | 40°29'44.99648" | 85°40'23.73171" | 736.777 | 171,241.5307 | 794,837.6766 |
| GRANT | DM4046 | MZZ C | 40°29'04.56370" | 85°41'03.97646" | 742.062 | 167,148.8817 | 791,729.0937 |
| GREENE | KA0405 | S 280 | 39°00'57.25623" | 86°50'24.41309" | 564.641 | 324,325.2984 | 861,245.9983 |
| HAMILTON | LB2498 | ARCADA | 40°11'15.13980" | 86°01'24.71806" | 756.035 | 222,861.6338 | 780,824.8298 |
| HAMILTON | AH8320 | EAGLE CEM | 40°00'45.06185" | 86°13'35.31715" | 761.514 | 159,180.1474 | 723,958.9265 |
| HAMILTON | LB2522 | EKIN | 40°12'11.09987" | 86°09'41.31525" | 799.031 | 228,564.8085 | 742,293.0309 |
| HAMILTON | KA1908 | FRAZIER | 39°58'12.08440" | 86°00'30.45617" | 709.638 | 143,619.2620 | 785,028.6910 |

| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| HAMILTON | LB2735 | HAM 51 | 40°04’03.48757” | 86°11’11.76824” | 820.605 | 179,233.9151 | 735,170.7651 |
| HAMILTON | AE8503 | HM 18 | 40°02’33.48818” | 86°00’41.19530” | 658.352 | 170,071.8865 | 784,195.9416 |
| HAMILTON | LB2736 | LEE 9 | 40°01’39.71072” | 86°13’16.94967” | 799.385 | 164,706.7219 | 725,401.8697 |
| HANCOCK | JZ2401 | A 242 | 39°54’06.71211” | 85°35’01.51204” | 907.928 | 209,933.9279 | 848,073.1639 |
| HANCOCK | JZ2521 | HAN G 5 | 39°47’15.10078” | 85°42’52.73418” | 781.511 | 168,220.3407 | 811,387.1800 |
| HANCOCK | DM4043 | MQJ A | 39°50’18.32650” | 85°54’37.69699” | 746.928 | 186,768.8537 | 756,376.0590 |
| HANCOCK | DM4044 | MQJ B | 39°50’37.12540” | 85°53’31.69569” | 742.161 | 188,665.3102 | 761,526.7145 |
| HANCOCK | AE8499 | MT COMFORT | 39°50’34.02715” | 85°54’53.50674” | 740.901 | 188,359.1793 | 755,144.7965 |
| HANCOCK | DG9008 | NPAL | 39°44’57.78765” | 85°54’49.84133” | 728.558 | 154,334.5032 | 755,387.4422 |
| HANCOCK | JZ3390 | PALESTINE | 39°44’43.04664” | 85°54’43.36542” | 731.071 | 152,842.2251 | 755,891.4082 |
| HANCOCK | JZ2483 | V 240 | 39°54’00.89844” | 85°50’34.91651” | 760.635 | 209,275.0896 | 775,325.9641 |
| HANCOCK | JZ2455 | V 241 | 39°54’06.21122” | 85°39’29.20207” | 840.582 | 209,841.4150 | 827,210.2261 |
| HARRISON | AE8504 | S 51 | 38°12’30.00399” | 86°07’35.43236” | 439.546 | 212,189.9798 | 794,150.2430 |
| HENDRICKS | AE8491 | AVON | 39°45’40.88847” | 86°24’11.94690” | 720.222 | 176,903.9857 | 814,581.5942 |
| HENDRICKS | KA1665 | K 352 | 39°41’00.75783” | 86°30’28.13063” | 713.676 | 148,543.1689 | 785,200.6368 |
| HENDRICKS | AE8498 | LIZTON | 39°53’36.25787” | 86°32’13.56037” | 856.334 | 224,994.6850 | 776,989.4045 |
| HENRY | AE8464 | DERROW RM 3 | 39°59’58.16091” | 85°27’42.81395” | 952.636 | 208,997.5934 | 784,067.9193 |
| HENRY | JZ1518 | METRO | 39°48’17.97259” | 85°19’11.12190” | 977.226 | 138,169.6807 | 823,994.6946 |
| HOWARD | AD8762 | AP 1964 STA A2 | 40°31’58.75566” | 86°03’41.39898” | 709.283 | 184,789.3890 | 812,001.4210 |
| HUNTINGTON | LA0906 | E 214 | 40°45’23.26629” | 85°22’25.44435” | 747.167 | 156,924.1562 | 822,382.6644 |
| JACKSON | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| JASPER | ME2545 | AIX 2 | 41°01’34.30831” | 87°09’05.90777” | 579.458 | 236,964.1725 | 773,150.6004 |
| JASPER | CM2705 | ASPHALT RM 3 | 41°05’59.77928” | 86°58’30.68102” | 586.839 | 263,853.4362 | 821,800.8136 |
| JASPER | ME1360 | C 156 | 41°11’39.29711” | 87°01’46.74478” | 555.688 | 298,200.4153 | 806,761.9927 |
| JASPER | LB2146 | MEODEL | 40°45’56.30406” | 87°12’59.68886” | 631.974 | 142,046.8858 | 755,105.3571 |

