The State Plane Coordinate System: History, Policy, and Future Directions

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Executive Summary

The State Plane Coordinate System (SPCS) is a system of conformal map projections created by the National Geodetic Survey (NGS). SPCS was established to support surveying, engineering, and mapping activities in the United States and its territories. The current version, SPCS 83, is referenced to the North American Datum of 1983 (NAD 83) and consists of 125 zones based on the Lambert Conformal Conic, Transverse Mercator, and Oblique Mercator projections. Because NGS will replace NAD 83 with the 2022 Terrestrial Reference Frames (TRFs), SPCS 83 will also be replaced by the State Plane Coordinate System of 2022 (SPCS2022). The main objective of this publication is to provide the historical, practical, and philosophical context for initiating development of SPCS2022. To achieve that objective, a review is conducted of NGS technical documents and policy from the mid-1800s to the present. The historical review is augmented with a brief assessment of current trends in usage of SPCS and other projected coordinate systems. In addition, defining parameters are given for all zones since the inception of SPCS—the first time all have been presented in a single NGS document. Also provided is the status of SPCS 83 in state statute and regulations, including which jurisdictions adopted the U.S. survey or international foot.

As first conceived in the 1930s, SPCS provided a way to perform "geodetic" surveys using plane trigonometry, making it among the earliest practical means to access the National Spatial Reference System (NSRS). Because of electronic computers, SPCS is no longer used for that original purpose. Yet rather than decline, SPCS usage has grown due to widespread adoption of technologies such as Computer Aided Drafting and Design (CADD), Geographic Information Systems (GIS), and Global Navigation Satellite Systems (GNSS).

Over its long history, the characteristics and usage of SPCS have varied considerably. There have been substantial departures from policies and conventions typically associated with SPCS; for example: not always using aggregated counties for zone boundaries; greatly exceeding the nominal criterion of 1:10,000 for maximum scale error; establishing "layered" zones that completely overlap one another; modifying reference ellipsoid dimensions; scaling SPCS coordinates to "ground"; and even using a non-conformal projection. In addition, there have been recent developments in design and usage of projected coordinate systems outside of SPCS. These developments include establishing statewide zones and small zones intended to minimize linear distortion (scale error) at the topographic surface. Many such systems have been officially adopted by states and local government agencies, and there is interest in having them become part of SPCS.

The intent of this publication is two-fold. The first purpose is to give an historical overview that consolidates complete definitions of every version of SPCS into a single document. The second is to provide information useful for determining the appropriate bounds for design and implementation of SPCS2022. The overall goal is that this publication will aid in defining a projected coordinate system framework that serves as a technically sound and practical foundation for building the SPCS of the future.

Introduction: Purpose and Scope

Two main objectives drove the development of this publication. The first was to give context for development of a new State Plane Coordinate System (SPCS) referenced to the four Terrestrial Reference Frames (TRFs) of 2022 (Smith, *et al.*, 2017). That context is in terms of convention, intent, and policy, as revealed through the entire SPCS history. A key part of this objective is to provide the National Geodetic Survey (NGS) with the information and perspective to appropriately and effectively move forward with an update of SPCS. Importantly, that includes determining a balance between the desires of NGS customers and what can be achieved within the technical, practical, and philosophical bounds of SPCS. This document serves as a basis and reference for development of the State Plane Coordinate System of 2022 (SPCS2022).

The second objective was adopted during the preparation of this report. It was found that no NGS document or webpage contained a complete definition of the current SPCS. Nor is there a singular reference for the overall history of SPCS development, policy, and implementation that had been carried through to the present day. This publication provides a summary of the entire SPCS history. This document also serves as the only official NGS compendium containing complete sets of defining parameters for all SPCS versions.

Research for this report was limited mostly to NGS publications or publications by NGS' predecessors, the U.S. Coast & Geodetic Survey (C&GS) and the U.S. Coast Survey, although other supporting and corroborating documents were referenced, as necessary. Perhaps most striking is the extraordinary volume of work done by C&GS on map projections, extending back to the mid-1800s; such publications number in the hundreds. Several dozen of these documents provide the theoretical and practical basis for what ultimately became SPCS, including ground-breaking work on conformal projections in the early 1900s. Most of the documents consist of projection and intersection tables for computing coordinates and plotting maps. Such documents may seem mundane, but the effort required to generate the tables is astounding; it required computing projected coordinates (and related quantities) at 1 arc-minute and 2-1/2 arc-minute intervals over the entire United States, with significant overlap between zones. Remarkably, most of that work was done before electronic computing was available. After 1990, essentially no documents were published by NGS on SPCS or map projections in general, other than occasional policy statements.

A few NGS and C&GS documents stand out as particularly important. Perhaps most significant is *NOAA Manual NOS NGS 5* (Stem, 1990), the official defining document of SPCS 83. This publication was intended to supplement (rather than replace) *Special Publication 235* by Mitchell and Simmons (1945 and 1977), which served a similar role for SPCS 27, but also for SPCS overall. *Special Publication 235* was the only SPCS document referenced in the SPCS policy statement in the Federal Register (1977), published in preparation for the North America Datum of 1983 (NAD 83). That Federal Registry entry was in turn cited in SPCS policy (NGS, 2001), and again in the nearly identical, later superseding, SPCS policy (NGS, 2012).

Although this report is intended to be comprehensive in breadth, there is too much material and history for an in-depth treatment. Nonetheless, it should provide a fairly complete picture of SPCS origin, evolution, and current status.

Before the North American Datum of 1927

The earliest found U.S. Coast Survey publication that provides a detailed treatment of map projections was an annual report by Superintendent Alexander Bache (1853). This report focused in particular on the Polyconic projection, which had been introduced approximately in 1820 by Ferdinand Hassler, the first superintendent of the Survey of the Coast (Snyder, 1987). From 1853 through approximately 1920 (C&GS, 1898; Adams, 1919), most C&GS publications on projections were on the Polyconic. By the 1880s it had become a standard in the United States for maps and charts, and C&GS published several editions of Polyconic projection tables from 1884 to 1935 (e.g., C&GS 1900 and 1935). It was also adopted by the U.S. Geological Survey (USGS) in the 1880s and used for nearly all large-scale USGS mapping into the 1950s (Snyder, 1987). The main advantage of the Polyconic is that it is easy to construct geometrically. However, it is neither a conformal nor an equal-area projection.

A system of “progressive maps” for the entire United States based on Polyconic projections was proposed by C&GS in 1919 (Bowie and Adams), both for civilian and military use. That system was soon incorporated into the World Polyconic Grid (WPG) by the Army Map Service (Snyder, 1987). Although not adopted for civilian mapping, it demonstrated the usefulness of an integrated system of map projections and ultimately led to development of both SPCS and the Universal Transverse Mercator (UTM) system. The Department of Defense replaced WPG with the conformal UTM system in the 1940s.

Conformal Map Projections

Conformality was recognized as an important and desirable property for map projections used for certain types of computations, such as those in engineering, surveying, and military applications. Briefly, conformality enforces the condition that, at a point, angles are preserved and scale error is the same in all directions. These qualities preserve shape locally, and it makes them particularly useful for calculations involving directions, azimuths, and distances. They are, however, much more difficult to compute and construct. Apart from the regular Mercator projection used for nautical charts, conformal projections were not employed by official mapping authorities anywhere in the world (with one exception noted below) until around 1920 (Eckman, 2015). Two now-familiar conformal projections were adopted at about that time. One was an ellipsoidal form of the Lambert Conformal Conic (LCC) adopted by C&GS, as described and developed by Deetz (1918) and Adams (1918). The other was the ellipsoidal Gauss-Krüger form of the Transverse Mercator (TM) adopted by Prussia (Germany), as developed by Krüger in 1919. Interestingly, both the LCC and TM were originally derived nearly 150 years earlier, by Lambert in 1772, although the TM was limited to its spherical form (Snyder, 1987). An ellipsoidal form of the TM was developed by Gauss in 1825. The TM was further refined by Schreiber in 1866 and 1897, and then by Krüger in 1912 and 1919 (Snyder 1987; Eckman, 2015). NGS used the Gauss-Schreiber form of the TM for SPCS 27 and the Gauss-Krüger form for SPCS 83 (Stem, 1990). These two forms of the TM yield slightly different coordinates, particularly as distance from the central meridian increases.

To give credit where due, the earliest adoption of a conformal mapping projection by a national mapping agency was indeed much earlier, by Sweden in 1817. It was essentially identical to the LCC, but derived independently by Spens in 1817, without knowledge of Lambert's work (Eckman, 2015). The LCC as presented by Lambert was not used until C&GS re-derived its ellipsoidal form (following the work of Gauss) and published projection tables in 1918.

Non-Conformal Plane Rectangular Coordinates

Although development of map projections occurred at C&GS, beginning with the Polyconic and later including the LCC (as well as other projections), additional work was done for computing rectangular coordinates without a map projection. This included a method for computing local rectangular coordinates published by Reynolds (1921). It is essentially a (non-conformal) local geodetic horizon or "tangent plane" system of limited areal extent (e.g., three "zones" were used for Greater New York City). The document by Reynolds was republished in 1936 and 1938 with minor revision, shortly after the development of SPCS. No records were found of such non-projected rectangular coordinate systems after this time, although it appears the 1938 document served as the basis for the Guam Zone of SPCS 27, described as an "approximate" Azimuthal Equidistant projection (not conformal); for details of its usage and implementation, see Claire (1968, pp. 35-39 and 52-54) and Snyder (1987, pp. 194-201).

State Plane Coordinate System of 1927

In early 1933, the North Carolina State Highway and Public Works Commission contacted C&GS concerning the creation of a system of plane coordinates for the state. The request was described by Adams (1937) in the first known published use of the term "State Plane Coordinates." It was decided to use a conformal projection to preserve angles, and the C&GS-developed LCC was used in a single zone for North Carolina, since it is longer in the east-west direction. New Jersey was chosen as the test case for states long in the north-south direction, using the Gauss-Schreiber form of the TM. Both projections worked well for the intended purpose: to provide surveyors a means for using planar mathematics to perform "geodetic" surveys based on the new North American Datum of 1927 (NAD 27). With the launch of the Civil Works Administration, the need for such planar systems was apparent, and development was expedited. In an example of remarkable diligence, design of the entire State Plane system was completed within a year. By early 1934, a total of 110 projections were designed for all the 48 states of that time (66 LCC and 44 TM zones).

It is interesting to note that SPCS was originally considered a practical "engineering" solution within C&GS. Adams (1937) described it as a "…State-wide systems of plane coordinates… undertaken at the request of a practical engineer and surveyor… not as a result of a brainstorm of some theoretical mathematician and geodesist." This viewpoint persists throughout various C&GS and NGS documents.

Timeline of SPCS 27 Development and Implementation

From the 1930s through the 1960s, significant effort was expended by C&GS to facilitate and promote the use of SPCS 27. A majority of that work consisted of providing education and tools to support customers. The activity in this time period is summarized in the following timeline.

1935. Manuals of traverse computations were published, one for the LCC and the other for the TM projection (Adams and Claire, 1935a and 1935b, respectively). Much of this work was greatly simplified by publication of SPCS 27 coordinates on control stations, and the later publication of projection and intersection tables in the 1950s and 1960s.

1936. Federal Board of Surveys and Maps recommended that all federal agencies "adopt the system of plane coordinates devised by… the Coast and Geodetic Survey…" (Mitchell and Simmons, 1945 and 1977). It was also the first known use of the term "State plane-coordinate systems." This plural form of the name was used in C&GS and NGS publications until the 1990 manual by Stem for SPCS 83.

1945. "The State Coordinate Systems (A Manual for Surveyors)" was published by C&GS (Mitchell and Simmons, 1945). This document provided a comprehensive description of SPCS 27, including guidance on how to perform fieldwork and computations. It also provided parameters for all 111 zones defined at that time (for the 48 states). This is the first known C&GS documentation of California Zone 7 for Los Angeles County, which was not part of the original 110 zones defined for SPCS 27. Zone 7 was not included in the projection tables of the 1936 triangulation report for California (Mitchell, 1936), but it was included in later projection tables (C&GS, 1951).

1947. U.S. Army replaced the World Polyconic Grid with UTM, expanding the role of conformal projected coordinate systems (Snyder, 1987). UTM later also became the basis for the U.S. National Grid (referenced to NAD 83).

1948. "Manual of Plane-Coordinate Computation" published by C&GS (Adams and Claire, 1948). This publication, along with the 1945 SPCS manual, served essentially the same role Stem's 1990 manual serves for SPCS 83. The combined 1945 and 1948 documents are lengthier than Stem's (348 pages vs. 130 pages); the 1948 manual required a great deal of detail to demonstrate how to perform computations manually and necessitated lengthy tables.

1950. To encourage the use of SPCS by engineers, C&GS published a manual on its use in route surveying (Mitchell, 1950).

1950 – 1969. Creation of projection tables (at 1 arc-minute intervals) for use in computing SPCS coordinates for all states (except Alaska). These tables were accompanied by C&GS publications of trigonometric and logarithmic tables, for use in slide rule and mechanical machine computation. Intersection tables were also published for all states at 2-1/2 arc-minute intervals, for use in plotting maps (and for interpolating coordinates in Alaska).

1950s. USGS began changing its topographic quadrangle maps from the Polyconic to the projection used in the SPCS for the principal state on the map (Snyder, 1987).

1952. In recognition of the importance of conformal projections for the C&GS and their customers, "Conformal Projections in Geodesy and Cartography" was published (Thomas, 1952). This combined and expanded on previous C&GS publications on conformal projections, putting all the existing C&GS computations into a single document.

1957. C&GS began using electronic computers for mass computation of SPCS 27 coordinates (Claire, 1968). Prior to this, coordinates were computed from latitude and longitude rounded to 0.001 arc-second (approximately 3 centimeters or 0.1 foot).

ca. 1960. C&GS defined ten SPCS 27 zones for Alaska and five for Hawaii. Zone 1 for the Alaska panhandle was based on the Oblique Mercator (OM) projection, as developed by Martin Hotine in 1947 (Snyder, 1987). Alaska Zone 1 added a third conformal projection type to SPCS. Alaska Zone 1 is the only zone that uses this projection (for both SPCS 27 and 83), possibly because it did not exist when SPCS was first created. However, it has also been used for other government applications in the United States, such as the U.S. Lake Survey (Snyder, 1987).

1964. LCC projections referenced to a "scaled" Clarke 1866 ellipsoid were adopted for the three zones in Michigan. The projections replaced the three previous TM zones that were based on the unscaled 1866 ellipsoid (Burkholder, 1980; Lusch, 2005). This was done to reduce the magnitude of map projection linear distortion (map scale error) throughout the state to within 1:10,000 *at the topographic surface*. A mean land elevation of 800 feet was used to compute a factor of exactly 1.0000382 at 44° latitude, and the ellipsoid semi-major axis was scaled by this value with its flattening held constant (C&GS, 1979). Such an approach to modifying the reference ellipsoid has not been used for any other state in the SPCS, and it was not used for the three SPCS 83 LCC zones in Michigan.

1968. Formulas for computing SPCS 27 coordinates by electronic means were published (Claire, 1968). Rather than strive for the most accurate coordinates, for the sake of consistency the formulas were instead intended to replicate the approximate values in the previously published projection and intersection tables. Although only accurate to about 3 centimeters (0.1 foot) in an absolute sense, the coordinates had greater relative accuracy, making them suitable for surveying and engineering work in areas of limited extent.

Status of State Plane in the 1970s

With the creation of the National Oceanic and Atmospheric Administration (NOAA) in 1970, C&GS was folded into the National Ocean Service (NOS), and NGS was created from the geodesy portion of C&GS. Even by this time, SPCS was not used as widely within the surveying and engineering community as NGS had hoped (Dracup, 1974 and 1977). The 1974 document by Dracup provides the earliest explicit description of procedures for scaling State Plane coordinates to "ground" (the topographic surface) and creating a "project datum." This idea was apparently first published by Pryor (1958), an engineer with the Bureau of Public Roads. But, the 1974 document is the first known occurrence of this scaling procedure in an NGS or C&GS publication. The approach was widely taught in NGS workshops from the late 1960s into the 1990s (Zilkoski, 2017). It is often referred to as "modified State Plane," although it appears NGS has not used that terminology. The 1974 document by Dracup is also the first known published use of the abbreviation "SPCS."

In 1974, a revised version of the 1945 State Plane "Manual for Surveyors" (*Special Publication 235*) was published, and it was soon followed by a 1977 revision (Mitchell and Simmons, 1977). The 1977 version is apparently identical, with the exception of a 1977 Federal Register Notice (FRN) that was inserted at the beginning of the document. The 1977 FRN was related to the new 1983 datum, as described in the next section. The 1974 and 1977 versions of *Special Publication 235* included an additional 23 zones, for a total of 134 zone definitions. Three of the new zones replaced three previous zones (in Michigan), so there was a net increase of 20 zones from the 111 defined in the 1945 edition of the manual, for a total set of 131 zones for the final SPCS 27 version. The 23 additional zones are listed below:

- Ten for Alaska (1 LCC, 8 TM, and 1 OM).
- Five for Hawaii (TM).
- Two for Puerto Rico and the U.S. Virgin Islands (LCC).
- One additional "offshore" zone for Louisiana, for the northern Gulf of Mexico (LCC).
- One for American Samoa (LCC).
- One for Guam (a non-conformal "approximate" Azimuthal Equidistant projection).
- Three new LCC zones for Michigan to replace the previous three TM zones, with the new zones referenced to a "scaled" version of the Clarke 1866 ellipsoid (as discussed above).

The original 110 zones (prior to CA 7) and the final 131 zones of SPCS 27 are listed in Table 1, along with the current 125 zones of SPCS 83. Cells shaded orange indicate changes in the number of zones, projection type, defining parameters, or zone configuration. It does not indicate a change in grid origins (false eastings and/or northings), since, in the transition from SPCS 27 to SPCS 83, grid origins were changed for all zones (except for Alaska Zone 1 and the North Carolina zone, which are identical in both SPCS 27 and 83). Note that SPCS 27 zones associated with islands (Hawaii, Puerto Rico and the U.S. Virgin Islands, American Samoa, Guam, and islands in the Bering Sea) are referenced to datums other than NAD 27, as indicated in the Table 1 footnotes. However, all SPCS 27 zones were based on the Clarke 1866 ellipsoid, regardless of the datum used (except for the "scaled" Clarke 1866 ellipsoid used for the three LCC Michigan zones defined in 1964).

All SPCS zones for the entire NSRS are shown in Figure 1. The 23 zones of SPCS 83 with yellow hatching indicate changes in geodetic parameters from SPCS 27; changes in grid origins (false eastings and/or northings) are not indicated. The seven SPCS 83 zones with red hatching indicate changes from SPCS 27 in zone configuration (e.g., change in county boundaries), absorption of zones within other zones (e.g., California Zone 7 of SPCS 27 becoming part of Zone 5 in SPCS 83), and addition of the new statewide Kentucky zone without removing the existing north and south Kentucky zones (this unique variation in SPCS layout is revisited later).

Table 1. Zones of the State Plane Coordinate System. Orange shading denotes change in the number of zones, projection type, or parameters other than grid origins (false eastings and/or northings). See Appendix A and B for the complete set of defining characteristics for SPCS 83 and 27, respectively.

State / Territory	**Original SPCS 27**			**Final SPCS 27**				**Current SPCS 83**			
	LCC	TM	**Total**	LCC	TM	Other	**Total**	LCC	TM	Other	**Total**
Alabama		2	**2**		2		**2**		2		**2**
Alaska	—	—	**—**	1	1(a)	1(b)	**10**	1	8	1(b)	**10**
Arizona		3	**3**		3		**3**		3		**3**
Arkansas	2		**2**	2			**2**	2			**2**
California	6		**6**	7			**7**	6			**6**
Colorado	3		**3**	3			**3**	3			**3**
Connecticut	1		**1**	1			**1**	1			**1**
Delaware		1	**1**		1		**1**		1		**1**
Florida	1	2	**3**	1	2		**3**	1	2		**3**
Georgia		2	**2**		2		**2**		2		**2**
Hawaii	—	—	**—**		5(c)		**5**		5		**5**
Idaho		3	**3**		3		**3**		3		**3**
Illinois		2	**2**		2		**2**		2		**2**
Indiana		2	**2**		2		**2**		2		**2**
Iowa	2		**2**	2			**2**	2			**2**
Kansas	2		**2**	2			**2**	2			**2**
Kentucky	2		**2**	2			**2**	3(d)			**3**
Louisiana	2		**2**	3			**3**	3			**3**
Maine		2	**2**		2		**2**		2		**2**
Maryland	1		**1**	1			**1**	1			**1**
Massachusetts	2		**2**	2			**2**	2			**2**
Michigan		3	**3**	3			**3**	3			**3**
Minnesota	3		**3**	3			**3**	3			**3**
Mississippi		2	**2**		2		**2**		2		**2**
Missouri		3	**3**		3		**3**		3		**3**
Montana	3		**3**	3			**3**	1			**1**
Nebraska	2		**2**	2			**2**	1			**1**
Nevada		3	**3**		3		**3**		3		**3**
New Hampshire		1	**1**		1		**1**		1		**1**
New Jersey		1	**1**		1		**1**		1(e)		**1**
New Mexico		3	**3**		3		**3**		3		**3**
New York	1	3	**4**	1	3		**4**	1	3(e)		**4**
North Carolina	1		**1**	1			**1**	1			**1**
North Dakota	2		**2**	2			**2**	2			**2**
Ohio	2		**2**	2			**2**	2			**2**
Oklahoma	2		**2**	2			**2**	2			**2**
Oregon	2		**2**	2			**2**	2			**2**
Pennsylvania	2		**2**	2			**2**	2			**2**

State / Territory	**Original SPCS 27**			**Final SPCS 27**				**Current SPCS 83**			
	LCC	TM	**Total**	LCC	TM	Other	**Total**	LCC	TM	Other	**Total**
Rhode Island		1	**1**		1		**1**		1		**1**
South Carolina	2		**2**	2			**2**	1			**1**
South Dakota	2		**2**	2			**2**	2			**2**
Tennessee	1		**1**	1			**1**	1			**1**
Texas	5		**5**	5			**5**	5			**5**
Utah	3		**3**	3			**3**	3			**3**
Vermont		1	**1**		1		**1**		1		**1**
Virginia	2		**2**	2			**2**	2			**2**
Washington	2		**2**	2			**2**	2			**2**
West Virginia	2		**2**	2			**2**	2			**2**
Wisconsin	3		**3**	3			**3**	3			**3**
Wyoming		4	**4**		4		**4**		4		**4**
Puerto Rico & U.S. Virgin Islands	—	—	**—**	2(f)			**2**	1			**1**
American Samoa	—	—	**—**	1(g)			**1**	—	—	—	**—**
Guam	—	—	**—**			1(h)	**1**		1		**1**
Totals	66	44	**110**	75	54	2	**131**	69	55	1	**125**

(a) Alaska Zone 9 consists of islands referenced to four local datums (the St. Lawrence, St. Matthew, St. Paul, and St. George datums of 1952).

(b) Oblique Mercator projection.

(c) Referenced to Old Hawaiian Datum.

(d) Additional statewide zone added to existing North and South zones for Kentucky in 2001.

(e) New Jersey (2900) and New York East (3101) SPCS 83 zones have identical defining parameters.

(f) Referenced to Puerto Rico 1940 Datum.

(g) One-parallel (tangent) LCC projection referenced to the American Samoa 1962 Datum.

(h) “Approximate” Azimuthal Equidistant projection (non-conformal) referenced to Guam 1963 Datum.

SPCS zones of the conterminous United States (CONUS) are shown in Figure 2. The top map shows the final 112 CONUS zones of SPCS 27, and the bottom map shows the current 108 CONUS zones of SPCS 83. The same yellow and red hatching schemes are used to indicate changes from SPCS 27 to 83.

Figure 3 shows SPCS 27 and 83 zones for Alaska (10 zones), Hawaii (5 zones), and Puerto Rico and the U.S. Virgin Islands (PRVI). For SPCS 27, PRVI consisted of two zones, which were consolidated into a single zone for SPCS 83. However, the two SPCS 27 and the one SPCS 83 zones all had identical geodetic parameters; the only difference between them is the grid origins (false eastings and/or northings).

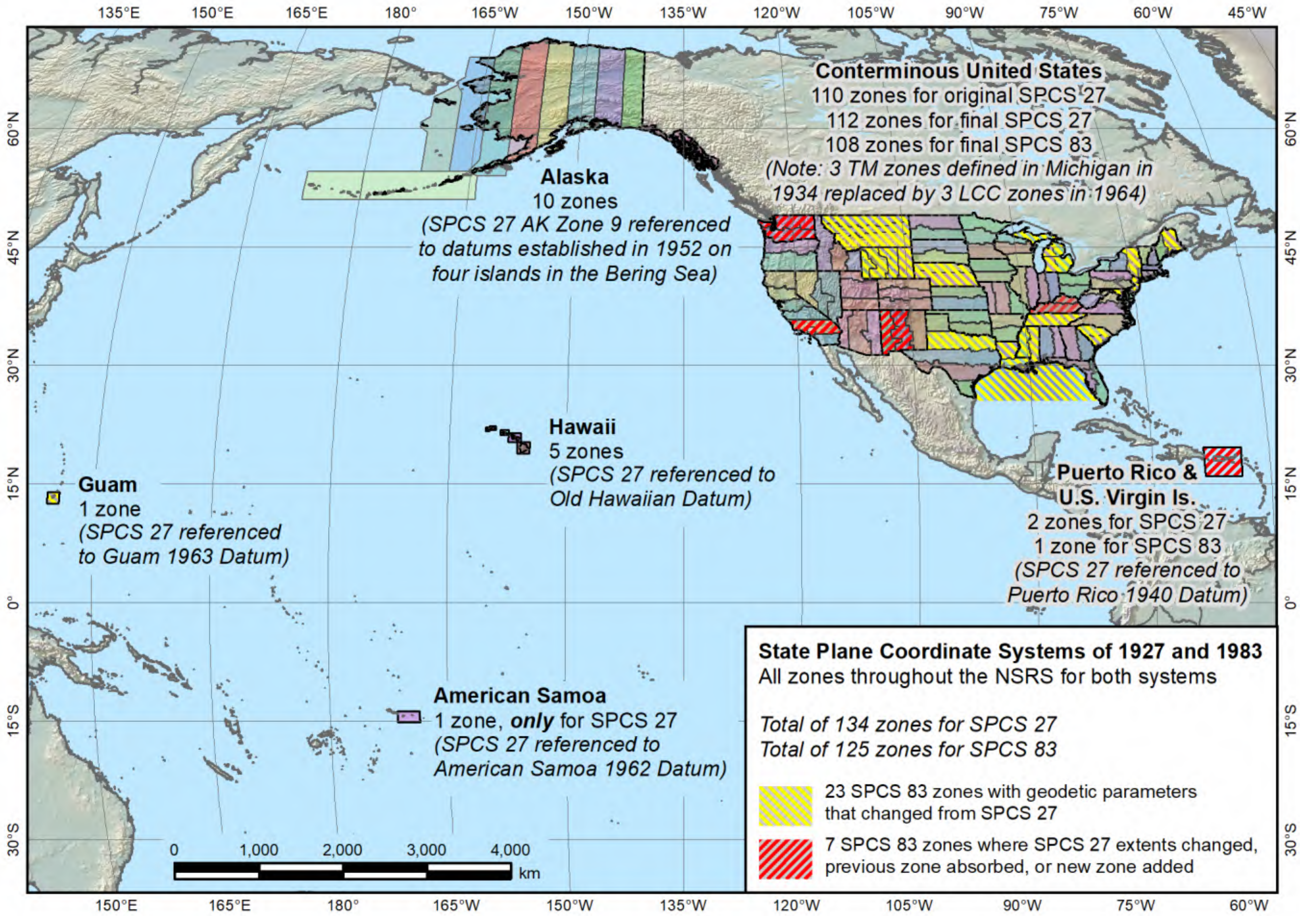

Figure 1. Zones of the State Plane Coordinate Systems of 1927 and 1983 for the entire NSRS.

A zone for American Samoa was defined for SPCS 27 but not for SPCS 83. The SPCS 27 zone for Guam was the only non-conformal projection ever used for SPCS (the "approximate" Azimuthal Equidistant projection mentioned above); it was changed to a TM for SPCS 83. Despite being called "SPCS 27", zones for these and several other islands were not referenced to NAD 27 because they were too far from the North America mainland for connection using line-of-sight surveying methods available when they were established (Smith and Bilich, 2017). These eight astronomically determined local horizontal island datums are the Puerto Rico 1940 Datum in the Caribbean; the Old Hawaiian, American Samoa 1962, and Guam 1963 datums in the Pacific; and the St. Lawrence, St. Matthew, St. Paul, and St. George datums of 1952 in the Bering Sea (all in Alaska Zone 9; see Figure 3).

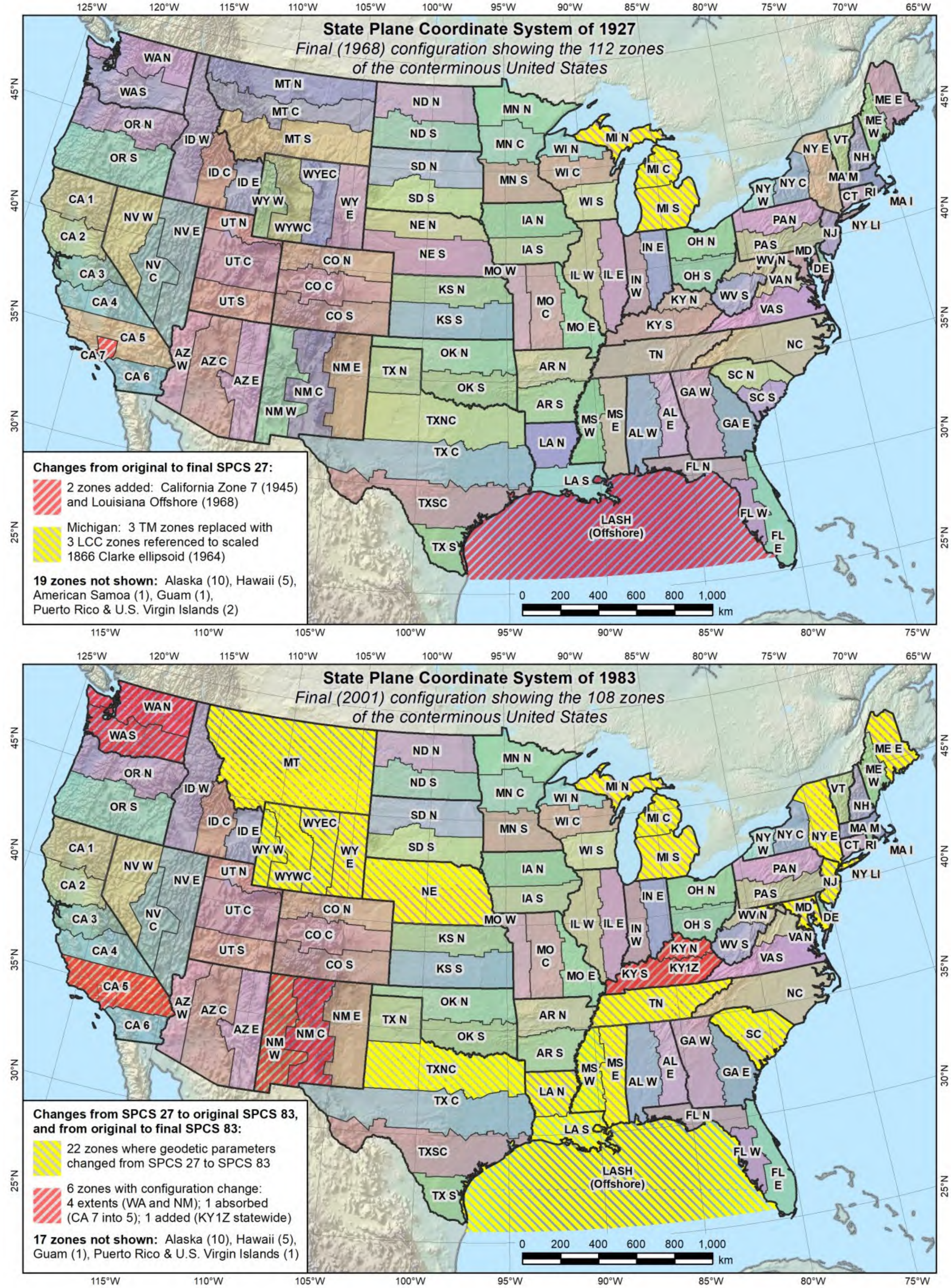

Figure 2. Zones of the State Plane Coordinate System of 1927 (top) and 1983 (bottom) in CONUS.