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|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| JASPER | LB2139 | MOODY | 40°59’33.47966” | 87°04’01.13434” | 621.226 | 224,732.4852 | 796,515.4016 |
| JASPER | CM4549 | SHARON AZ MK | 40°50’40.46093” | 87°09’15.68880” | 570.363 | 170,788.8929 | 772,359.7714 |
| JASPER | ME2543 | VIRGIE | 41°06’53.93901” | 87°09’05.70481” | 577.781 | 269,314.6700 | 773,185.2922 |
| JAY | LA0533 | L 227 RESET | 40°32’29.00171” | 84°55’48.50179” | 744.569 | 206,062.2434 | 806,817.6518 |
| JEFFERSON | AE8506 | JPG 1 | 38°49’41.13808” | 85°22’55.05903” | 784.884 | 219,397.3011 | 778,294.3178 |
| JEFFERSON | AE8505 | MADP | 38°45’36.74696” | 85°27’47.14343” | 697.728 | 194,690.0024 | 755,148.4032 |
| JENNINGS | JZ2113 | NORTH VERNON | 39°00’25.09356” | 85°37’28.97262” | 612.925 | 193,542.0470 | 837,213.6701 |
| JOHNSON | KA1968 | DECALB | 39°27’24.44666” | 86°01’07.96016” | 619.336 | 175,249.2533 | 824,426.1683 |
| JOHNSON | DO8799 | HFY A | 39°37’46.44455” | 86°05’19.42551” | 708.365 | 238,165.5305 | 804,658.7137 |
| JOHNSON | DO8800 | HFY B | 39°38’04.27839” | 86°05’16.90660” | 707.489 | 239,970.2238 | 804,854.5593 |
| JOHNSON | DO8801 | HFY C | 39°37’21.42597” | 86°05’23.76908” | 709.953 | 235,633.7410 | 804,320.5463 |
| KNOX | JA0881 | Q 314 | 38°41’02.76465” | 87°27’22.31114” | 424.553 | 221,579.7894 | 785,630.7855 |
| KOSCIUSKO | AH8406 | KOKU | 41°22’45.66618” | 85°42’04.51806” | 807.718 | 383,893.3160 | 828,223.6429 |
| KOSCIUSKO | MD1919 | WARPORT AZ MK | 41°17’04.95807” | 85°50’46.85132” | 727.669 | 349,372.7357 | 788,403.8702 |
| LAGRANGE | MD1495 | BRUSHY | 41°37’48.15660” | 85°16’13.57015” | 884.713 | 256,645.4525 | 836,492.4804 |
| LAGRANGE | MD1505 | TT 19 D USGS 1947 | 41°37’34.39691” | 85°29’50.09791” | 807.147 | 255,205.0897 | 774,481.3206 |
| LAKE | ME3214 | GRIPORT | 41°31’10.49339” | 87°23’54.37708” | 518.808 | 416,737.4796 | 787,827.7505 |
| LAKE | ME2580 | HAMMOND S BASE | 41°29’56.31947” | 87°31’04.88418” | 519.297 | 409,251.6738 | 755,067.6749 |
| LAKE | ME3364 | STOCKTON 2 RESET | 41°37’44.86578” | 87°23’40.01485” | 480.996 | 456,656.2607 | 788,917.7570 |
| LAPORTE | ME0558 | G 335 | 41°25’31.72371” | 86°52’19.41610” | 619.749 | 309,602.0586 | 753,924.0309 |
| LAPORTE | ME2431 | KINGSBURY | 41°32’13.73383” | 86°42’02.92957” | 644.575 | 350,273.5130 | 800,866.5902 |
| LAPORTE | ME3218 | LAPPORT | 41°34’31.72883” | 86°43’56.58368” | 693.211 | 364,238.1227 | 792,220.0999 |
| LAPORTE | ME3222 | MICPORT | 41°41’57.97068” | 86°49’22.59213” | 541.675 | 409,415.6196 | 767,479.3016 |
| LAPORTE | DM4010 | PPO A | 41°34’21.85210” | 86°44’10.98370” | 691.160 | 363,238.1921 | 791,125.7516 |
| LAPORTE | DM4047 | PPO B | 41°33’57.58772” | 86°44’18.05534” | 685.163 | 360,782.0502 | 790,588.5644 |

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|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| LAWRENCE | JA0132 | V 281 | 38°50'18.09569" | 86°26'07.65274" | 618.499 | 387,026.6176 | 805,785.0860 |
| MADISON | AJ8261 | AID A | 40°06'22.46054" | 85°36'35.85396" | 795.031 | 284,370.8273 | 840,561.6641 |
| MADISON | AJ8262 | AID B | 40°06'40.87528" | 85°37'23.99809" | 761.846 | 286,226.6170 | 836,816.9138 |
| MADISON | LA2440 | ALEPORT | 40°13'57.61116" | 85°38'23.75354" | 785.730 | 330,414.3248 | 832,094.3035 |
| MADISON | LA2448 | ANDPORT | 40°06'36.54922" | 85°36'57.95709" | 780.021 | 285,792.9378 | 838,841.1882 |
| MADISON | LA2449 | ANDPORT AZ MK | 40°06'45.08045" | 85°37'20.46650" | 765.799 | 286,652.7112 | 837,090.4660 |
| MARION | KA1653 | F 350 | 39°45'51.75497" | 86°18'09.37991" | 672.371 | 287,303.9868 | 744,497.6467 |
| MARION | KA2080 | IMAGIS 16 | 39°53'01.42473" | 86°02'03.81659" | 731.721 | 330,766.9915 | 819,844.5427 |
| MARION | KA2078 | IMAGIS 32 | 39°48'38.95515" | 86°15'21.60402" | 640.356 | 304,204.0671 | 757,619.6901 |
| MARION | KA2079 | IMAGIS 37 | 39°46'54.69612" | 86°00'22.46229" | 748.000 | 293,668.8765 | 827,805.4974 |
| MARION | AE8494 | IMAGIS 47 | 39°40'53.27048" | 86°01'06.38033" | 735.461 | 257,091.2770 | 824,430.3794 |
| MARION | JZ3601 | IMAGIS 54 | 39°39'07.94013" | 85°58'21.01005" | 686.101 | 246,455.3770 | 837,381.0862 |
| MARION | KA2081 | IMAGIS 56 | 39°39'00.72492" | 86°08'58.27381" | 637.285 | 245,675.8846 | 787,535.0245 |
| MARION | AA6382 | ZID A | 39°44'22.56161" | 86°16'47.56232" | 684.661 | 278,268.4865 | 750,873.8918 |
| MARION | AA6381 | ZID B | 39°44'18.12646" | 86°17'16.84443" | 680.714 | 277,823.1160 | 748,585.6727 |
| MARSHALL | ME0261 | MARSHALL | 41°19'55.54862" | 86°16'04.38465" | 724.733 | 275,553.9030 | 796,220.5486 |
| MARSHALL | ME3226 | PLYPORT | 41°21'57.06297" | 86°18'28.09723" | 682.571 | 287,851.7391 | 785,257.5076 |
| MARTIN | JA0699 | JOSEPHINE 2 | 38°40'54.26366" | 86°48'33.23003" | 605.996 | 293,588.4341 | 827,587.0509 |
| MIAMI | LB0247 | T 179 | 40°53'42.13252" | 86°01'38.99494" | 690.245 | 316,710.6425 | 821,269.1342 |
| MIAMI | LB0274 | Y 175 RESET | 40°40'03.75317" | 86°07'43.33134" | 679.293 | 233,861.5713 | 793,308.2519 |
| MONROE | AE8492 | BLO 1 | 39°07'09.96918" | 86°33'24.09238" | 618.011 | 179,829.6125 | 771,314.3274 |
| MONROE | KA2024 | BLOOMINGTON NCMN 7291 | 39°10'45.62165" | 86°29'54.27817" | 718.827 | 201,644.0036 | 787,850.5876 |
| MONTGOMERY | KA0639 | A 105 | 39°58'52.16850" | 86°54'59.02450" | 693.138 | 311,601.7177 | 796,817.5627 |
| MORGAN | KA0159 | C 64 | 39°37'11.68674" | 86°21'43.96707" | 566.232 | 362,156.4771 | 826,217.0712 |