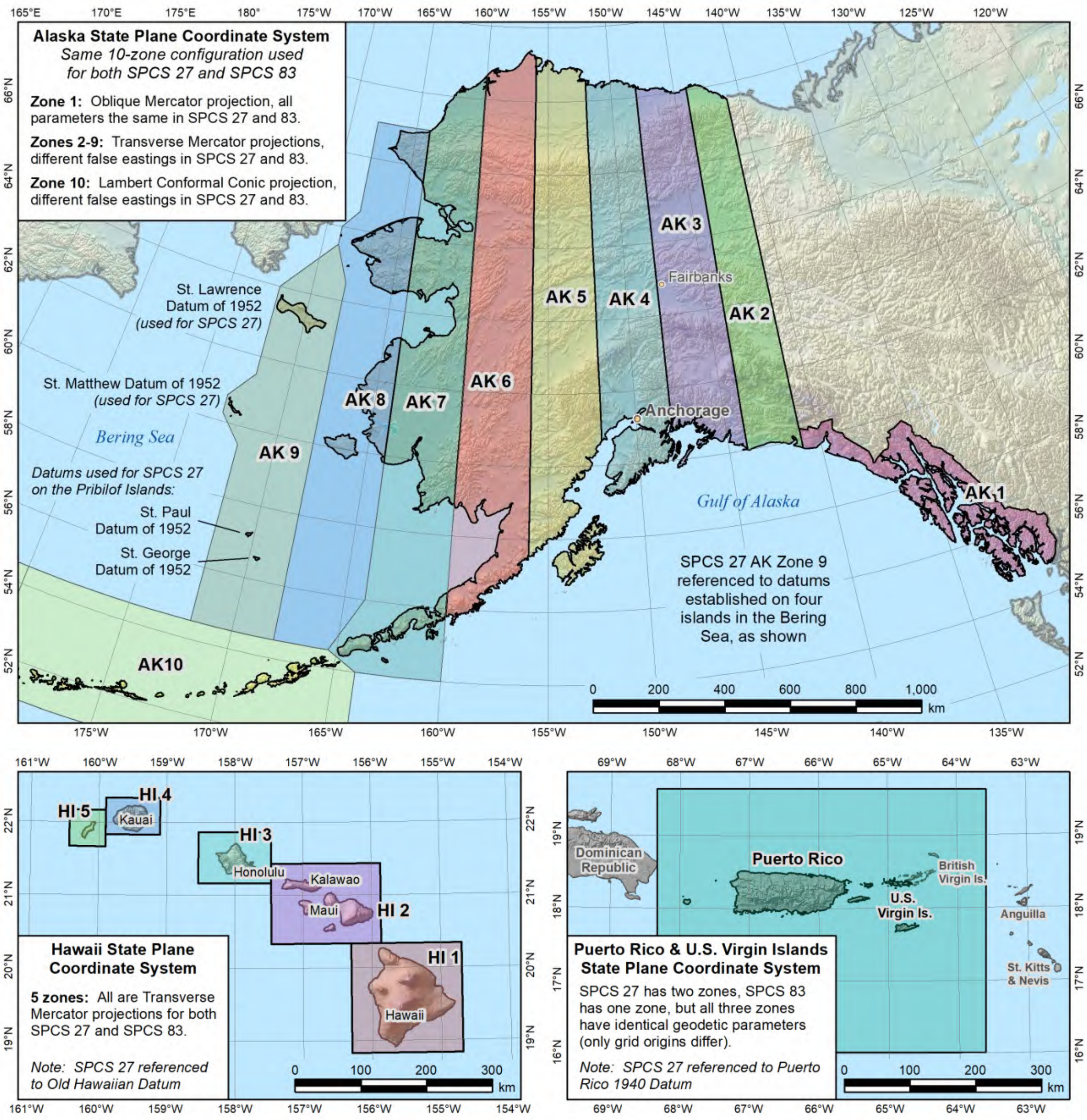

Figure 3. Zones of the State Plane Coordinate Systems of 1927 and 1983 for Alaska, Hawaii, and Puerto Rico and the U.S. Virgin Islands.

Appendices A and B give the defining parameters for all SPCS 83 and SPCS 27 zones, respectively, In performing research for this report, finding a complete set of reliable (and legible) defining constants for these three versions of SPCS proved difficult. Including that information in this publication is the only known occurrence of a complete set of all SPCS zone definitions in an official NGS document. It appears no NGS document—nor NGS webpage—has a complete set of zone definitions for SPCS 83 (Stem's 1990 manual does not include the more recent Guam or statewide Kentucky zones).

State Plane Coordinate System of 1983

Transition to a New Datum and Naming Conventions

The 1977 revision of the 1974 SPCS 27 manual (Mitchell and Simmons, 1977) immediately followed the publication of the Federal Register Notice (1977), "Policy on Publication of Plane Coordinates." As stated above, it appears the only difference between the 1974 and the 1977 versions of the manual is the addition of the 1977 FRN. This activity was in preparation for a new SPCS that would reference the North American Datum of 1983 (NAD 83).

With regard to naming conventions, the 1977 Federal Register Notice (FRN) is the first known use of the abbreviation "SPC" for "State Plane Coordinates" (without the "S" for "Systems" or "System"). The abbreviation "SPCS" was employed earlier by Dracup (1974) for the plural version of the name ("Systems"), as first used in the 1930s. A singular version of the name (and abbreviation) was first published in the State Plane technical manual by Stem in 1989 (revised in 1990 with minor corrections), as the "State Plane Coordinate System of 1983." It was in the 1989/1990 manual where the first known published use of the abbreviations "SPCS 27" and "SPCS 83" was found to distinguish the two systems. That naming and abbreviation convention is used in this publication.

Evaluation of State Plane and Changes from SPCS 27 to SPCS 83

According to Stem (1990), NGS performed studies in the mid-1970s to evaluate other NAD 83 projected coordinate systems as possible alternatives to the type of system used for SPCS 27. Part of the motivation was concern over complexity of a system based on three projection types (actually four, if Guam as defined at the time is included) and the large number of zones (131 at the time). Among the alternatives considered were the existing UTM system and a UTM-like system with narrower zones (to reduce scale error and arc-to-chord corrections). In the end, it was decided to retain the fundamental SPCS 27 design for the following three reasons:

- SPCS had already been accepted as part of NAD 83 statute in 37 states (presently 48 states and two territories).
- Because SPCS had been in use for more than 40 years, there was widespread familiarity with its definition and the procedures for using it.
- The availability of electronic computation made the advantages of reducing the number of zones or projection types largely irrelevant.

With the decision to retain the overall structure of SPCS 27, NGS announced a policy for State Plane (as well as UTM) referenced to NAD 83 in the Federal Register (1977). More details of the Federal Register policy will be discussed in the next section. But it is worth noting at this point that the 1977 announcement was used as an impetus for NGS to solicit comments from April 1978 through January 1979. Input was obtained from the land surveyor board members of the National Council of Engineering Examiners (NCEES), officers and affiliates of the American Congress on Surveying and Mapping (ACSM), and various state and local public agencies. This effort produced committees or liaison contacts in 43 states. The resulting input, together with characteristics of NAD 83 itself, and existing NGS policy, resulted in several changes from SPCS 27 to SPCS 83. The more important of these changes are listed below.

- Geodetic Reference System of 1980 (GRS 80) ellipsoid (Moritz, 2000) replaced the Clarke 1866 ellipsoid.
- Gauss-Krüger form of the TM replaced the Gauss-Schreiber form (they do not yield the same results, and the difference increases with distance from the central meridian).
- Grid origins (false eastings and northings) were defined in meters rather than U.S. survey feet (although grid origins for three states are non-exact conversions to meters from U.S. survey feet: Colorado, Connecticut, and North Carolina).
- Grid origins were changed by significant amounts for all zones to ensure projected coordinates differed substantially from SPCS 27. *Exceptions:* they did not change at all for Alaska Zone 1; changed false easting by less than 1 centimeter for North Carolina (due to conversion of SPCS 27 grid origins to meters rounded to nearest centimeter); decreased false easting by exactly 4 feet (1.219 meter) in South Carolina (due to treating SPCS 27 grid origin value of 2,000,000 U.S. survey feet as international feet, and then converting to meters).
- More accurate coordinates and related quantities were computed using new mapping equations and high-precision electronic computers.
- Projection type or the defining parameters of several zones were changed, some zones were eliminated, and a zone for one territory was removed (American Samoa). See Table 1 for a list of the states affected by these changes. These changes are also shown in the maps of figures 1 and 2.

Implementation and Documentation of SPCS 83

NAD 83 was completed in 1986 and the SPCS 83 technical manual by Stem was published in 1989 (then slightly revised in 1990). This manual was intended to *supplement* (rather than replace) the State Plane manual for surveyors (Mitchell and Simmons, 1977), and to *replace* the "State Plane coordinates by automatic data processing" (Claire, 1968). Stem's 1990 manual includes all the equations necessary for performing forward and inverse electronic computer-based coordinate computations to 1 millimeter (or better) accuracy within a zone, as well as for computing point scale factors, line scale factors, convergence angles, and arc-to-chord corrections. The manual also includes the parameters for 123 of the 125 current SPCS 83 zones shown in Table 1 (the Guam TM and Kentucky single statewide LCC zones were created after 1990, and the manual was not updated with those zones). In addition, the 1990 manual contains information on UTM, the status of NAD 83 legislation, formulas for approximate computations, examples of using SPCs in traverses, and background information on SPCS and projections in general.

Although intended to supplement the 1977 State Plane manual, Stem's 1990 manual has become the *de facto* sole defining document for SPCS 83, and it is widely referenced. It is interesting to note that the 1990 manual is also the last official NGS technical publication on SPCS 83, or on State Plane or map projections in general. This is in stark contrast to the half century from the

1930s through the 1970s. During that period, NGS and (mainly) C&GS published well over a hundred official documents on State Plane and map projections. Granted, most of those documents were projection and intersection tables, but there were also a few dozen technical publications that were not simply tabulated values. Given the changes in SPCS 83 and other activities on projected coordinate systems, it is unclear why NGS stopped publishing on the subject and why Stem's 1990 manual was not updated. With the need to define and document SPCS2022, NGS will produce new official reports on map projections within the next few years. This publication is the first among those new NGS documents.

The only known NGS publications on map projections after Stem (1990) are related to policy, specifically four official policy statements (from 1991 through 2012) and a dozen NGS Federal Registry entries made in the mid-to-late 2000s regarding linear units of SPCS 83 coordinates as adopted by various states. NGS policy on State Plane is the topic of the next section.

State Plane Coordinate System Policies

Defining Policy on Projected Coordinates in the Federal Register

As previously mentioned, the earliest known published policy on State Plane was in 1977 in the Federal Register (1977). This policy notice was made in preparation for the transition to NAD 83, and it includes both SPCS and UTM (in the context of NAD 83). For SPCS, it references a single document, *Special Publication 235* (the 1974 version of the State Plane "Manual for Surveyors"). Within three years, this 1974 version was revised (Mitchell and Simmons, 1977) by incorporating the 1977 FRN in its first two pages. For all practical purposes, *Special Publication 235* has been superseded by Stem (1990).

For UTM, the 1977 Federal Register Notice (FRN) cites the 1958 Department of Army Technical Manual TM 5-241-8. This manual has been superseded more than once; the current UTM references are to the National Geospatial-Intelligence Agency (NGA 2014a and 2014b). Since NGS will continue to publish UTM coordinates referenced to the four 2022 TRFs, the most current NGA documentation should be referenced, as there have been changes, including computation methods (discussed later in this publication).

The 1977 FRN on plane coordinates is short, as well as specific, with regard to SPCs. Most of the items have been adopted for SPCS 83, but not all (those that have not are reviewed in the next section). To summarize the main items, the policy note states that parameters will be defined and coordinates published in meters, and that computed coordinate error will not exceed 0.1 millimeters within a zone. It includes amendments based on desires and needs within states, such as elimination of negative coordinates within zones and changing grid origins. The two more interesting entries are those of allowing part of a zone to not follow a county boundary (Grant County in Washington state), and redefining or adding zones to avoid the splitting of major metropolitan areas (such as Washington, D.C.) across zones. It also states that SPC constants will not be published until 1982, to allow time for states to legislate their definitions—one year prior to the planned release of NAD 83 (which was not finalized until 1986). That is the same as if NGS would now say SPCS2022 parameters would not be published until 2021.

Policies on Changes to State Plane

The previous section mentioned that NGS solicited input on the 1977 Federal Register policy notice. Yet there were no later entries in the Federal Register reflecting such input. This implies that the 1977 FRN policy still stands. And indeed it has been referenced in two later NGS policy statements: "Policy on Changes to Plane Coordinate Systems" (NGS, 2001), superseded by "Policy on Changes to State Plane Coordinates" (NGS, 2012). The two policies are nearly identical. Summarizing the current (2012) policy, all proposed SPCS 83 changes must satisfy the following conditions:

1. Changes must be in writing to the NGS Director and be co-signed by the state Department of Transportation (DOT), state office of Geographic Information Systems (GIS), state land surveyor professional organization, and other organizations determined by NGS on a state-by-state basis. A similar request must also be submitted to the USGS.
2. Limited to LCC, TM, and OM projections, defined with respect to the GRS 80 ellipsoid.
3. Changes must be adopted by state law (or regulations with no public opposition), including all defining parameters and legislated units (meters, U.S. survey feet, or international feet).
4. Zones must be defined only by international, state, or county boundaries. This item references the 1977 FRN policy. But, the FRN does not explicitly include such a requirement, and in fact includes exceptions for a specific county and for metropolitan areas. (This will be revisited in the next section.)
5. Coordinates for new zones must differ by at least 10,000 meters from SPCS 27.
6. Must have a distinct naming convention.
7. May require state reimbursement for expenses incurred by NGS for changes to SPCS.
8. Requires that the state publish articles and provide education concerning any accepted changes to SPCS, and those must be available on the internet. Travel expenses for NGS personnel to provide technical support must be reimbursed by the state.