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| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| MORGAN | KA0393 | N 13 | 39°24’26.35845” | 86°30’42.28065” | 484.694 | 284,687.2484 | 784,081.2273 |
| MORGAN | KA0314 | T 76 | 39°29’13.07654” | 86°26’33.39746” | 508.490 | 313,703.4052 | 803,598.5749 |
| NEWTON | LB2688 | KENPORT | 40°45’31.15728” | 87°26’04.39367” | 587.436 | 139,482.2736 | 777,827.0384 |
| NEWTON | ME1115 | LAKE VILLAGE | 41°08’42.54150” | 87°26’56.45943” | 535.383 | 280,306.1037 | 773,899.1754 |
| NOBLE | DM4007 | C62 A | 41°28’18.46271” | 85°15’39.80637” | 885.054 | 198,985.5539 | 839,182.7704 |
| NOBLE | DM4040 | C62 B | 41°28’19.37754” | 85°16’06.01189” | 889.342 | 199,073.8803 | 837,187.5631 |
| NOBLE | DM4039 | C62 C | 41°28’18.82618” | 85°15’11.02842” | 891.258 | 199,027.2302 | 841,373.5373 |
| NOBLE | MD0939 | D 165 | 41°16’29.01092” | 85°24’47.21962” | 879.641 | 127,121.5289 | 797,539.0497 |
| OHIO | AH8173 | OHIO | 38°57’39.75620” | 84°51’01.76081” | 408.014 | 231,402.5735 | 801,479.4517 |
| ORANGE | JA2126 | FRENCH AZ MK | 38°30’16.90136” | 86°38’47.94585” | 679.067 | 265,528.7795 | 745,430.5319 |
| OWEN | KA1711 | M 351 | 39°13’53.88803” | 87°02’38.26569” | 551.374 | 147,877.7271 | 746,617.4963 |
| PARKE | KA0837 | K 71 RESET | 39°43’22.54254” | 87°06’20.19171” | 628.772 | 162,983.2049 | 856,146.8539 |
| PERRY | JA2131 | MORGAN | 38°00’53.14380” | 86°41’17.96226” | 550.455 | 196,318.5337 | 790,764.3230 |
| PERRY | HA0540 | S 329 | 37°57’57.68510” | 86°46’10.54646” | 304.025 | 178,576.8254 | 767,335.2409 |
| PERRY | HA0536 | T 329 | 37°57’30.93816” | 86°46’20.45097” | 302.109 | 175,871.7840 | 766,539.9465 |
| PERRY | DP5960 | TEL A | 38°01’20.65434” | 86°41’51.56611” | 500.740 | 199,101.2467 | 788,074.9027 |
| PERRY | DP5961 | TEL B | 38°01’05.15626” | 86°41’24.80583” | 529.645 | 197,533.6285 | 790,216.4975 |
| PIKE | AE8500 | PC 64 | 38°18’19.78151” | 87°05’30.96028” | 437.361 | 284,055.3289 | 847,108.5786 |
| PIKE | DG9009 | PETERSBURG | 38°29’15.88902” | 87°17’07.99653” | 326.148 | 350,363.0345 | 791,534.9828 |
| PORTER | AE8463 | CHESTER RM 1 | 41°34’56.04948” | 87°02’42.68947” | 580.383 | 439,573.4589 | 802,395.4675 |
| PORTER | ME2533 | HURLBURT | 41°21’51.38611” | 87°12’00.88911” | 666.301 | 360,161.5814 | 759,880.6391 |
| PORTER | ME0580 | HUTTON | 41°26’38.25020” | 86°59’34.84537” | 647.217 | 389,199.6131 | 816,733.8544 |
| PORTER | ME2148 | POLA | 41°41’44.61168” | 86°55’57.42511” | 507.919 | 480,968.6656 | 833,115.0194 |
| PORTER | ME1206 | VALPARAISO | 41°27’49.30335” | 87°02’56.61297” | 695.405 | 396,377.5169 | 801,362.7498 |
| PORTER | ME0963 | WHEELER | 41°30’39.17850” | 87°10’36.94812” | 556.895 | 413,577.4572 | 766,328.9752 |

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| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| POSEY | AE8495 | HARM | 38°03'43.95848" | 87°57'58.89618" | 277.805 | 231,805.0122 | 782,689.5521 |
| POSEY | JA2056 | MUMFORD | 38°12'27.39644" | 87°56'12.88178" | 394.730 | 284,755.5647 | 791,160.9910 |
| PULASKI | DG9014 | FRANCESVILLE RESET | 40°59'03.54515" | 86°53'12.55365" | 569.989 | 148,861.3476 | 749,622.9923 |
| PULASKI | LB1139 | G 129 | 40°59'04.84794" | 86°52'05.22835" | 561.994 | 148,985.6695 | 754,786.7684 |
| PULASKI | AE8465 | MARY AZ MK | 41°07'18.61199" | 86°53'29.11345" | 591.278 | 198,970.0094 | 748,434.1430 |
| PULASKI | LB1153 | W 129 | 40°58'12.27918" | 86°37'55.38901" | 591.049 | 143,665.0939 | 819,973.0650 |
| PULASKI | CM4003 | WINAMAC AZ MK | 41°02'44.51329" | 86°36'57.92273" | 605.602 | 171,224.5514 | 824,339.2062 |
| PUTNAM | KA0601 | F 122 | 39°37'37.47137" | 86°49'09.04721" | 699.044 | 182,639.7911 | 824,250.7349 |
| RANDOLPH | LA0244 | C 246 | 40°10'18.25115" | 84°55'16.55584" | 1,003.741 | 289,988.7646 | 823,377.7142 |
| RIPLEY | DP4743 | BILBY | 39°07'04.97961" | 85°17'38.13348" | 882.052 | 197,532.0481 | 789,123.4748 |
| RIPLEY | DP4742 | BILBY AZ MK | 39°06'55.24950" | 85°17'47.19604" | 879.034 | 196,547.5273 | 788,409.2208 |
| RIPLEY | AH8172 | GLASGOW RM 2 DIS… | 39°06'13.07312" | 85°17'48.79203" | 881.993 | 192,280.1635 | 788,283.5695 |
| RIPLEY | JZ1825 | J 264 | 39°17'38.82995" | 85°12'11.68739" | 868.893 | 261,679.9710 | 814,784.8395 |
| RUSH | JZ1684 | B 47 | 39°35'53.63693" | 85°29'42.60723" | 874.775 | 299,632.8909 | 831,032.7448 |
| SCOTT | HZ1678 | E 60 | 38°36'30.56103" | 85°46'35.28235" | 496.302 | 285,136.6304 | 736,970.4980 |
| SCOTT | DG9012 | SCOTT S 12 | 38°38'57.54760" | 85°44'47.66818" | 493.323 | 299,992.0715 | 745,536.7976 |
| SHELBY | AE8497 | L 244 RESET | 39°41'54.65525" | 85°39'06.15721" | 808.673 | 263,372.1049 | 857,268.6708 |
| SHELBY | JZ3600 | YEAGER ECCENTRIC | 39°38'00.35000" | 85°54'19.83207" | 692.755 | 239,566.6255 | 785,848.3399 |
| SPENCER | HA0727 | HATFIELD | 37°54'11.18210" | 87°14'32.43551" | 283.195 | 173,921.6380 | 731,900.0293 |
| SPENCER | HA0568 | HONEY | 37°56'26.87993" | 87°02'26.57648" | 289.986 | 187,591.1766 | 790,077.5879 |
| SPENCER | JA1979 | JACKSON | 38°03'39.63223" | 87°02'59.46985" | 324.865 | 231,367.0752 | 787,442.4015 |
| STARKE | ME0522 | D 335 | 41°23'09.54893" | 86°36'31.16277" | 570.963 | 295,219.4434 | 826,188.1493 |
| STARKE | ME3284 | FAA OXI A | 41°19'45.99714" | 86°39'42.17905" | 568.480 | 274,597.2081 | 811,648.1452 |
| STARKE | DI3739 | OXI B | 41°20'09.39282" | 86°39'41.00744" | 569.694 | 276,965.3344 | 811,735.1145 |
| STARKE | DI3740 | OXI C | 41°19'28.96550" | 86°39'41.23227" | 570.061 | 272,873.3958 | 811,722.1390 |

| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| STEUBEN | MD1896 | ANGPORT | 41°38’11.44229” | 85°05’15.78213” | 872.492 | 167,867.1296 | 763,420.5412 |
| STEUBEN | MD1897 | ANGPORT AZ MK | 41°38’29.82346” | 85°04’49.48801” | 877.082 | 169,725.7913 | 765,418.9656 |
| STEUBEN | AJ8284 | ANQ A | 41°38’09.75787” | 85°04’08.49876” | 876.747 | 167,691.9833 | 768,529.6834 |
| STEUBEN | MD1853 | BERLEIN | 41°37’45.01674” | 84°53’06.87206” | 964.798 | 165,200.9210 | 818,775.1406 |
| STEUBEN | MD1865 | BERLEIN 2 | 41°37’44.41652” | 84°53’06.89098” | 965.221 | 165,140.1628 | 818,773.7846 |
| STEUBEN | MD0591 | Z 21 | 41°42’03.76536” | 84°57’23.32255” | 941.222 | 191,374.6322 | 799,285.6952 |
| STJOSEPH | DG9007 | G 103 | 41°43’37.32598” | 86°20’09.67200” | 699.260 | 419,467.5357 | 777,567.0232 |
| STJOSEPH | AJ8277 | SBN A | 41°42’09.30097” | 86°18’16.23620” | 653.762 | 410,555.2752 | 786,168.3486 |
| STJOSEPH | AJ8285 | SBN B | 41°42’19.19159” | 86°19’29.63437” | 670.241 | 411,557.3911 | 780,600.7739 |
| STJOSEPH | AJ8278 | SBN C | 41°43’01.81119” | 86°19’05.02148” | 681.406 | 415,871.0453 | 782,468.6925 |
| STJOSEPH | ME3288 | SOUTH BEND CBL 0 | 41°43’27.68619” | 86°07’40.98370” | 654.694 | 418,536.5792 | 834,341.7198 |
| STJOSEPH | ME0042 | U 167 | 41°38’10.00864” | 86°15’02.25208” | 697.321 | 386,337.1943 | 800,897.5415 |
| STJOSEPH | ME2210 | WYATT | 41°30’16.07573” | 86°09’22.85017” | 706.275 | 338,393.8892 | 826,750.3216 |
| SULLIVAN | KA1335 | R 54 | 39°01’43.10440” | 87°30’30.86616” | 370.482 | 164,964.3486 | 784,964.1712 |
| SWITZERLAND | HZ1030 | MCKAY | 38°43’37.22626” | 85°06’14.42702” | 359.652 | 146,221.9902 | 729,195.8282 |
| SWITZERLAND | HZ0790 | SWIT 8 | 38°53’59.24357” | 84°52’15.31537” | 365.350 | 209,089.7327 | 795,676.3525 |
| TIPPECANOE | LB0781 | B 120 | 40°23’06.26391” | 86°45’06.07396” | 570.563 | 185,569.4571 | 828,718.4940 |
| TIPPECANOE | LB1690 | M 94 | 40°13’05.27112” | 87°04’25.49815” | 645.799 | 124,762.7413 | 738,875.7921 |
| TIPPECANOE | DG9010 | PENC | 40°25’49.51199” | 86°54’53.51293” | 599.897 | 202,055.9223 | 783,261.6181 |
| TIPPECANOE | DG9011 | PEND | 40°25’49.55307” | 86°54’53.44758” | 599.913 | 202,060.0788 | 783,266.6726 |
| TIPPECANOE | LB0933 | Q 94 | 40°25’00.66256” | 86°55’52.80697” | 498.736 | 197,113.5270 | 778,674.4053 |
| TIPPECANOE | LB1162 | Z 125 | 40°32’33.60880” | 86°50’45.47902” | 557.069 | 242,955.4837 | 802,418.0925 |
| TIPTON | AE8501 | RESSLER RESET | 40°18’13.81108” | 86°02’52.13227” | 760.687 | 265,233.1992 | 774,063.2482 |
| UNION | JZ1661 | K 3 USGS RESET | 39°39’50.94476” | 85°00’14.37603” | 682.046 | 268,974.4819 | 800,352.7806 |
| VANDERBURGH | JA1259 | ARP | 38°02’13.18667” | 87°31’56.51287” | 278.274 | 204,415.3723 | 792,479.3788 |

| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| VANDERBURGH | HA1116 | B 326 | 37°56'52.49430" | 87°30'41.69388" | 275.852 | 171,976.8312 | 798,478.7692 |
| VANDERBURGH | DM9916 | EVV A | 38°02'22.08595" | 87°31'28.04543" | 286.945 | 205,316.1344 | 794,756.7099 |
| VANDERBURGH | DM9917 | EVV B | 38°02'50.80039" | 87°30'58.51402" | 317.775 | 208,221.5855 | 797,118.2790 |
| VANDERBURGH | DM9918 | EVV C | 38°02'49.51323" | 87°32'11.87884" | 288.208 | 208,089.8916 | 791,249.4741 |
| VANDERBURGH | HA1098 | N 325 | 37°56'47.44039" | 87°40'31.03871" | 391.971 | 171,487.6031 | 751,269.6412 |
| VANDERBURGH | AE8508 | TT 2 CEM | 38°08'46.18052" | 87°39'10.79192" | 333.598 | 244,186.1670 | 757,778.3457 |
| VANDERBURGH | JA1605 | V 356 | 38°01'27.74509" | 87°32'19.35410" | 280.597 | 199,818.3149 | 790,652.4915 |
| VANDERBURGH | AE8507 | VANDERBURGH STC | 38°03'49.73647" | 87°28'46.30235" | 275.150 | 214,189.3881 | 807,690.0411 |
| VANDERBURGH | JA1606 | W 356 | 38°00'47.95280" | 87°32'20.33977" | 282.306 | 195,793.0105 | 790,574.0948 |
| VERMILLION | KA1741 | B 360 | 39°42'36.09838" | 87°23'56.46804" | 408.162 | 158,193.6893 | 773,608.4996 |
| VERMILLION | KA1750 | D 361 | 39°50'19.01558" | 87°24'39.36172" | 546.754 | 205,037.8160 | 770,288.1019 |
| VERMILLION | LB2105 | W 361 | 40°04'31.26858" | 87°27'07.88478" | 504.763 | 291,289.6455 | 758,800.9439 |
| VIGO | KA2051 | FAA 3I3 A | 39°32'53.85850" | 87°22'42.95887" | 385.583 | 226,773.2595 | 807,535.3135 |
| VIGO | AJ8286 | HUF A | 39°27'02.90362" | 87°18'08.61789" | 469.372 | 191,288.4181 | 829,084.0079 |
| VIGO | AJ8287 | HUF B | 39°27'35.39409" | 87°18'48.86403" | 452.598 | 194,570.9338 | 825,921.9436 |
| VIGO | AJ8288 | HUF C | 39°26'52.49483" | 87°19'07.50513" | 461.659 | 190,228.0823 | 824,466.1586 |
| WABASH | LA1838 | E 173 | 40°42'33.39309" | 85°49'40.14239" | 693.788 | 139,707.4071 | 793,550.1890 |
| WABASH | LA1681 | M 178 | 40°54'47.45699" | 85°53'22.87119" | 655.806 | 214,002.3846 | 776,430.4880 |
| WARREN | LB1710 | Y 94 | 40°28'28.80798" | 87°05'34.33664" | 596.045 | 309,319.0174 | 845,027.4608 |
| WARREN | LB2108 | Z 361 | 40°08'30.57965" | 87°26'47.19942" | 475.573 | 188,026.1980 | 746,455.7064 |
| WARRICK | JA1047 | N 316 | 38°09'33.78415" | 87°26'44.67273" | 345.865 | 230,810.4574 | 745,492.7481 |
| WASHINGTON | DN5872 | I83 A | 38°36'10.38557" | 86°09'04.79540" | 718.329 | 355,882.8198 | 787,019.3034 |
| WASHINGTON | DN5873 | I83 B | 38°36'18.35524" | 86°08'29.23695" | 716.199 | 356,689.2141 | 789,842.1378 |
| WASHINGTON | DN5874 | I83 C | 38°36'18.16772" | 86°09'21.16190" | 736.481 | 356,670.1830 | 785,720.0523 |
| WASHINGTON | JA0188 | LOST | 38°37'27.01080" | 86°13'57.81921" | 731.787 | 363,645.5783 | 763,763.7522 |

| | National Geodetic Survey | | NAD 83(2011) epoch 2010.00 | | | InGCS Grid Coordinates | |
|---|---|---|---|---|---|---|---|
| InGCS Zone / | Station Information | | North | West | Ellipsoidal | (U.S. Survey Feet) | |
| IN County Name | PID | Designation | Latitude | Longitude | Height | Northing | Easting |
| WAYNE | JZ1469 | F 277 | 39°45’21.99168” | 84°51’07.08660” | 1,011.445 | 138,611.1329 | 843,080.4532 |
| WAYNE | DM4049 | RID A | 39°45’19.29992” | 84°50’42.99407” | 1,020.024 | 138,342.9809 | 844,962.7684 |
| WAYNE | DM4050 | RID B | 39°44’59.26169” | 84°50’19.61417” | 1,027.101 | 136,319.5344 | 846,793.6028 |
| WAYNE | JZ1175 | WALTING RM 1 | 39°54’38.57044” | 84°51’21.23080” | 1,058.833 | 194,930.1623 | 841,853.5324 |
| WELLS | LA0984 | Q 213 | 40°44’30.88076” | 85°16’45.64088” | 721.390 | 188,032.1996 | 779,268.0920 |
| WHITE | DM4008 | MCX A | 40°42’37.44353” | 86°46’04.38171” | 563.185 | 304,089.0448 | 824,028.6074 |
| WHITE | DM4041 | MCX B | 40°42’51.47935” | 86°46’03.86583” | 563.103 | 305,509.6105 | 824,066.1979 |
| WHITE | DM4042 | MCX C | 40°42’14.86123” | 86°45’56.85021” | 559.316 | 301,804.4671 | 824,612.1195 |
| WHITE | LB1086 | S 107 | 40°52’03.42899” | 86°57’06.92270” | 569.182 | 361,347.4904 | 773,038.5077 |
| WHITE | LB1175 | X 147 | 40°39’59.78089” | 86°48’47.02275” | 567.391 | 288,117.1295 | 811,518.9786 |
| WHITLEY | MD0682 | COLUMBIA RM 2 | 41°09’25.55033” | 85°29’47.07032” | 765.871 | 302,873.7862 | 788,389.0718 |

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# APPENDIX E
## Field Validations of Proprietary Geospatial Software Platforms

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### *Geospatial Field Software Quality Control*

A series of RTN field observations were collected on two separate days on Station "PERCH" with some of the proprietary field software platforms more widely-utilized in Indiana as a *limited* means of ensuring that they were positioning correctly relative to NAD 83(2011) epoch 2010.00 and to compare the average RTN values of each platform with the position derived for Station "PERCH."

The National Geodetic Survey's OPUS utility was employed to provide the values of latitude, longitude, ellipsoidal height, and NAVD 88 (from Geoid12B) per NAD 83(2011) epoch 2010.00 for Station "PERCH." The data listed in Table E.1 were the results of five, 24-hour static GPS sessions submitted to OPUS after the corresponding precise ephemerides were available. Each session was collected using a different Trimble GNSS antenna/receiver in unique GPS weeks. The University of Southern Indiana provided the *R6 Model* 2. Seiler Instrument and Manufacturing, Inc. provided the *R8 Model 3, R8 Model 4*, and *R10*. Lochmueller Group provided the Zephyr II, NetR5 (which later became part of the Trimble VRS Now RTN network). The mean of the solutions retrieved from OPUS was then used as the baseline position for the remainder of this exercise. The positions of latitude and longitude were converted to InGCS "Vanderburgh" zone grid coordinates in U.S. Survey Feet using Trimble Business Center Version 3.70 and its Coordinate System Manager Version 3.2.4.0.

***Table E.1:*** *OPUS Solutions of Station "PERCH."*

| OPUS Precise Orbit Solutions (24-Hour Sessions) of Station "PERCH" (PID: BBDX16) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *NAD 83(2011) epoch 2010.00* | | | | | | | | | | | | |
| Trimble GNSS Antenna/Receiver | Date | Obs. Used | # Fixed Amb's | Overall RMS (m) | Latitude (N) | ±m | Longitude | ±m | Ellipsoid Ht (m) | ±m | NAVD 88 (G12B)(m) | ±m |
| R6 Model 2 | 2015/06/01 | 96% | 95% | 0.015 | 37°57'38.68585" | 0.015 | 87°40'38.92257" | 0.004 | 123.643 | 0.028 | 154.527 | 0.050 |
| R8 Model 4 | 2015/06/07 | 96% | 88% | 0.019 | 37°57'38.68572" | 0.003 | 87°40'38.92261" | 0.008 | 123.641 | 0.010 | 154.525 | 0.022 |
| R10 | 2015/07/05 | 95% | 86% | 0.020 | 37°57'38.68562" | 0.012 | 87°40'38.92320" | 0.026 | 123.654 | 0.022 | 154.538 | 0.040 |
| R8 Model 3 | 2015/07/20 | 95% | 76% | 0.025 | 37°57'38.68553" | 0.016 | 87°40'38.92247" | 0.026 | 123.651 | 0.046 | 154.535 | 0.079 |
| Zephyr II/NetR5 | 2015/08/03 | 96% | 88% | 0.017 | 37°57'38.68564" | 0.015 | 87°40'38.92262" | 0.012 | 123.645 | 0.035 | 154.529 | 0.061 |
| **Mean** | | | | | **37°57'38.68567"** | | **87°40'38.92269"** | | **123.647** | | **154.531** | |
| ***InGCS "Vanderburgh" zone Grid Coordinates and NAVD 88 Orthometric Height, U.S. Survey Feet*** | | | | | | | | | | | | |
| | | | | | **N 176,672.258** | | **E 750,645.190** | | | | **506.990** | |