The main difference between the 2001 and 2012 policy statements is that the 2012 statement includes an explanatory preamble. It provides context to the policy and recognizes that other projected coordinate systems may be designed for specific local uses, but that coordinates from such systems will not be published by NGS. For such cases, NGS recommended that the local systems be designed and implemented within the state. This recommendation includes any "layered" systems of zones that overlap one another or SPCS zones.

Other State Plane Policies

The only other SPCS policies—whether published directly by NGS or posted in the Federal Register—concern linear units. The earliest is "Policy of the National Geodetic Survey Concerning Units of Measure for the State Plane Coordinate System of 1983" (NGS, 1991). This policy was a change to the 1977 FRN policy that stated SPCS 83 coordinates would only be published in meters. Its main requirement was that linear units of feet (U.S. survey or international) be specifically statute-defined for NGS to publish SPCS 83 coordinates in feet. It was updated in "Policy of the National Geodetic Survey Concerning Units of Measure for the State Plane Coordinate System of 1983" (NGS, 2006). Part of the update allowed for situations where units of feet were not defined in statute, by publishing the change in the Federal Register (among other requirements). That condition is why there are twelve Federal Register notices concerning SPCS linear units from 2006 to 2009, as mentioned previously. Currently, 46 states have specifically defined SPCS 83 linear units (40 in U.S. survey feet and six in international feet); see NGS (2009). Table C1 in Appendix C lists the current linear unit adopted for each state, along with associated legislation or FRN, and it gives the definition of each type of foot.

The Role of Legislation in the State Plane Coordinate System

It is not the intent of this publication to provide a detailed discussion of legislation related to SPCS. Yet legislation has played an integral role in the adoption and use of the SPCS since its inception in the 1930s. To illustrate, consider the closing statement of the 1977 FRN: "The National Geodetic Survey will not change projection defining parameters in states that have legally adopted the SPC system until the state amends its legislation."

Efforts to encourage adoption of SPCS in legislation played a prominent role in C&GS and NGS publications throughout the history of the SPCS. It is mentioned by Adams (1937), and it was an important part of *Special Publication 235*, the State Plane "Manual for Surveyors" (Mitchell and Simmons, 1945 and 1977), which served as the defining document for SPCS 27. *Special Publication 235* contains extensive appendix entries on state legislation, including a model act for SPCs. The model act has sections for specifying all defining parameters of the zones within a state and specifically identifies the Clarke 1866 ellipsoid and NAD 27. For defining property corners in the public record using SPCs, it specifies the accuracy of surveys and a maximum distance of half a mile to geodetic control with published SPC values.

Stem's SPCS manual (1990) effectively replaced *Special Publication 235* and also contains an extensive discussion of SPCS legislation, along with an updated version of the model act. It is very similar to the previous model act, but with some differences. Both SPCS 27 and SPCS 83 are allowed and defined, although a section is included at the end of the model act where a date can be specified for when SPCS 83 will replace SPCS 27. There are also SPCS 27 to SPCS 83 changes from U.S. survey feet to meters; from x, y coordinates to eastings and northings; and from half a mile to 1 kilometer for maximum distance to geodetic control (2nd order or better). Interestingly, a brief note at the end of the model act mentions that the 1 kilometer limitation should be re-evaluated in light of emerging GPS technology.

Currently, 48 states and two territories have adopted SPCS 83 legislation, although it appears few (if any) have amended their legislation to accommodate GPS or other improvements in geodetic positioning. Table C1 in Appendix C lists citations (with embedded hyperlinks) for all states and territories with SPCS 83 legislation. Figure 4 shows the states and territories that have enacted SPCS 83 legislation, and the type of foot adopted (if any).

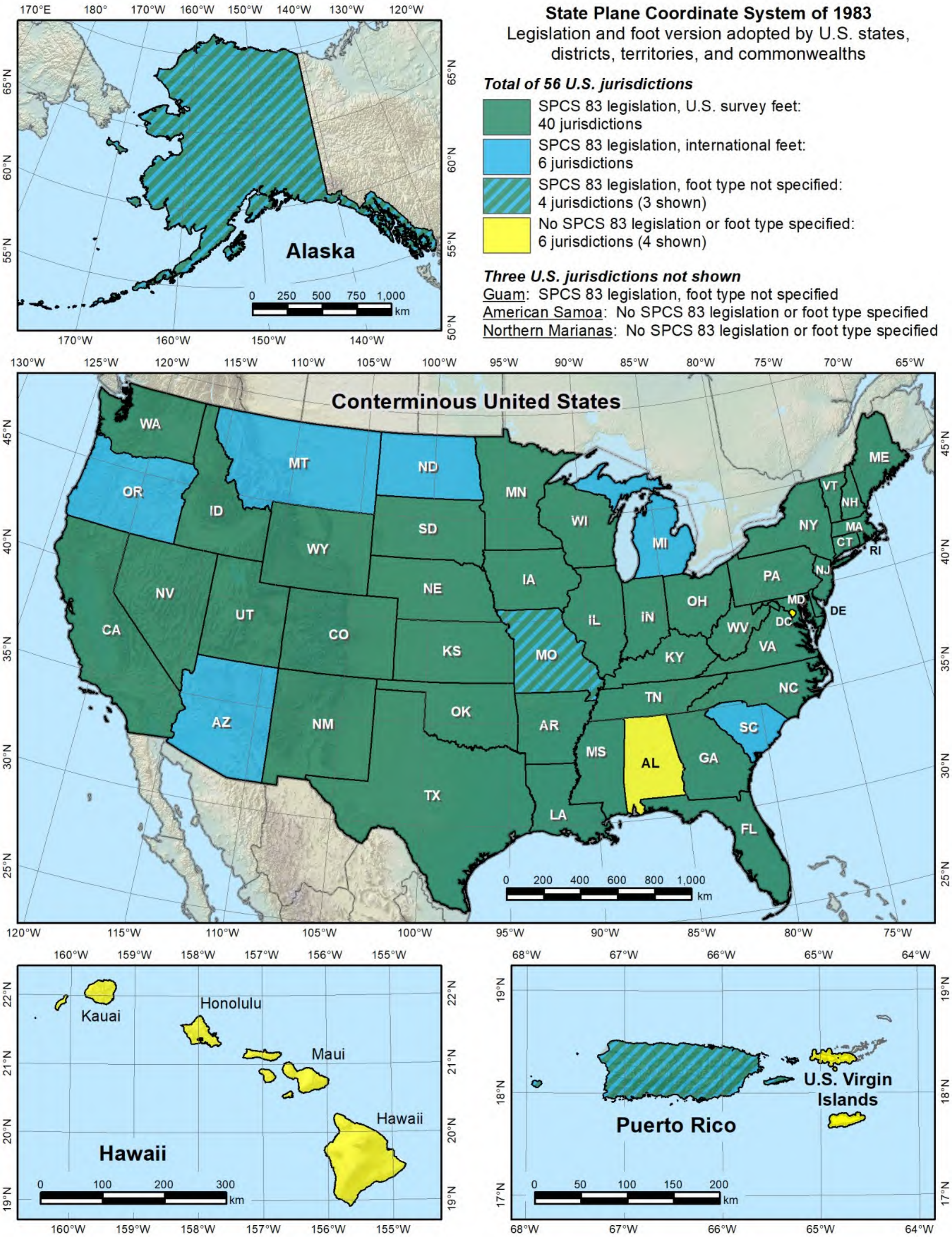

Figure 4. States and territories with SPCS 83 legislation and the type of foot adopted.

As part of the transition from NAD 83 (and SPCS 83) to the new 2022 TRFs, NGS is working with the National Society of Professional Surveyors (NSPS) and the American Association for Geodetic Surveying (AAGS) to draft a statute template that states may use in updating their statutes. Part of this effort is to address the two main weaknesses in existing statute: 1) specific reference to NAD 83 and 2) giving technical details of the defining parameters for each SPCS zone. The approach for removing the first problem is to exclude specific names of datums and adopt generic terminology, for example "the National Spatial Reference System or its successor." Because legislation can be difficult to change, another goal is to have states remove the defining SPCS parameters from statute and place them where they are easy to modify, such as in administrative rules. NSPS will work with states to adopt the new templates, and a draft version has been developed (NSPS, 2016).

Departures from Policy and Convention

As described in the previous two sections, there are three current NGS policies on projected coordinates: "Policy on Changes to State Plane Coordinates" (NGS, 2012), "Policy of the National Geodetic Survey Concerning Units of Measure for the State Plane Coordinate System of 1983" (NGS, 2006), and "Policy on Publication of Plane Coordinates" (Federal Register, 1977). Both the 2012 and 2006 NGS policies cite the 1977 Federal Register policy notice. The 2012 policy cites it directly, and the 2006 indirectly as an explicit update to the 1991 policy, which does directly reference it.

The NGS 2006 policy on linear units is in conformance with the 1977 FRN policy, even though the notice specifies coordinates in meters. It is in conformance, because it is an update to the NGS 1991 policy that explicitly identifies the portion of the 1977 FRN policy being amended, and it specifies how such changes can be made.

In contrast, the NGS 2012 SPCS policy references the 1977 Federal Register notice without modification. This implies that all parts of the 1977 FRN are still in effect (other than the requirement for coordinates in meters, which was amended with the 2006 and 1991 policy statements). Discrepancies between the 1977 FRN and NGS 2012 SPCS policies are listed below. The distinction between "policy" and "convention" is not always clear, and actual implementation can be a proxy for either one. Thus, both types are considered, with items considered as departures from "policy" listed first, with prefix "P."

P1. <u>Zone boundaries must conform to county, state, or international boundaries</u>. The obvious and well-known exception to this policy is in Alaska, where the first nine zones are bound by meridians, and Zone 10 is associated with the Aleutian Islands west of Unimak Island (see Figure 3). A less well-known exception is in Hawaii, where Zone 4 and 5 are both in Kauai County, but on separate islands (lower left map in Figure 3). Another obscure exception is Grant County in Washington state, where the boundary between the north and south Washington zones is along a parallel within the county (compare upper and lower maps in Figure 2). Interestingly, this exception is specifically stated in the 1977 FRN as part of the transition from SPCS 27 to SPCS 83. Perhaps more importantly, the restriction to political boundaries is not explicitly stated as a policy requirement. It may instead be a convention adopted from how the SPCS was originally created. Although the distinction between policy and convention is not entirely clear for this case, it could be argued that it is a policy, since an amendment in the 1977 FRN was used to change the Grant County boundary. In any event, a simple amendment was all that was required for the change. There is another entry in the 1977 FRN suggesting that zones do not necessarily have to correspond to political boundaries. That is addressed in the next item.

P2. <u>Large urbanized areas located on or near zone boundaries</u>. Perhaps the most interesting entry in the 1977 FRN concerns metropolitan areas in multiple zones. It states that zone parameters can be modified or new zones defined so that a large urban area that straddles zones will be in a single zone. There are many urban areas in that situation (for example, New York City, Los Angeles, Chicago, St. Louis), and it does present problems for users. Had this been pursued for SPCS 83, such problems could possibly have been ameliorated. It is worth noting that California Zone 7 of SPCS 27 effectively served that purpose for the Los Angeles metro area (it consisted only of Los Angeles County). This zone was created in 1938 based on consultation of local and state government officials with then retired C&GS Division of Geodesy Chief Major William Bowie (Trimm and Derby, 1966). Based on Major Bowie's recommendation, an LCC projection was designed that minimized scale error in the county. In addition, the grid origin of the projection was selected, such that the coordinates differed as little as possible with those of a previously defined Polyconic projection of the same area, also based on NAD 27 (that is why the false easting and northing for this zone are not "clean" values; see tables B1 and B2 in Appendix B). By 1945, this zone was added to SPCS 27 by C&GS, and in 1947 it was adopted by state statute along with the other six original zones as part of the California Coordinate System (Alexander, 1988). This is an early and noteworthy example of mutually beneficial collaboration that served local needs while maintaining consistency with the nationally defined system. When SPCS 83 was created, CA Zone 7 was eliminated and its area incorporated into CA Zone 5, perhaps because the metro area had grown well beyond the boundaries of Los Angeles County by that time. In any case, including the idea of metropolitan region zones in the 1977 FRN—and the earlier cooperative development of CA Zone 7—shows flexibility in how zones could be defined for special situations. Yet it was never pursued as part of SPCS 83.

P3. <u>"Layered" zones</u>. The preamble in the 2012 policy recommends against SPCS "zones in various layering configurations" (although it does not go quite so far as to forbid it). Here "layered" zones are taken as zones that are entirely within a larger zone (to distinguish from previously mentioned metropolitan zones with partial overlap). Interestingly, a layered system was created in Kentucky in 2001 (Kentucky Legislature, 2001; Kentucky Geography Network, 2002). This statewide Kentucky "one zone" is now officially part of SPCS 83 as KY1Z (code 1600), along with the previously existing north and south zones. KY1Z coordinates are provided on NGS products and services, such as datasheets (along with KY North and/or South coordinates), and on Online Positioning User Service (OPUS) reports, where they are the only SPCS 83 coordinates for solutions in Kentucky.

Figure 5 shows linear distortion at the topographic surface for all three current SPCS 83 zones in Kentucky. As expected, the range in distortion for the statewide zone is greater for the statewide zone, but the positive and negative values are better balanced around zero, indicating there was an attempt to minimize distortion at the topographic surface. Table A1 in Appendix A gives defining parameters for all three zones. Statewide zones are discussed in greater detail later in this publication.

P4. Restriction of projected coordinates to SPCS only. The 2012 NGS policy states that NGS will only publish SPCS projected coordinates. However, NGS also publishes UTM coordinates (as well as closely related U.S. National Grid coordinates). It is explicitly stated in the 1977 FRN that NGS will publish and support UTM as defined by the Department of Defense (but referenced to NAD 83).

P5. Computational accuracy. The 1977 FRN states that the error of computed SPCS 83 coordinates will never exceed 0.1 millimeter within a zone. It is not clear whether this objective was achieved in all areas of all zones. Stem (1990) states that computations using the SPCS 83 formulas are accurate to 1 millimeter within a zone, if at least 12 digits of numerical precision are used. Other than this statement by Stem, there is no known documentation of SPCS 83 computational accuracy. The accuracy of calculations is also affected by distance from the projection axis (central parallel for the LCC, central meridian for the TM, and skew axis for the OM projections). Creation of a single large zone for entire states in SPCS 83 (such as Montana) could degrade computational accuracy, as well as increase maximum scale error (as discussed in the next item).

P6. Maximum scale error limitation. A limit on maximum scale error (linear distortion) is not explicitly stated in the 1977 FRN or other policy statements. However, many other C&GS and NGS documents (including *Special Publication 235* referenced in the 1977 FRN) state that SPCS zone design is based on a maximum scale error criterion of 1:10,000 *with respect to the ellipsoid* (not the topographic surface); this value can also be expressed as ±100 parts per million (ppm). In some sense, this is a convention that has taken on the color of policy, similar to the "convention" of using aggregated counties to define zone extents. And, similar to the county boundary convention/policy, there are exceptions. As shown in the 1977 edition of *Special Publication 235*, the maximum scale error criterion was exceeded in only 11 of the 131 zones. The largest was 1:7300 (±137 ppm) for the Texas South Central Zone and 1:6600 (±152 ppm) for Alaska Zone 10. Both of these are nonetheless substantially less than the maximum scale error of 1:2500 (±400 ppm) for UTM, which was considered too large (Stem, 1990). Yet for SPCS 83, three states were changed from multiple to single zone systems, with a corresponding increase in scale error. Most significant among these was Montana, which went from three LLC zones to one. This change caused an increase in maximum linear distortion to 1:1600 (±625 ppm), which is substantially greater than that of UTM. Moreover, for nearly all areas in all zones, distortion is greater at the topographic surface than on the ellipsoid.

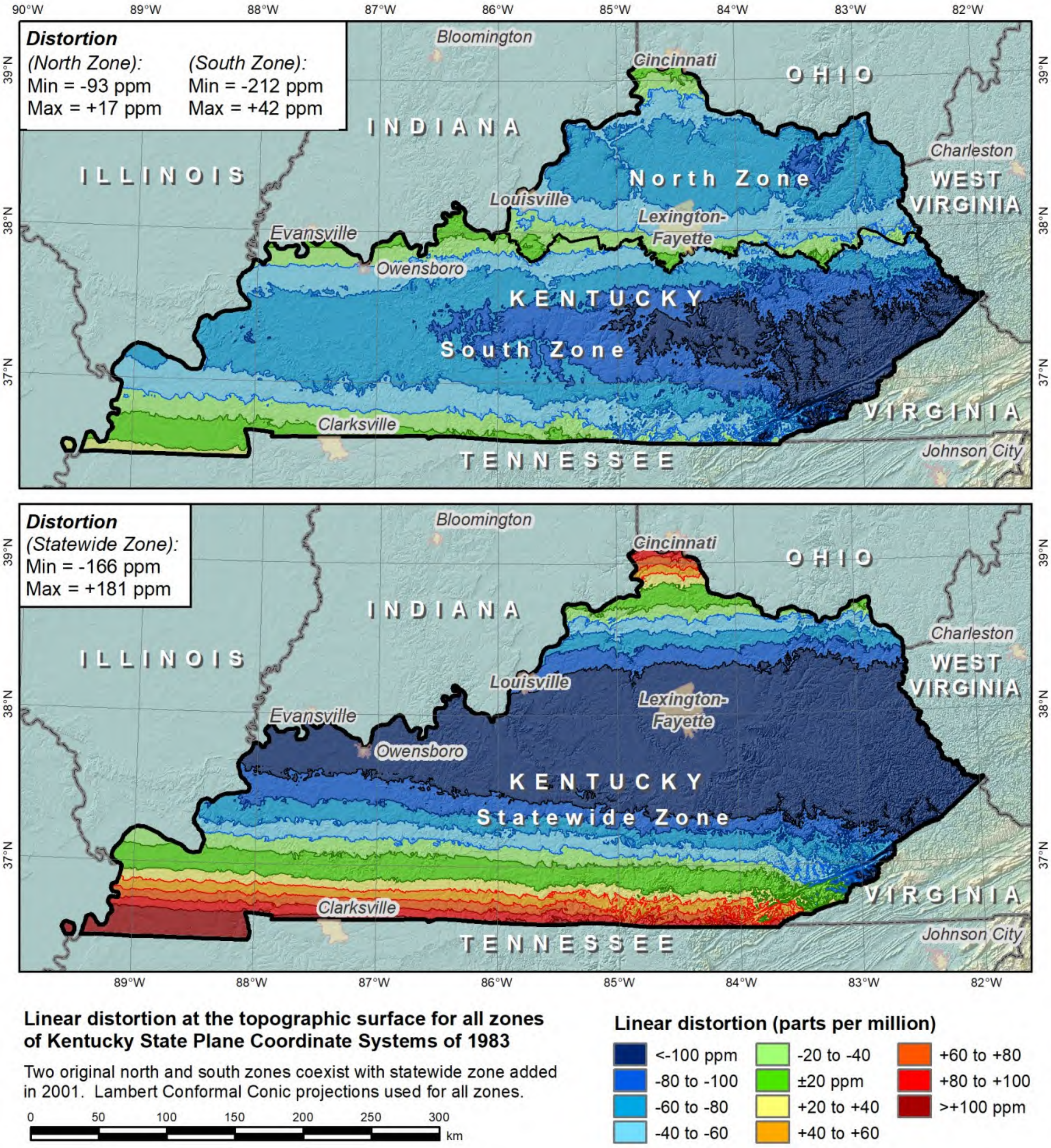

Figure 5. Linear distortion at the topographic surface for the current "layered" SPCS 83 zones in Kentucky: the original north and south zones (top) and the statewide zone added in 2001 (bottom).

In addition to the above issues that could be considered implicit policy, other "irregularities" in SPCS design and implementation can be construed as departures from convention. These have occurred over the history of SPCS, and several are listed below, with prefix "C."

C1. <u>Projection type and implementation</u>. The 2012 NGS policy explicitly limits SPCS to the three conformal projections LCC, TM, and OM. Yet mathematical variants of these projections exist, most notably the Gauss-Schreiber (used for SPCS 27) and Gauss-Krüger (used for SPCS 83) versions. The difference in coordinates for these two versions of the TM projection (as implemented by C&GS/NGS) increases with distance from the central meridian, reaching about 10 centimeters at a distance of 150 kilometers (mostly in northing). The American Samoa zone (which exists only for SPCS 27) was based on a one-parallel (tangent) version of the LCC. This is a perfectly valid form of the LCC, but the algorithm currently used by NGS will fail with a division-by-zero error for a one-parallel LCC. These two cases show the importance of not just naming the projection type, but also clearly specifying its mathematical implementation. And finally, the SPCS 27 zone for Guam used an "approximate" Azimuthal Equidistant projection. It is not conformal, and it is probably better described as a tangent plane coordinate system. This approach was selected despite the stated importance of conformality from the very beginning of SPCS in the 1930s, and it is the only zone in the SPCS that is not an LCC, TM, or OM projection (the SPCS 83 zone for Guam is a TM projection). It is not known why such a system was used for Guam in SPCS 27, but it does illustrate the variability of approaches used for SPCS.

C2. <u>Reference ellipsoid</u>. The 2012 NGS policy explicitly states SPCS should be "…defined at the surface of the ellipsoid of the current Datum." It is not entirely clear what is meant by "surface," since only three zones in the entire history of SPCS are tangent; all others are "secant" (i.e., the developable surface of the projection is "below" the ellipsoid surface for most of a zone's area). This requirement is thus taken to mean that the mapping equations refer directly to the unmodified reference ellipsoid (Clarke 1866 for SPCS 27 and GRS 80 for SPCS 83). An exception to this was created in 1964 for three SPCS 27 zones in Michigan, which were based on a "scaled" version of the Clarke 1866 ellipsoid (as described earlier). As with projection types, this shows how SPCS varied over time.

C3. <u>Datums and reference frames</u>. Policies and model laws state that SPCS 27 should be referenced to NAD 27, and SPCS 83 to NAD 83. However, nine SPCS 27 zones refer to other datums (as listed in the notes at the bottom of Table 1), although all were based on the Clarke 1866 ellipsoid. This was out of necessity, since in all cases these were islands that could not at the time be accurately connected to the NAD 27 geodetic network in North America. Nonetheless, it represents a (slight) inconsistency that can cause confusion. All SPCS 83 zones are referenced to NAD 83, but there is a complication here as well: there are three NAD 83 frames, nominally referenced to the North America, Pacific, and Mariana tectonic plates, although SPCS 83 uses the GRS 80 ellipsoid in all cases. Using these three frames is an unavoidable characteristic of the modern GNSS-based realizations of NAD 83, but it can still be a source of confusion.

C4. Scaling of SPCS coordinates to "ground." The SPCS grid distance between a pair of points is almost always different (usually shorter) than the actual horizontal distance on the topographic surface, which is often called the "grid to ground" problem by surveyors and engineers. In high-elevation areas, this difference can greatly exceed the nominal maximum 1:10,000 scale error. The problem can be dealt with in a number of different ways. One method has been taught by NGS and is presented in at least one technical document (Dracup, 1974). Without going into detail, it consists of dividing the SPCS coordinates by the "combined factor" for an area of interest. This factor is a function of both location and (ellipsoid) height, and it is usually less than 1. The purpose is to "scale" the coordinates such that the distance between points is approximately equal to the actual horizontal ground distance. It works because SPCS uses conformal projections, so the scale error (linear distortion) is the same in all directions from a point. Dracup called these scaled coordinates "project datum coordinates." They have often gone by other names, such as "modified" State Plane or State Plane "at ground," but these names are misleading, since the coordinates are no longer State Plane once they have been scaled. In any event, this approach has become very common. It is the approach used by many DOTs, and it has been incorporated into various commercial geospatial software packages. Although NGS taught this process in the past, it appears NGS no longer teaches this method, and (apart from the 1974 Dracup document) it seems it is not included in any NGS technical manuals, memoranda, reports, or policy. This has created something of a vacuum within the geospatial community and a consequent lack of a standard approach: there is no universally accepted way to perform the scaling; projects based on scaled coordinates lack sufficient metadata; and it has caused a proliferation of local coordinate systems that can easily be confused with "true" State Plane (typically every project has its own scaled coordinate system). The problem is actually larger than scaling SPCS coordinates; it also applies to other methods used for minimizing linear distortion. An example is the previously mentioned three Michigan SPCS 27 zones based on a "scaled" Clarke 1866 ellipsoid (which, similar to the creation of CA Zone 7 discussed earlier, is a notable instance of cooperation between C&GS and the local surveying community). Other methods for reducing linear distortion exist—as discussed below in the section on low distortion projections—but there is a lack of uniformity in the approaches used.

C5. Zone uniqueness. None of the SPCS policies explicitly state that the parameters for each zone must be unique. Yet such a convention could be inferred from other requirements for changes to SPCS as stated in the 2012 NGS policy. Despite such an inference, every defining parameter for the New Jersey and New York East TM zones are completely identical in SPCS 83, so they are effectively a single zone (their SPCS 27 parameters were different). This may have been done to achieve consistency in coordinates in the two zones, in a manner similar to defining zones for metropolitan areas as proposed in the 1977 FRN policy statement. But that reason seems unlikely, since these zones share major urbanization with the adjoining and completely distinct New York Long Island LCC (NY L) zone. Regardless of the reason, as part of documenting apparent irregularities in SPCS, it is worthwhile to point out that two SPCS 83 zones are identical.

C6. Ambiguous SPCS 83 Guam zone definitions. Similar to the Kentucky statewide "one zone," the SPCS 83 zone for Guam is not defined in any official NGS publication or webpage. Yet SPCS 83 coordinates are computed for Guam on NGS datasheets and OPUS solution reports. Compounding this problem is the NGS computer program used for SPCS 83 computations (NGS, 2002a). Its Fortran source code has three TM definitions for the Guam zone. The first is commented out, and it has the same ID number (133) as the second one, which is not commented out. The third has a different ID number (135), and it is identical to the second, with the exception that its false easting and northing values are swapped. This is a confusing situation for determining which definition is used by NGS. For this publication, it was determined that the second definition is used by NGS (the version of ID 133 that is not commented out, with zone code 5400) by duplicating datasheet and OPUS SPCS 83 coordinates for Guam. This was further confirmed by comparison to the *Guam Annotated Code* (Guam Compiler of Laws, 2017), a geodetic network report (Dyson, 1995), and the European Petroleum Survey Group (EPSG) *Geodetic Registry* (EPSG, 2017). The third Guam definition (ID 135) in the NGS SPCS 83 Fortran program was apparently never implemented. Why it exists in the program is unknown, but it was assigned an NGS zone code of 5401. These NGS zone (or "FIPS") codes are discussed in the next item.

C7. NGS SPCS "FIPS" codes. SPCS zones are identified by a four-digit NGS code in Stem's 1990 manual and the SPCS 83 computer program. The first two digits identify the state, and the last two identify the zone. These codes are often referred to as "FIPS" (Federal Information Processing Standard) codes, particularly outside of NGS. However, the state part of the code does not match the official FIPS codes used for states and territories by the U.S. federal government (U.S. Census Bureau, 2015). Documentation on the source of this discrepancy has proven difficult to find. According to Esri (2017), the NGS SPCS codes were part of a proposed FIPS that was withdrawn. Because of that, NGS zones are often identified (incorrectly) as FIPS zones by many organizations, individuals, and software vendors. In the case of Esri, this is done intentionally to maintain continuity with historic zone identifiers.

The above items are not intended to indicate that SPCS is somehow deficient. Rather, the intent is to identify inconsistencies and the importance of documentation, particularly in the context of updating the NSRS for 2022. Any of the above discrepancies can be remedied through appropriate updates of policy and through additional documentation (such as this publication). But policy updates for SPCS 83 are likely unnecessary at this time, since it will soon be replaced by SPCS2022. Preparation for SPCS2022 will afford NGS the opportunity to completely and consistently define SPCS policy.

Recent Developments in Projected Coordinate Systems

Although NGS has not published an official technical document on SPCS since Stem's 1990 manual, that is not to say there has been no activity on projected coordinate systems in the United States. A subtle but important change that has occurred since Stem's manual is how SPCS is used. The original reason for creating SPCS was to give surveyors and engineers a mathematically sound way to using simple plane trigonometry for performing “geodetic” surveys referenced to the NSRS. An essential part of making that possible was to provide a means for converting between geodetic and projected coordinates and azimuths. These were important considerations prior to electronic computers. Massive effort was dedicated to developing instructions, performing computations, and publishing the necessary information in numerous manuals and tables. Even as late as 1990, Stem’s manual devotes eight pages to a detailed example on performing a traverse in SPCS using plane trigonometry. Another 44 pages of that manual are used to provide an approximate polynomial method for manually computing coordinates in the 68 LCC zones of SPCS 83 (excluding the Kentucky single statewide zone). Yet by that time it was already evident such methods were becoming obsolete with the rise of inexpensive electronic hand calculators and personal computers. This change is foreshadowed in the 1990 manual by the absence of an approximate coordinate computation method for the 55 TM zones. According to Stem, it had not yet been fully developed “…pending the demonstrated requirement for such a method.” That comment was prescient; the requirement would never arise.

By the mid to late 1990s the situation had changed completely. Powerful hand-held field computers (“data collectors”) were becoming common. These devices had sufficient power and numerical precision to reliably perform complex geodetic reductions and map projection computations essentially instantaneously. The days of tedious manual computations were over. A parallel change was occurring in the office with the adoption of Computer Aided Drafting and Design (CADD) and Geographic Information Systems (GIS). Projected coordinates were becoming the dominant currency for representing geospatial information, and the use of coordinate geometry was particularly important in CADD. For both surveying and engineering, CADD implementations worked in 3D topocentric Cartesian space. The horizontal plane is defined, more often than not, using conformal projected coordinates. The vertical component is simply “height” or “elevation” perpendicular to the mapping plane. GNSS accelerated the use of projected coordinates, especially SPCS, because some type of projection was needed to convert the geodetic output of GNSS to a useful, local, topocentric Cartesian system. SPCS was increasingly used, because it was easy for manufacturers to preload all SPCS zones into field and office software, and users could simply pick their zone from a list. SPCS (and UTM) were embraced in GIS for largely the same reason—the coordinate systems were preloaded in the software, and standard implementations simply used the zone corresponding to their location. Surveying, engineering, CADD, and GIS all use essentially such an approach to this day. Even sophisticated modern 3D applications in CADD and GIS are usually more “2.5D” than true 3D—they are typically implemented as projected coordinate systems, with the third dimension “extruded” perpendicular to the mapping plane.

Two changes in the “traditional” definition and usage of SPCS (and similar conformal projected coordinate systems) warrant further discussion. One is the establishment of single statewide zones, even for states much too large to achieve the nominal SPCS maximum scale error (linear distortion) of 1:10,000 (±100 ppm) on the ellipsoid. The other is the creation of small zones that minimize linear distortion at the topographic surface (rather than at the ellipsoid), for example to 1:50,000 (±20 ppm), or even less. These two apparently opposing approaches have their origins several decades in the past. But, both have seen a recent resurgence in interest due in no small part to the ubiquity of electronic computers. Each is discussed in the following two sections.