The RTN testing progress consisted of (1) utilizing INDOT's InCORS network as the sole RTN provider, (2) conducting observations on Station "PERCH" on two consecutive days, (3) stagger the schedule (time of day) when the two blocks of observing sessions for each GNSS platform were conducted by as much as reasonable (given the particular day's circumstances), with four hours being the preferred minimum offset, (4) determine the mean positional values observed for each day (i.e., mean values of Day #1 and mean values of Day #2) (5) determine the final mean positional values from the mean values from Day #1 and Day #2, and (6) compare the final mean RTN positional values to the mean OPUS values. Refer to the following Tables for the summary of these results for the platforms tested.

***Table E.2:*** *RTN Testing: Trimble Navigation*

| InGCS and RTN Positioning QC Testing | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Manufacturer: Trimble Navigation* | | | *Software Version: Access 2015.21 (9569)** | | | *GNSS Antenna/Receiver: R8 Model 3* | | |
| *InGCS, "Vanderburgh" zone - NAD 83(2011) epoch 2010.00 - U.S. Survey Feet* | | | | | | | | |
| | Date | Grid Northing | Grid Easting | NAVD 88 (Geoid12B) | Max PDOP | Max RMS | Max Horizontal Precision (95%) | Max Vertical Precision (95%) |
| Mean Day #1 | 2015/12/14 | 176,672.251 | 750,645.183 | 506.962 | 1.423 | 0.012 | 0.048 | 0.060 |
| Mean Day #2 | 2015/12/14 | 176,672.245 | 750,645.213 | 506.959 | 3.711 | 0.010 | 0.130 | 0.205 |
| Final Mean | | 176,672.248 | 750,645.198 | 506.960 | | | | |
| "OPUS vs. RTN" Deltas | | -0.010 | +0.008 | -0.031 | | | | |

* Note: Trimble Access Version 2015.21 (9569) did not include the InGCS; however, Trimble Business Center Version 3.61 did at the date of the RTN observations listed above. The *Coordinate System Database* (Current.csd) file included in TBC 3.61 was renamed to "current.csd," transferred to the Trimble TSC3 data collector and used for the RTN observations. The InGCS was later introduced to Trimble Access in Version 2016.00.

***Table E.3:*** *RTN Testing: Leica Geosystems*

| InGCS and RTN Positioning QC Testing | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Manufacturer: Leica Geosystems* | | | *Software Version: Captivate Version 1.30* | | | *GNSS Antenna/Receiver: Viva GS14* | | |
| *InGCS, "Vanderburgh" zone - NAD 83(2011) epoch 2010.00 - U.S. Survey Feet* | | | | | | | | |
| | Date | Grid Northing | Grid Easting | NAVD 88 (Geoid12B) | Max GDOP | Max PDOP | Max HDOP | Max VDOP |
| Mean Day #1 | 2016/04/20 | 176,672.288 | 750,645.217 | 507.034 | 1.2 | 1.1 | 0.6 | 0.9 |
| Mean Day #2 | 2016/04/21 | 176,672.247 | 750,645.160 | 506.720 | 1.7 | 1.5 | 0.9 | 1.2 |
| Final Mean | | 176,672.268 | 750,645.188 | 506.877 | | | | |
| "OPUS vs. RTN" Deltas | | +0.010 | -0.002 | -0.113 | | | | |

# APPENDIX F

## Basis of Bearings Statements

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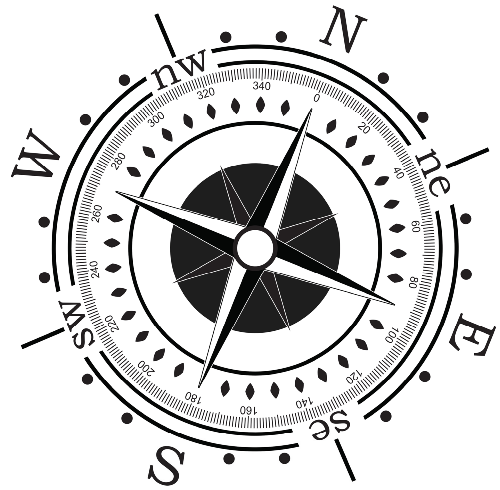
***Note:*** The following *Basis of Bearings* statements for all 92 Indiana counties/InGCS zones are provided as recommended templates for Indiana Professional Surveyors to include on their plats of surveys and within their Surveyors Reports.