Statewide Zones

Montana's move from three LCC zones in SPCS 27 to a single LCC zone in SPCS 83 represents the most extreme existing example of exceeding the nominal maximum SPCS scale error of 1:10,000. The maximum scale error for the SPCS 83 Montana zone is 1:1646 (-607 ppm) with respect to the ellipsoid, which is significantly greater than even the UTM limit of 1:2500 (±400 ppm). And, because of the overall high elevations in Montana, the scale error (linear distortion) at the topographic surface is greater yet. In the city of Missoula, located near the central parallel, the linear distortion with respect to the ellipsoid is about 1:1650 (-606 ppm), as expected. But, since the topographic height of Missoula is approximately 1000 meters, the total linear distortion at the ground surface is about 1:1310 (-764 ppm). That means a horizontal distance of 100 meters on the ground is 7.6 centimeters shorter when represented using SPCS 83 coordinates. For engineering plans and survey plats, such a difference could easily be detected even with a tape measure used for construction layout or boundary measurements. But does it matter? As long as all users of the geospatial data understand the situation, and the appropriate scale factors are used, then this does not necessarily represent a problem. Clearly, the state of Montana did not consider it a problem when they elected to use a single zone, and many within the state continue to use it to this day (including the Montana Department of Transportation, although they use SPCS scaled "to ground" to minimize linear distortion for projects with tight tolerances, such as bridges).

Figure 6 shows linear distortion at the topographic surface in Montana, based on the three zones of the SPCS 27 definition (top), and for the single SPCS 83 zone definition (bottom). Note the very large increase in (negative) distortion for the statewide SPCS 83 version: minimum of -1045 ppm, versus -655 ppm for SPCS 27 (in the south zone). The minimum and maximum distortion occurs in the south SPCS 27 zone, due to its greater north-south width, and thus its more widely spaced standard parallels (see Table B1 in Appendix B for the full set of defining SPCS 27 parameters).

For the single SPCS 83 Montana zone shown in Figure 6, it is interesting to note that the south and north standard parallels (45°N and 49°N; see Table A1 in Appendix A) are further apart than necessary to provide balanced positive and negative distortion coverage for Montana (with respect to the ellipsoid). It is not known why these standard parallels were used, as balanced distortion of lower magnitude (on par with UTM) could have been achieved through selection of more closely spaced parallels.

In the context of planning for SPCS2022, the use of such a large SPCS zone in Montana raises some questions. Does it render the 1:10,000 maximum scale error design criterion of SPCS obsolete or irrelevant? Should SPCS2022 switch to a system where every state has a single zone? If this works in Montana, then it would certainly work in all or most other states. Only Texas and Alaska have their shortest dimension larger (California has greater area than Montana, but it is narrower perpendicular to its long axis).

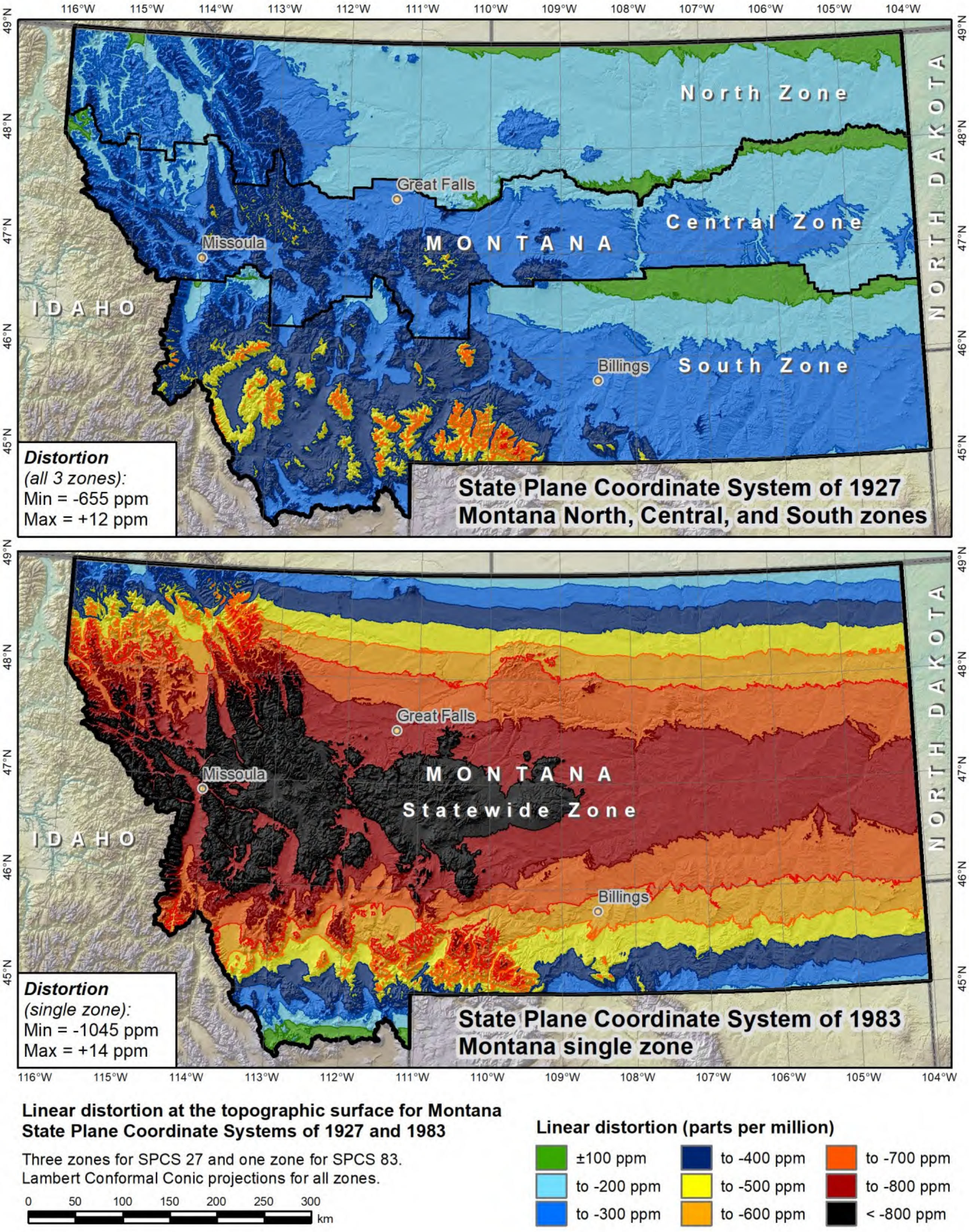

Figure 6. Linear distortion at the topographic surface for Montana SPCS 27 (top) and SPCS 83 (bottom).

Many states have designed their own statewide projections. One for Kentucky was discussed earlier in this report, and it was incorporated into SPCS 83 (without replacing its previously existing north and south zones). Many other states have also designed statewide zones, although they have not become part of SPCS 83. The main motivation for these statewide zones is that they are especially useful for a statewide GIS. Many analytical operations in GIS require a single geometry (such as linear referencing and network analysis), and a conformal projected coordinate system is particularly useful for such operations.

Low Distortion Projections

At the opposite extreme from that of Montana, other states have designed multiple-zone projected coordinate systems, where each zone covers a relatively small area, such as a county or specific topographically-defined region. The objective for such systems is to reduce linear distortion at the topographic surface such that it is negligible for most practical applications. Such systems are not new; both Wisconsin and Minnesota have had statewide county coordinate systems since the 1980s (Wisconsin State Cartographer's Office, 2012; Minnesota Department of Transportation, 2009), and these have long been incorporated in commercial software packages. In recent years there has been an increase in interest and implementation of such systems, which are often called "low distortion projections" (LDPs). Examples include Oregon (Armstrong *et al.*, 2017), Kansas (Dennis, 2017), and Indiana (Badger, 2016).

The motivation for LDPs is to have a consistent set of projected coordinates that yield distances so close to horizontal ground distances that no additional scale factor is required. This desire had been met for many years using the "project datum" approach of scaling SPCs, as described earlier in this report. Reasons for moving away from the scaled SPC approach are that it: 1) creates systems that can easily be confused with "true" SPCS; 2) is not readily transferrable across platforms, especially GIS; and 3) does not optimally minimize distortion. Coupled with this is: 1) the growing capabilities of modern geospatial software, such as the ability to design custom projections without having to use existing projected coordinates; 2) standardization of machine-readable projection definitions; 3) "projection-on-the-fly" capabilities that allow data with different projections to coexist; and 4) improvement in the ability to optimally minimize linear distortion over large areas (Dennis, 2016).

To provide an indication of the number of LDP systems in the United States, examples of those that are government sanctioned are listed in Table 2 and shown in Figure 7. Note the wide variety of zone types. Included are those in the eastern and central United States that consist of a single county or group of counties, metropolitan areas (Washington, D.C. and Las Vegas), single cities (San Francisco), and topographically defined regions (Oregon and Alaska). The one in northwestern Arizona is for an Indian reservation (Navajo Nation) that is too large to achieve what most would consider "low distortion" (within about ±25 ppm). Nonetheless, it was designed to minimize linear distortion at the topographic surface (at a mean ellipsoid height of 1800 meters), making it more akin to LDPs than traditional SPCS.

Table 2. Examples of U.S. LDP coordinate systems. (see Figure 7 for locations and zones).

Multiple-zone LDP systems	Single-zone LDP systems
1. Oregon Coordinate Reference System, OCRS (39 zones)	11. City of Flagstaff Low Distortion Grid Coordinate System
2. Rocky Mountain Tribal Coordinate Reference System, RMTCRS (10 zones)	12. Maricopa County Low Distortion Projection
3. Minnesota County Coordinate System, MCCS (97 zones)	13. Gila Valley Low Distortion Projection, GVLDP
4. Wisconsin Coordinate Reference Systems, WISCRS (72 zones)	14. Cochise County Low Distortion Projection
5. Iowa Regional Coordinate System, IaRCS (14 zones)	15. Navajo Nation Coordinate System
6. Indiana Geospatial Coordinate System, IGCS (92 zones)	16. Lancaster County Grid Low Distortion Projection
7. Kansas Regional Coordinate System, KRCS (20 zones)	17. Craighead County Low Distortion Projection Coordinate System
8. Nevada Coordinate Reference System, NCRS (2 zones)	18. Washington Metropolitan Area Transit Authority (WMATA) Low Distortion Projection Coordinate System
9. Pima County Coordinate System, PCCS (4 zones)	19. Southeast High-Speed Rail - Richmond Area to Potomac Segment (SEHSR-RAPS) Low Distortion Coordinate System
10. Alaska Low Distortion Projection Coordinate System (47 zones)	20. City & County of San Francisco 2013 Coordinate System, SFCS13

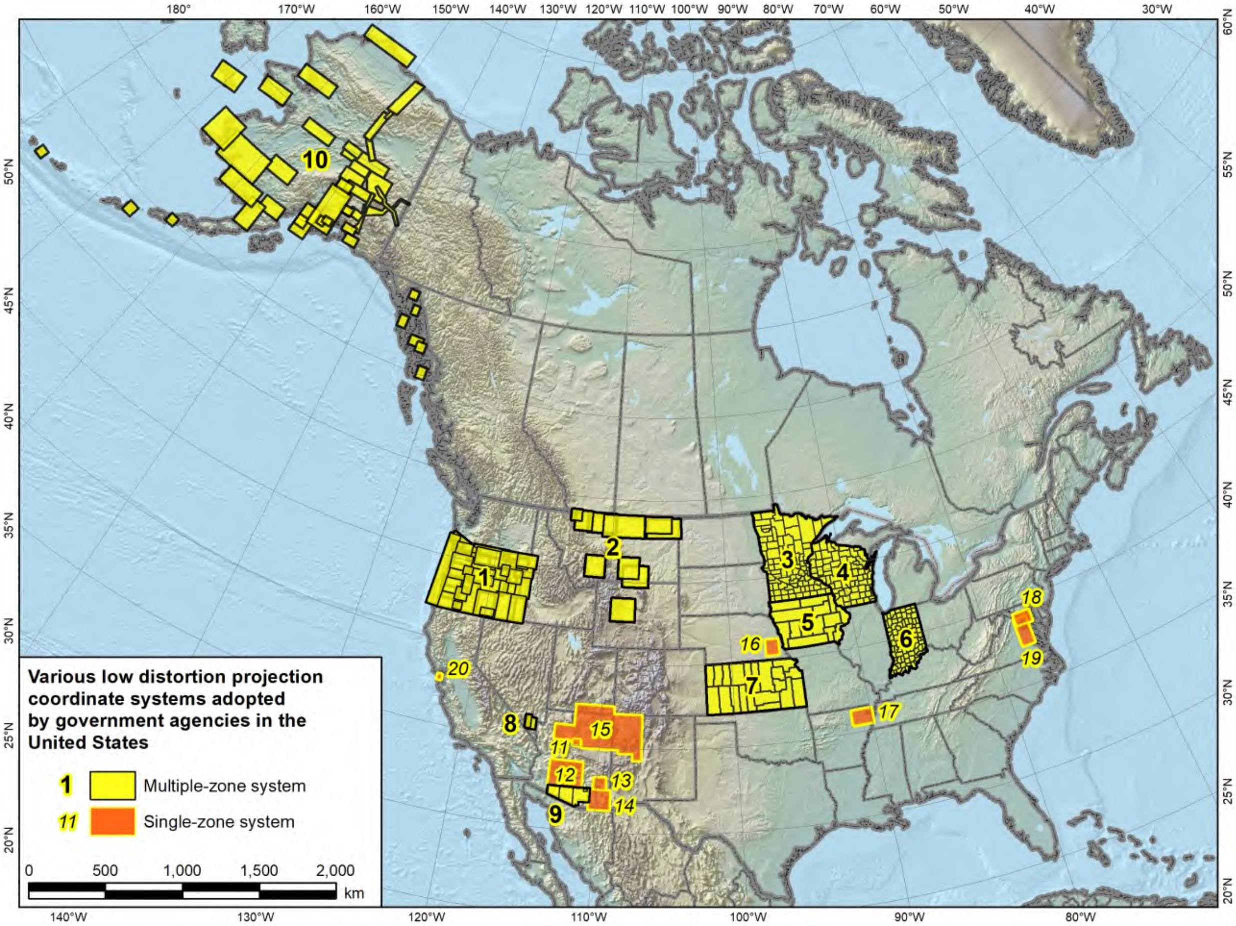

Figure 7. Examples of U.S. LDP coordinate systems (see Table 2 for additional information).

Clearly, there is significant and growing use of LDPs. But, like single statewide zones, this raises questions about how or whether LDPs should be implemented in SPCS2022, as well as what NGS' role should be. How do LDPs fit into SPCS, if at all? If LDPs are incorporated into SPCS2022, how will that be accomplished? Would it be an "either/or" situation, where a state must use LDPs or larger (even single statewide) zones, but not both? Or will "layered" systems be permitted? A layered system already exists in SPCS 83 for Kentucky—should this be perpetuated for Kentucky or elsewhere?

Even if LDPs are allowed in SPCS2022, it is highly unlikely NGS will have the resources to design them. Instead, NGS could provide standards, guidelines, and criteria for designing appropriate LDPs for inclusion in SPCS2022. Yet questions remain over how NGS would manage and deliver coordinates for such a large number of zones (e.g., by OPUS and on datasheets), particularly if layered systems are used. Alternatively, for the case where LDPs do not become part of SPCS2022, NGS may need to consider providing other mechanisms that allow users to reference the NSRS when using LDPs.

Whether or not NGS decides to support statewide projections or LDPs (or both) as part of SPCS2022 (or by other means), it is worth noting that detailed and standardized information on coordinate systems is readily available from other sources. One of the best known is the European Petroleum Survey Group (EPSG) *Geodetic Parameter Registry* (2017). The registry is a freely available database of various geodetic parameters used worldwide, including projected coordinate reference systems. Importantly, it provides machine-readable definitions in both Well-Known Text (WKT) and Geography Markup Language (GML) formats, and it is widely used by commercial and government organizations. The parameters for zones of the statewide and LDP projected coordinate systems mentioned above are available through EPSG. Such a resource would likely make implementation of these various projected systems much simpler for NGS.