### *InGCS "Adams" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Adams" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Adams" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Adams" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 84°57'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 40°33'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Allen" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Allen" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Allen" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Allen" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°03'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Bartholomew” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Bartholomew" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Bartholomew” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Bartholomew" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°51'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 39°00'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Benton” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Benton" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Benton” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Benton" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°18'00" west longitude
Central Meridian scale factor: 1.000029
Latitude of Grid Origin: 40°27'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Blackford" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Blackford" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Blackford" and "Delaware" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Blackford" and "Delaware" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°24'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 40°03'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Boone" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Boone" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Boone" and "Hendricks" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Boone" and "Hendricks" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 39°36'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Brown" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Brown" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Brown" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Brown" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°18'00" west longitude
Central Meridian scale factor: 1.000030
Latitude of Grid Origin: 39°00'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Carroll" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Carroll" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Carroll" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Carroll" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°39'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 40°24'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Cass” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Cass" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Cass” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Cass" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°24'00" west longitude
Central Meridian scale factor: 1.000028
Latitude of Grid Origin: 40°33'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Clark” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Clark" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Clark," “Floyd,” and "Scott” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Clark," "Floyd," and "Scott" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°36'00" west longitude
Central Meridian scale factor: 1.000021
Latitude of Grid Origin: 38°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Clay" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Clay" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Clay" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Clay" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°09'00" west longitude
Central Meridian scale factor: 1.000024
Latitude of Grid Origin: 39°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Clinton" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Clinton" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Clinton" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Clinton" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°36'00" west longitude
Central Meridian scale factor: 1.000032
Latitude of Grid Origin: 40°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Crawford” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Crawford" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Crawford," “Lawrence,” and "Orange” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Crawford," "Lawrence," and "Orange" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 38°06’00” north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Daviess” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Daviess" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Daviess" and “Greene” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Daviess" and "Greene" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°06'00" west longitude
Central Meridian scale factor: 1.000018
Latitude of Grid Origin: 38°27'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Dearborn" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Dearborn" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Dearborn," "Ohio," and "Switzerland" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Dearborn," "Ohio," and "Switzerland" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 84°54'00" west longitude
Central Meridian scale factor: 1.000029
Latitude of Grid Origin: 38°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Decatur" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Decatur" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Decatur" and "Rush" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Decatur" and "Rush" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°39'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 39°06'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “DeKalb” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "DeKalb" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “DeKalb” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "DeKalb" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 84°57'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 41°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Delaware” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Delaware" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Delaware" and “Blackford” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Blackford" and "Delaware" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°24'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 40°03'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Dubois" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Dubois" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Dubois" and "Martin" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Dubois" and "Martin" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°57'00" west longitude
Central Meridian scale factor: 1.000020
Latitude of Grid Origin: 38°12'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Elkhart" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Elkhart" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Elkhart," "Kosciusko," and "Wabash" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Elkhart," "Kosciusko," and "Wabash" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°51'00" west longitude
Central Meridian scale factor: 1.000033
Latitude of Grid Origin: 40°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Fayette” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Fayette" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Fayette," “Franklin,” and "Union” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Fayette," "Franklin," and "Union" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°03'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 39°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Floyd” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Floyd" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Floyd," “Clark,” and "Scott” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Clark," "Floyd," and "Scott" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°36'00" west longitude
Central Meridian scale factor: 1.000021
Latitude of Grid Origin: 38°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Fountain” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Fountain" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Fountain" and “Warren” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Fountain" and "Warren" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°18'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 39°57'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Franklin” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Franklin" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Franklin," “Fayette,” and "Union” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Fayette," "Franklin," and "Union" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°03'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 39°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Fulton" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Fulton" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Fulton," "Marshall," and "St.Joseph" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

InGCS "Fulton," "Marshall," and "St.Joseph" Zone Parameters
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°18'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Gibson" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Gibson" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Gibson" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

InGCS "Gibson" Zone Parameters
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°39'00" west longitude
Central Meridian scale factor: 1.000013
Latitude of Grid Origin: 38°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Grant” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Grant" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Grant” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Grant" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°42'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 40°21'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Greene” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Greene" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Greene" and “Daviess” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Daviess" and "Greene" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°06'00" west longitude
Central Meridian scale factor: 1.000018
Latitude of Grid Origin: 38°27'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Hamilton” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Hamilton" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Hamilton" and “Tipton” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Hamilton" and "Tipton" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°00'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 39°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Hancock” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Hancock" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Hancock" and “Madison” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Hancock" and "Madison" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°48'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 39°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Harrison" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Harrison" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Harrison" and "Washington" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Harrison" and "Washington" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°09'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 37°57'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Hendricks" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Hendricks" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Hendricks" and "Boone" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Boone" and "Hendricks" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 39°36'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Henry” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Henry" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Henry” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Henry" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°27'00" west longitude
Central Meridian scale factor: 1.000043
Latitude of Grid Origin: 39°45'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Howard” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Howard" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Howard" and “Miami” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Howard" and "Miami" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°09'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 40°21'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Huntington" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Huntington" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Huntington" and "Whitley" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Huntington" and "Whitley" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°30'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 40°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Jackson" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Jackson" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Jackson" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Jackson" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°57'00" west longitude
Central Meridian scale factor: 1.000022
Latitude of Grid Origin: 38°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Jasper” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Jasper" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Jasper" and “Porter” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Jasper" and "Porter" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°06'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 40°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Jay” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Jay" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Jay” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Jay" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°00'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 40°18'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Jefferson” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Jefferson" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Jefferson” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Jefferson" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°21'00" west longitude
Central Meridian scale factor: 1.000028
Latitude of Grid Origin: 38°33'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Jennings” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Jennings" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Jennings” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Jennings" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°48'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 38°48'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Johnson" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Johnson" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Johnson" and "Marion" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Johnson" and "Marion" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°09'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 39°18'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Knox" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Knox" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Knox" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Knox" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°27'00" west longitude
Central Meridian scale factor: 1.000015
Latitude of Grid Origin: 38°24'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Kosciusko” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Kosciusko" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Kosciusko," “Elkhart,” and "Wabash” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Elkhart," "Kosciusko," and "Wabash" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°51'00" west longitude
Central Meridian scale factor: 1.000033
Latitude of Grid Origin: 40°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “LaGrange” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "LaGrange" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “LaGrange" and “Noble” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "LaGrange" and "Noble" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°27'00" west longitude
Central Meridian scale factor: 1.000037
Latitude of Grid Origin: 41°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Lake” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Lake" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Lake" and “Newton” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Lake" and "Newton" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°24'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 40°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “LaPorte” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "LaPorte" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “LaPorte," ”Pulaski,” and "Starke” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "LaPorte," "Pulaski," and "Starke" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°45'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Lawrence” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Lawrence" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Lawrence," “Crawford,” and "Orange” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Crawford," "Lawrence," and "Orange" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 38°06’00” north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Madison” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Madison" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Madison" and “Hancock” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Hancock" and "Madison" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°48'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 39°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Marion" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Marion" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Marion" and "Johnson" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Johnson" and "Marion" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°09'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 39°18'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Marshall" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Marshall" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Marshall," "Fulton," and "St.Joseph" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Fulton," "Marshall," and "St.Joseph" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°18'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Martin” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Martin" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Martin" and “Dubois” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Dubois" and "Martin" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°57'00" west longitude
Central Meridian scale factor: 1.000020
Latitude of Grid Origin: 38°12'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Miami” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Miami" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Miami" and “Howard” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Howard" and "Miami" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°09'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 40°21'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

***InGCS "Monroe" zone:***

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Monroe" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Monroe" and "Morgan" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Monroe" and "Morgan" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000028
Latitude of Grid Origin: 38°57'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