Projection Computations

Methods for performing projection computations have also evolved since Stem's 1990 manual. Dramatic improvements in computer power have made it possible to compute more accurate coordinates. One way to accomplish this is simply by including additional terms from the traditional series expansions used for the ellipsoidal mapping equations. Another way is to use more complex algorithms or derivations that were too computationally expensive in the past.

Although a fairly extensive review of NGS and C&GS documents was performed for this report, no technical documents were found regarding the sources of the SPCS 83 map projection algorithms. Stem (1990) provides the formulas, but only includes references for a few specific computations. Checking comments in the SPCS 83 Fortran source code (NGS, 2002a) showed that all three projections were written, or last revised, by Thaddeus Vincenty in 1984 and 1985. The lack of documentation is in contrast to the many technical documents published for SPCS 27. But, the SPCS 27 formulas will not give the same results as the Vincenty algorithms, particularly for the TM projections, as different derivations were used (Gauss-Schreiber for SPCS 27 and Gauss-Krüger for SPCS 83).

It is not clear whether the SPCS 83 algorithms meet the 1977 FRN objective of 0.1 millimeter coordinate accuracy throughout every zone (especially large zones such as Montana). No documents quantifying accuracy were found, apart from the statement of 1 millimeter within a zone in Stem (1990). The only other information found was a comment by Vincenty in the TM source code stating that calculations provide "geodetic accuracy" within ±3.5° longitude of the central meridian (NGS, 2002a).

Since NGS also publishes UTM coordinates (and will continue to do so for the 2022 TRFs), those algorithms were also checked (NGS, 2002b). They are identical to the 1984 and 1985 algorithms used for TM zones of SPCS 83. NGA (2014a) has published new, highly accurate formulas for the TM projection, which are now used by the DoD for performing UTM computations. If all terms are used, both the forward and inverse mapping equations are accurate to 0.01 millimeter within ±60° longitude of the central meridian, and to 0.00001 millimeter within ±40° (these accuracies are generalizations of the information given in NGA, 2014a, p. 19). Based on the information available, it appears these computations are more accurate than the current NGS TM algorithm. Because NGS produces UTM coordinates for NSRS stations, consistency with NGA algorithms is desirable, at least within well-defined bounds.

Summary and Conclusions

Since its inception in 1933, SPCS has become a well-established system that has enjoyed widespread use in the U.S. surveying, engineering, and mapping professions. Its history and usage are more complex and nuanced than might be expected. Characteristics of SPCS that are often assumed fixed have varied considerably, and some depart substantially from NGS policies and conventions, both today and in the past. These variations show that rather than being static, NGS has allowed for considerable flexibility over the long history of SPCS. The more important of these variants are summarized below:

- Not using aggregated counties for zone boundaries in all cases (Alaska and Washington) or having more than one zone per county (Hawaii).
- Establishing "layered" zones that completely overlap one another (the Kentucky north and south zones, with overlying statewide zone for SPCS 83).
- Greatly exceeding the nominal 1:10,000 maximum scale error for some zones (most notably the Montana statewide SPCS 83 zone).
- Modifying reference ellipsoid dimensions (scaling of the Clarke 1866 ellipsoid for the SPCS 27 Michigan LCC zones to reduce linear distortion at the topographic surface).
- Providing training on scaling of SPCS coordinates to "ground" to reduce linear distortion (which has been widely adopted, including by many DOTs and software vendors).
- Proposing in the 1977 FRN that additional zones be created for metropolitan areas that straddle two or more existing zones (e.g., Washington, D.C., New York City, Chicago).
- Usage of a non-conformal projection (for the Guam zone referenced to its 1963 datum).

There have also been recent developments in design and usage of projected coordinate systems outside of SPCS:

- Establishing statewide zones in states that do not have one defined in SPCS 83.
- Creation of "low distortion projection" (LDP) zones to minimize linear distortion (scale error) at the topographic surface (often coexisting with a statewide zone).
- Improvements in computational accuracy (e.g., the latest version of UTM developed by NGA).

Many statewide and LDP systems have been officially adopted by states and local governments, and there is interest in having them become part of SPCS. Whether or how NGS allows for such systems is not yet known, but these are issues that should be addressed in some manner as part of developing SPCS2022.

SPCS began at the request of NGS customers, and its role as a product for NGS customers continues to this day. NGS does not use SPCS for internal operations. Ideally, then, the characteristics of SPCS should conform to the needs of NGS customers. Yet SPCS must also be a technically correct and robust system that can be efficiently and effectively implemented nationwide, not just at the local level. Fortunately, modern databases and recent standardization of coordinate system definitions (such as the WKT and GMT formats) greatly simplify the task of managing large coordinate system datasets. The *EPSG Geodetic Parameter Registry* is an example of one that is not only freely available but also covers the entire world—including all versions of SPCS and many of the U.S. state, county, and city systems.

In designing SPCS2022, NGS must balance the desires of customers at the local level with the mission to support the NSRS at the national level. This publication is intended to help with that process, by providing context to SPCS through its history and recent trends in the use of projected coordinate systems. The goal is to provide information that helps in making informed decisions. That will ensure SPCS2022 is a technically sound, consistent, and practical product that meets the needs of NGS customers.

Acknowledgments

The initial inspiration for this publication came from NGS' NSRS Modernization Manager Dru Smith, as part of the SPCS2022 Project. His idea was to prepare a document that defined the history and bounds of SPCS, a document that would serve as a guide in developing SPCS2022. This publication grew from that idea, into something more substantial than either of us anticipated. While it was more work than originally expected, it puts the SPCS2022 Project on a better footing, and this document stands on its own as a much-needed supplement to existing NGS SPCS literature.

Others also provided important contributions to this publication. First among those was the NGS Executive Steering Committee in their review of the first draft. Their direction changed (and improved) its trajectory, from a somewhat awkward policy and procedures document to a solid report on the history and status of SPCS. This was followed by helpful input from many others, mostly on matters of SPCS history and documentation. Those whose generous assistance affected the content of this publication are listed alphabetically, first from NGS: Dana Caccamise, Ed Carlson, Joe Evjen, David Grosh, Ross Mackay, Dan Martin, Mark Schenewerk, Bruce Tran, and Dave Zilkoski; and from California (regarding the mysterious history of SPCS 27 CA Zone 7): Cesar Bregaudit, Scott Martin, Steven Martin, and Jay Satalich.

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Appendix A. SPCS 83 Defining Parameters (125 Zones)

Table A1. Complete defining parameters for the 125 zones of the State Plane Coordinate System of 1983 (SPCS 83). All projections are defined with respect to the Geodetic Reference System of 1980 (GRS 80) ellipsoid, with semi-major axis a = 6,378,137 meters (exact) and inverse geometric flattening $1/f$ = 298.257222101 (derived). Information in this table is available in digital format on the NGS website (geodesy.noaa.gov), including geodetic origins in decimal degrees. Table A2 gives additional information for the “Comments” column of this table. Note the following:

- Changes from SPCS 27. Denoted by entries in *italics*. No parameters changed for zones Alaska 1 or North Carolina.
- Projection axis scale. Ratio values for LCC zones were computed and rounded to nearest whole number. Decimal values that are not infinitely repeating are shown as exact; repeating values are rounded to nine decimal places with ellipses indicating they are not exact.
- Origin longitude. Central meridian for LCC and TM projections. A central meridian is not defined for the OM projection (the convergence angle is zero at the local origin but does not remain zero along that meridian).
- Grid origin (false eastings and northings). Given as the exact metric values used to define a zone, including the three states where the origins are not whole numbers (Colorado, Connecticut, and North Carolina), even though the metric conversion is not exact.
- Abbreviations.
    - *Projections:* LCC = Lambert Conformal Conic; TM = Transverse Mercator; OM = Oblique Mercator.
    - *Standard parallels (applies only to LCC projections):* S std = South standard; N std = North standard
    - *Linear units of grid origins:* sft = U.S. survey feet; ift = international feet