***InGCS "Montgomery" zone:***

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Montgomery" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Montgomery" and "Putnam" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Montgomery" and "Putnam" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°57'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 39°27'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Morgan” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Morgan" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Morgan" and “Monroe” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Monroe" and "Morgan" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000028
Latitude of Grid Origin: 38°57'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Newton” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Newton" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Newton" and “Lake” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Lake" and "Newton" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°24'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 40°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Noble” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Noble" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Noble" and “LaGrange” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "LaGrange" and "Noble" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°27'00" west longitude
Central Meridian scale factor: 1.000037
Latitude of Grid Origin: 41°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Ohio” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Ohio" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Ohio," “Dearborn,” and "Switzerland” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Dearborn," "Ohio," and "Switzerland" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 84°54'00" west longitude
Central Meridian scale factor: 1.000029
Latitude of Grid Origin: 38°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Orange” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Orange" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Orange," “Crawford,” and "Lawrence” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Crawford," "Lawrence," and "Orange" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°30'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 38°06’00” north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Owen” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Owen" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Owen” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Owen" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°54'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 39°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Parke" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Parke" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Parke" and "Vermillion" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Parke" and "Vermillion" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°21'00" west longitude
Central Meridian scale factor: 1.000022
Latitude of Grid Origin: 39°36'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Perry" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Perry" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Perry" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Perry" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°42'00" west longitude
Central Meridian scale factor: 1.000020
Latitude of Grid Origin: 37°48'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Pike" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Pike" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Pike" and "Warrick" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Pike" and "Warrick" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°18'00" west longitude
Central Meridian scale factor: 1.000015
Latitude of Grid Origin: 37°51'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Porter" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Porter" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Porter" and "Jasper" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Jasper" and "Porter" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°06'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 40°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Posey” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Posey" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Posey” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Posey" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°57'00" west longitude
Central Meridian scale factor: 1.000013
Latitude of Grid Origin: 37°45'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Pulaski” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Pulaski" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Pulaski," “LaPorte,” and "Starke” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "LaPorte," "Pulaski," and "Starke" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°45'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Putnam" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Putnam" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Putnam" and "Montgomery" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Montgomery" and "Putnam" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°57'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 39°27'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Randolph" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Randolph" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Randolph" and "Wayne" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Randolph" and "Wayne" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°03'00" west longitude
Central Meridian scale factor: 1.000044
Latitude of Grid Origin: 39°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Ripley” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Ripley" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Ripley” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Ripley" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°18'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 38°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Rush” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Rush" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Rush" and “Decatur” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Decatur" and "Rush" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°39'00" west longitude
Central Meridian scale factor: 1.000036
Latitude of Grid Origin: 39°06'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “St.Joseph” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "St.Joseph" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “St.Joseph," “Fulton,” and "Marshall” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Fulton," "Marshall," and "St.Joseph" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°18'00" west longitude
Central Meridian scale factor: 1.000031
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Scott” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Scott" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Scott," “Clark,” and "Floyd” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Clark," "Floyd," and "Scott" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°36'00" west longitude
Central Meridian scale factor: 1.000021
Latitude of Grid Origin: 38°09'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Shelby" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Shelby" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Shelby" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Shelby" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°54'00" west longitude
Central Meridian scale factor: 1.000030
Latitude of Grid Origin: 39°18'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Spencer" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Spencer" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Spencer" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Spencer" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°03'00" west longitude
Central Meridian scale factor: 1.000014
Latitude of Grid Origin: 37°45'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Starke" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Starke" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Starke," "LaPorte," and "Pulaski" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "LaPorte," "Pulaski," and "Starke" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°45'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 40°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Steuben" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Steuben" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Steuben" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Steuben" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°00'00" west longitude
Central Meridian scale factor: 1.000041
Latitude of Grid Origin: 41°30'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Sullivan" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Sullivan" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Sullivan” zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone’s name.

<u>InGCS "Sullivan" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°30'00" west longitude
Central Meridian scale factor: 1.000017
Latitude of Grid Origin: 38°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Switzerland” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Switzerland" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Switzerland," “Dearborn,” and "Ohio” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Dearborn," "Ohio," and "Switzerland" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 84°54'00" west longitude
Central Meridian scale factor: 1.000029
Latitude of Grid Origin: 38°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Tippecanoe" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Tippecanoe" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Tippecanoe" and "White" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Tippecanoe" and "White" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°54'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 40°12'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Tipton" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Tipton" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Tipton" and "Hamilton" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Hamilton" and "Tipton" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°00'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 39°54'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Union" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Union" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Union," "Fayette," and "Franklin" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Fayette," "Franklin," and "Union" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°03'00" west longitude
Central Meridian scale factor: 1.000038
Latitude of Grid Origin: 39°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Vanderburgh" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Vanderburgh" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Vanderburgh" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Vanderburgh" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°33'00" west longitude
Central Meridian scale factor: 1.000015
Latitude of Grid Origin: 37°48'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Vermillion" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Vermillion" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Vermillion" and "Parke" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Parke" and "Vermillion" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°21'00" west longitude
Central Meridian scale factor: 1.000022
Latitude of Grid Origin: 39°36'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Vigo" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Vigo" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Vigo" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Vigo" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°27'00" west longitude
Central Meridian scale factor: 1.000020
Latitude of Grid Origin: 39°15'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Wabash” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Wabash" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Wabash," “Elkhart,” and "Kosciusko” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Elkhart," "Kosciusko," and "Wabash" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°51'00" west longitude
Central Meridian scale factor: 1.000033
Latitude of Grid Origin: 40°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Warren” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Warren" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Warren" and “Fountain” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Fountain" and "Warren" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°18'00" west longitude
Central Meridian scale factor: 1.000025
Latitude of Grid Origin: 39°57'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Warrick” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Warrick" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Warrick" and “Pike” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Pike" and "Warrick" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 87°18'00" west longitude
Central Meridian scale factor: 1.000015
Latitude of Grid Origin: 37°51'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS “Washington” zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Washington" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The “Washington" and “Harrison” zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones’ names.

<u>InGCS "Harrison" and "Washington" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°09'00" west longitude
Central Meridian scale factor: 1.000027
Latitude of Grid Origin: 37°57'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Wayne" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Wayne" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Wayne" and "Randolph" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Randolph" and "Wayne" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°03'00" west longitude
Central Meridian scale factor: 1.000044
Latitude of Grid Origin: 39°42'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Wells" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Wells" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Wells" zone was developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the county bearing this zone's name.

<u>InGCS "Wells" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°15'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 40°33'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "White" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "White" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "White" and "Tippecanoe" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Tippecanoe" and "White" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 86°54'00" west longitude
Central Meridian scale factor: 1.000026
Latitude of Grid Origin: 40°12'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

### *InGCS "Whitley" zone:*

Unless noted otherwise, all bearings, distances, areas, and coordinates shown hereon are based upon the Indiana Geospatial Coordinate System's (InGCS) "Whitley" zone per NAD 83 (2011) epoch 2010.00 and are reported in U.S. Survey Feet and decimal parts thereof. The "Whitley" and "Huntington" zones have identical parameters. These zones were developed to minimize the differences between ground-measured horizontal distances and the corresponding grid coordinate (map) distances within the counties bearing these zones' names.

<u>InGCS "Huntington" and "Whitley" Zone Parameters</u>
Geometric Datum: NAD 83(2011) epoch 2010.00
Projection Type: Transverse Mercator
Central Meridian: 85°30'00" west longitude
Central Meridian scale factor: 1.000034
Latitude of Grid Origin: 40°39'00" north latitude
False Northing: 36,000.000 m (118,110.00 U.S.Ft)
False Easting: 240,000.000 m (787,400.00 U.S.Ft)

**Michael R. Pence, Governor**
**Brandye Hendrickson, Commissioner**

**Indiana Department of Transportation**
100 North Senate Avenue, Room N755
Indianapolis, Indiana 46204

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