Zone abrev	Zone code	Zone designation	Type	Projection axis scale		Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters)		Comments (see Table A2 for additional information)
				(ratio)	(decimal)					Easting	Northing	
Alabama (AL): SPCS 83												
AL E	0101	East	TM	1:25,000	0.999 96	85°50'W	30°30'N	—	—	*200,000*	0	
AL W	0102	West	TM	1:15,000	0.999 933 333...	87°30'W	30°00'N	—	—	*600,000*	0	
Alaska (AK): SPCS 83												
AK 1	5001	1	OM	1:10,000	0.999 9	133°40'W	57°00'N	—	—	5,000,000	-5,000,000	Skew axis azimuth = $\tan^{-1}$ (-¾)
AK 2	5002	2	TM	1:10,000	0.999 9	142°00'W	54°00'N	—	—	*500,000*	0	
AK 3	5003	3	TM	1:10,000	0.999 9	146°00'W	54°00'N	—	—	*500,000*	0	
AK 4	5004	4	TM	1:10,000	0.999 9	150°00'W	54°00'N	—	—	*500,000*	0	
AK 5	5005	5	TM	1:10,000	0.999 9	154°00'W	54°00'N	—	—	*500,000*	0	
AK 6	5006	6	TM	1:10,000	0.999 9	158°00'W	54°00'N	—	—	*500,000*	0	
AK 7	5007	7	TM	1:10,000	0.999 9	162°00'W	54°00'N	—	—	*500,000*	0	
AK 8	5008	8	TM	1:10,000	0.999 9	166°00'W	54°00'N	—	—	*500,000*	0	
AK 9	5009	9	TM	1:10,000	0.999 9	170°00'W	54°00'N	—	—	*500,000*	0	
AK10	5010	10	LCC	1:6,582	0.999 848 060...	176°00'W	51°00'N	51°50'N	53°50'N	*1,000,000*	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters) Easting	Northing	Comments (see Table A2 for additional information)
Arizona (AZ): SPCS 83												
AZ E	0201	East	TM	1:10,000	0.999 9	110°10'W	31°00'N	—	—	*213,360*	0	Converted ift origin to meters
AZ C	0202	Central	TM	1:10,000	0.999 9	111°55'W	31°00'N	—	—	*213,360*	0	Converted ift origin to meters
AZ W	0203	West	TM	1:15,000	0.999 933 333...	113°45'W	31°00'N	—	—	*213,360*	0	Converted ift origin to meters
Arkansas (AR): SPCS 83												
AR N	0301	North	LCC	1:15,609	0.999 935 935...	92°00'W	34°20'N	34°56'N	36°14'N	*400,000*	0	
AR S	0302	South	LCC	1:12,265	0.999 918 470...	92°00'W	32°40'N	33°18'N	34°46'N	*400,000*	*400,000*	
California (CA): SPCS 83												
CA 1	0401	1	LCC	1:9,491	0.999 894 637...	122°00'W	39°20'N	40°00'N	41°40'N	*2,000,000*	*500,000*	
CA 2	0402	2	LCC	1:11,720	0.999 914 673...	122°00'W	37°40'N	38°20'N	39°50'N	*2,000,000*	*500,000*	
CA 3	0403	3	LCC	1:14,120	0.999 929 179...	120°30'W	36°30'N	37°04'N	38°26'N	*2,000,000*	*500,000*	
CA 4	0404	4	LCC	1:16,881	0.999 940 762...	119°00'W	35°20'N	36°00'N	37°15'N	*2,000,000*	*500,000*	
CA 5	0405	5	LCC	1:12,841	0.999 922 127...	118°00'W	33°30'N	34°02'N	35°28'N	*2,000,000*	*500,000*	Absorbed SPCS 27 zone CA 7
CA 6	0406	6	LCC	1:21,807	0.999 954 142...	116°15'W	32°10'N	32°47'N	33°53'N	*2,000,000*	*500,000*	
Colorado (CO): SPCS 83												
CO N	0501	North	LCC	1:23,173	0.999 956 846...	105°30'W	39°20'N	39°43'N	40°47'N	*914,401.8289*	*304,800.6096*	Converted sft origin to meters
CO C	0502	Central	LCC	1:15,603	0.999 935 910...	105°30'W	37°50'N	38°27'N	39°45'N	*914,401.8289*	*304,800.6096*	Converted sft origin to meters
CO S	0503	South	LCC	1:18,315	0.999 945 398...	105°30'W	36°40'N	37°14'N	38°26'N	*914,401.8289*	*304,800.6096*	Converted sft origin to meters
Connecticut (CT): SPCS 83												
CT	0600		LCC	1:59,314	0.999 983 140...	72°45'W	40°50'N	41°12'N	41°52'N	*304,800.6096*	*152,400.3048*	Converted sft origin to meters
Delaware (DE): SPCS 83												
DE	0700		TM	1:200,000	0.999 995	75°25'W	38°00'N	—	—	*200,000*	0	
Florida (FL): SPCS 83												
FL E	0901	East	TM	1:17,000	0.999 941 176...	81°00'W	24°20'N	—	—	*200,000*	0	
FL W	0902	West	TM	1:17,000	0.999 941 176...	82°00'W	24°20'N	—	—	*200,000*	0	
FL N	0903	North	LCC	1:19,392	0.999 948 433...	84°30'W	29°00'N	29°35'N	30°45'N	*600,000*	0	
Georgia (GA): SPCS 83												
GA E	1001	East	TM	1:10,000	0.999 9	82°10'W	30°00'N	—	—	*200,000*	0	
GA W	1002	West	TM	1:10,000	0.999 9	84°10'W	30°00'N	—	—	*700,000*	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters) Easting	Northing	Comments (see Table A2 for additional information)
Hawaii (HI): SPCS 83												
HI 1	5101	1	TM	1:30,000	0.999 966 667...	155°30'W	18°50'N	—	—	*500,000*	0	
HI 2	5102	2	TM	1:30,000	0.999 966 667...	156°40'W	20°20'N	—	—	*500,000*	0	
HI 3	5103	3	TM	1:100,000	0.999 99	158°00'W	21°10'N	—	—	*500,000*	0	
HI 4	5104	4	TM	1:100,000	0.999 99	159°30'W	21°50'N	—	—	*500,000*	0	
HI 5	5105	5	TM	Exact	1	160°10'W	21°40'N	—	—	*500,000*	0	
Idaho (ID): SPCS 83												
ID E	1101	East	TM	1:19,000	0.999 947 368...	112°10'W	41°40'N	—	—	*200,000*	0	
ID C	1102	Central	TM	1:19,000	0.999 947 368...	114°00'W	41°40'N	—	—	*500,000*	0	
ID W	1103	West	TM	1:15,000	0.999 933 333...	115°45'W	41°40'N	—	—	*800,000*	0	
Illinois (IL): SPCS 83												
IL E	1201	East	TM	1:40,000	0.999 975	88°20'W	36°40'N	—	—	*300,000*	0	
IL W	1202	West	TM	1:17,000	0.999 941 176...	90°10'W	36°40'N	—	—	*700,000*	0	
Indiana (IN): SPCS 83												
IN E	1301	East	TM	1:30,000	0.999 966 667...	85°40'W	37°30'N	—	—	*100,000*	*250,000*	
IN W	1302	West	TM	1:30,000	0.999 966 667...	87°05'W	37°30'N	—	—	*900,000*	*250,000*	
Iowa (IA): SPCS 83												
IA N	1401	North	LCC	1:18,304	0.999 945 368...	93°30'W	41°30'N	42°04'N	43°16'N	*1,500,000*	*1,000,000*	
IA S	1402	South	LCC	1:19,368	0.999 948 370...	93°30'W	40°00'N	40°37'N	41°47'N	*500,000*	0	
Kansas (KS): SPCS 83												
KS N	1501	North	LCC	1:23,176	0.999 956 851...	98°00'W	38°20'N	38°43'N	39°47'N	*400,000*	0	
KS S	1502	South	LCC	1:15,605	0.999 935 918...	98°30'W	36°40'N	37°16'N	38°34'N	*400,000*	*400,000*	
Kentucky (KY): SPCS 83												
KY1Z	1600	One	LCC	1:10,520	0.999 904 942...	85°45'W	36°20'N	37°05'N	38°40'N	1,500,000	1,000,000	Statewide zone added in 2001
KY N	1601	North	LCC	1:26,371	0.999 962 080...	84°15'W	37°30'N	37°58'N	38°58'N	*500,000*	0	
KY S	1602	South	LCC	1:18,316	0.999 945 402...	85°45'W	36°20'N	36°44'N	37°56'N	*500,000*	*500,000*	
Louisiana (LA): SPCS 83												
LA N	1701	North	LCC	1:11,729	0.999 914 741...	92°30'W	*30°30'N*	31°10'N	32°40'N	*1,000,000*	0	
LA S	1702	South	LCC	1:13,467	0.999 925 745...	91°20'W	*28°30'N*	29°18'N	30°42'N	*1,000,000*	0	
LASH	1703	Offshore	LCC	1:9,505	0.999 894 794...	91°20'W	*25°30'N*	26°10'N	27°50'N	*1,000,000*	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	Projection axis scale (decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters) Easting	Grid origin (meters) Northing	Comments (see Table A2 for additional information)
Maine (ME): SPCS 83												
ME E	1801	East	TM	1:10,000	0.999 9	68°30'W	*43°40'N*	—	—	*300,000*	0	
ME W	1802	West	TM	1:30,000	0.999 966 667...	70°10'W	42°50'N	—	—	*900,000*	0	
Maryland (MD): SPCS 83												
MD	1900		LCC	1:19,939	0.999 949 848...	77°00'W	*37°40'N*	38°18'N	39°27'N	*400,000*	0	
Massachusetts (MA): SPCS 83												
MA M	2001	Mainland	LCC	1:28,209	0.999 964 550...	71°30'W	41°00'N	41°43'N	42°41'N	*200,000*	*750,000*	
MA I	2002	Island	LCC	1:659,052	0.999 998 483...	70°30'W	41°00'N	41°17'N	41°29'N	*500,000*	0	
Michigan (MI): SPCS 83												
MI N	2111	North	LCC	1:10,292	0.999 902 834...	87°00'W	44°47'N	45°29'N	47°05'N	*8,000,000*	0	SPCS 27 used scaled ellipsoid
MI C	2112	Central	LCC	1:11,456	0.999 912 706...	*84°22'W*	43°19'N	44°11'N	45°42'N	*6,000,000*	0	SPCS 27 used scaled ellipsoid
MI S	2113	South	LCC	1:10,739	0.999 906 878...	*84°22'W*	41°30'N	42°06'N	43°40'N	*4,000,000*	0	SPCS 27 used scaled ellipsoid
Minnesota (MN): SPCS 83												
MN N	2201	North	LCC	1:10,290	0.999 902 817...	93°06'W	46°30'N	47°02'N	48°38'N	*800,000*	*100,000*	
MN C	2202	Central	LCC	1:12,824	0.999 922 023...	94°15'W	45°00'N	45°37'N	47°03'N	*800,000*	*100,000*	
MN S	2203	South	LCC	1:12,827	0.999 922 040...	94°00'W	43°00'N	43°47'N	45°13'N	*800,000*	*100,000*	
Mississippi (MS): SPCS 83												
MS E	2301	East	TM	*1:20,000*	*0.999 95*	88°50'W	*29°30'N*	—	—	*300,000*	0	
MS W	2302	West	TM	*1:20,000*	*0.999 95*	90°20'W	*29°30'N*	—	—	*700,000*	0	
Missouri (MO): SPCS 83												
MO E	2401	East	TM	1:15,000	0.999 933 333...	90°30'W	35°50'N	—	—	*250,000*	0	
MO C	2402	Central	TM	1:15,000	0.999 933 333...	92°30'W	35°50'N	—	—	*500,000*	0	
MO W	2403	West	TM	1:17,000	0.999 941 176...	94°30'W	36°10'N	—	—	*850,000*	0	
Montana (MT): SPCS 83												
MT	*2500*		LCC	*1:1,646*	*0.999 392 636...*	109°30'W	*44°15'N*	*45°00'N*	*49°00'N*	*600,000*	0	Used 3 zones for SPCS 27
Nebraska (NE): SPCS 83												
NE	*2600*		LCC	*1:2,929*	*0.999 658 595...*	*100°00'W*	*39°50'N*	*40°00'N*	*43°00'N*	*500,000*	0	Used 2 zones for SPCS 27
Nevada (NV): SPCS 83												
NV E	2701	East	TM	1:10,000	0.999 9	115°35'W	34°45'N	—	—	*200,000*	*8,000,000*	
NV C	2702	Central	TM	1:10,000	0.999 9	116°40'W	34°45'N	—	—	*500,000*	*6,000,000*	
NV W	2703	West	TM	1:10,000	0.999 9	118°35'W	34°45'N	—	—	*800,000*	*4,000,000*	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters) Easting	Northing	Comments (see Table A2 for additional information)
New Hampshire (NH): SPCS 83												
NH	2800		TM	1:30,000	0.999 966 667...	71°40'W	42°30'N	—	—	*300,000*	0	
New Jersey (NJ): SPCS 83												
NJ	2900		TM	*1:10,000*	*0.999 9*	*74°30'W*	38°50'N	—	—	*150,000*	0	Identical to NY E zone (3101)
New Mexico (NM): SPCS 83												
NM E	3001	East	TM	1:11,000	0.999 909 091...	104°20'W	31°00'N	—	—	*165,000*	0	Changed SPCS 27 zone boundary (Cibola County)
NM C	3002	Central	TM	1:10,000	0.999 9	106°15'W	31°00'N	—	—	*500,000*	0	
NM W	3003	West	TM	1:12,000	0.999 916 667...	107°50'W	31°00'N	—	—	*830,000*	0	
New York (NY): SPCS 83												
NY E	3101	East	TM	*1:10,000*	*0.999 9*	*74°30'W*	*38°50'N*	—	—	*150,000*	0	Identical to NJ zone (2900)
NY C	3102	Central	TM	1:16,000	0.999 937 5	76°35'W	40°00'N	—	—	*250,000*	0	
NY W	3103	West	TM	1:16,000	0.999 937 5	78°35'W	40°00'N	—	—	*350,000*	0	
NY L	3104	Long Island	LCC	1:196,094	0.999 994 900...	74°00'W	*40°10'N*	40°40'N	41°02'N	*300,000*	*0*	
North Carolina (NC): SPCS 83												
NC	3200		LCC	1:7,849	0.999 872 592...	79°00'W	33°45'N	34°20'N	36°10'N	609,601.22	0	Converted sft origin to meters
North Dakota (ND): SPCS 83												
ND N	3301	North	LCC	1:15,587	0.999 935 842...	100°30'W	47°00'N	47°26'N	48°44'N	*600,000*	0	
ND S	3302	South	LCC	1:15,589	0.999 935 852...	100°30'W	45°40'N	46°11'N	47°29'N	*600,000*	0	
Ohio (OH): SPCS 83												
OH N	3401	North	LCC	1:16,431	0.999 939 140...	82°30'W	39°40'N	40°26'N	41°42'N	*600,000*	0	
OH S	3402	South	LCC	1:15,602	0.999 935 908...	82°30'W	38°00'N	38°44'N	40°02'N	*600,000*	0	
Oklahoma (OK): SPCS 83												
OK N	3501	North	LCC	1:18,318	0.999 945 409...	98°00'W	35°00'N	35°34'N	36°46'N	*600,000*	0	
OK S	3502	South	LCC	1:15,611	0.999 935 942...	98°00'W	33°20'N	33°56'N	35°14'N	*600,000*	0	
Oregon (OR): SPCS 83												
OR N	3601	North	LCC	1:9,486	0.999 894 583...	120°30'W	43°40'N	44°20'N	46°00'N	*2,500,000*	0	
OR S	3602	South	LCC	1:9,488	0.999 894 608...	120°30'W	41°40'N	42°20'N	44°00'N	*1,500,000*	0	
Pennsylvania (PA): SPCS 83												
PA N	3701	North	LCC	1:23,170	0.999 956 840...	77°45'W	40°10'N	40°53'N	41°57'N	*600,000*	0	
PA S	3702	South	LCC	1:24,691	0.999 959 500...	77°45'W	39°20'N	39°56'N	40°58'N	*600,000*	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters) Easting	Northing	Comments (see Table A2 for additional information)
Rhode Island (RI): SPCS 83												
RI	3800		TM	1:160,000	0.999 993 75	71°30'W	41°05'N	—	—	*100,000*	0	
South Carolina (SC): SPCS 83												
SC	*3900*		LCC	*1:4,846*	*0.999 793 657...*	81°00'W	*31°50'N*	*32°30'N*	*34°50'N*	*609,600*	0	Used 2 zones for SPCS 27
South Dakota (SD): SPCS 83												
SD N	4001	North	LCC	1:16,424	0.999 939 112...	100°00'W	43°50'N	44°25'N	45°41'N	*600,000*	0	
SD S	4002	South	LCC	1:10,738	0.999 906 870...	100°20'W	42°20'N	42°50'N	44°24'N	*600,000*	0	
Tennessee (TN): SPCS 83												
TN	4100		LCC	1:19,380	0.999 948 401...	86°00'W	*34°20'N*	35°15'N	36°25'N	*600,000*	*0*	
Texas (TX): SPCS 83												
TX N	4201	North	LCC	1:11,220	0.999 910 876...	101°30'W	34°00'N	34°39'N	36°11'N	*200,000*	*1,000,000*	
TXNC	4202	North Central	LCC	1:7,851	0.999 872 623...	*98°30'W*	31°40'N	32°08'N	33°58'N	*600,000*	*2,000,000*	
TX C	4203	Central	LCC	1:8,456	0.999 881 744...	100°20'W	29°40'N	30°07'N	31°53'N	*700,000*	*3,000,000*	
TXSC	4204	South Central	LCC	1:7,312	0.999 863 244...	99°00'W	27°50'N	28°23'N	30°17'N	*600,000*	*4,000,000*	
TX S	4205	South	LCC	1:9,505	0.999 894 794...	98°30'W	25°40'N	26°10'N	27°50'N	*300,000*	*5,000,000*	
Utah (UT): SPCS 83												
UT N	4301	North	LCC	1:23,170	0.999 956 841...	111°30'W	40°20'N	40°43'N	41°47'N	*500,000*	*1,000,000*	
UT C	4302	Central	LCC	1:9,883	0.999 898 821...	111°30'W	38°20'N	39°01'N	40°39'N	*500,000*	*2,000,000*	
UT S	4303	South	LCC	1:20,533	0.999 951 297...	111°30'W	36°40'N	37°13'N	38°21'N	*500,000*	*3,000,000*	
Vermont (VT): SPCS 83												
VT	4400		TM	1:28,000	0.999 964 286...	72°30'W	42°30'N	—	—	*500,000*	0	
Virginia (VA): SPCS 83												
VA N	4501	North	LCC	1:19,374	0.999 948 385...	78°30'W	37°40'N	38°02'N	39°12'N	*3,500,000*	*2,000,000*	
VA S	4502	South	LCC	1:18,315	0.999 945 401...	78°30'W	36°20'N	36°46'N	37°58'N	*3,500,000*	*1,000,000*	
Washington (WA): SPCS 83												
WA N	4601	North	LCC	1:17,317	0.999 942 253...	120°50'W	47°00'N	47°30'N	48°44'N	*500,000*	0	Changed SPCS 27 zone boundary (Grant County)
WA S	4602	South	LCC	1:11,709	0.999 914 598...	120°30'W	45°20'N	45°50'N	47°20'N	*500,000*	0	
West Virginia (WV): SPCS 83												
WV N	4701	North	LCC	1:16,875	0.999 940 741...	79°30'W	38°30'N	39°00'N	40°15'N	*600,000*	0	
WV S	4702	South	LCC	1:13,455	0.999 925 678...	81°00'W	37°00'N	37°29'N	38°53'N	*600,000*	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (meters) Easting	Northing	Comments (see Table A2 for additional information)
Wisconsin (WI): SPCS 83												
WI N	4801	North	LCC	1:18,297	0.999 945 345...	90°00'W	45°10'N	45°34'N	46°46'N	*600,000*	0	
WI C	4802	Central	LCC	1:16,865	0.999 940 705...	90°00'W	43°50'N	44°15'N	45°30'N	*600,000*	0	
WI S	4803	South	LCC	1:14,825	0.999 932 547...	90°00'W	42°00'N	42°44'N	44°04'N	*600,000*	0	
Wyoming (WY): SPCS 83												
WY E	4901	*East*	TM	*1:16,000*	*0.999 937 5*	105°10'W	*40°30'N*	—	—	*200,000*	0	
WYEC	4902	*East Central*	TM	*1:16,000*	*0.999 937 5*	107°20'W	*40°30'N*	—	—	*400,000*	*100,000*	
WYWC	4903	*West Central*	TM	*1:16,000*	*0.999 937 5*	108°45'W	*40°30'N*	—	—	*600,000*	0	
WY W	4904	*West*	TM	*1:16,000*	*0.999 937 5*	110°05'W	*40°30'N*	—	—	*800,000*	*100,000*	
United States Territories												
Puerto Rico and U.S. Virgin Islands (PR and VI): SPCS 83												
PRVI	*5200*		LCC	1:165,138	0.999 993 944...	66°26'W	17°50'N	18°02'N	18°26'N	*200,000*	*200,000*	Used 2 zones for SPCS 27
Guam (GU): SPCS 83												
GU	5400		*TM*	*Exact*	*1*	*215°15'W* *(144°45'E)*	*13°30'N*	—	—	*100,000*	*200,000*	Zone added in 1995

Table A2. Additional information for “Comments” column of Table A1 for SPCS 83 zones.

State or Territory	Zones	Additional information
Alaska	AK 1	Skew axis azimuth = $\tan^{-1}(-¾)$ = -36°52'11.6315250385". The grid origin is defined at the “natural” origin on the equator of the “aposphere”, an intermediate surface of rotation with constant total curvature derived from the ellipsoid at the central point (local origin) of the projection. The ellipsoid is conformally projected onto the aposphere before final projection onto the plane. See NGS (1986) and Snyder (1987).
Arizona (all zones)	AZ E, C, W	False easting is exact metric conversion of 700,000 international feet, as defined by Arizona state law.
California	CA 5	Includes Los Angeles County, which was zone CA Zone 7 in SPCS 27 (see tables B1 and B2).
Colorado (all zones)	CO N, C, S	Grid origin is non-exact conversion of U.S. survey feet to meters: false easting = 3,000,000.000 316 sft and false northing = 999,999.999 996 sft (note discrepancy for false easting at fourth decimal place).
Connecticut	CT	Grid origin is non-exact conversion of U.S. survey feet to meters: false easting = 999,999.999 996 sft and false northing = 499,999.999 998 sft (note coordinate discrepancy at sixth decimal place).
Kentucky	KY1Z	Statewide zone added in 2001, after publication of SPCS 83 manual (Stem, 1990). Coexists with KY North and South zones.
Michigan (all zones)	MI N, C, S	Final version of SPCS 27 used LCC zones created in 1964 by scaling Clarke 1866 ellipsoid semi-major axis by a factor of exactly 1.0000382 with its flattening held constant (see tables B1 and B2). The SPCS 83 version of these zones are based on the GRS 80 ellipsoid without any modification.
Montana	MT	Three zones used for SPCS 27 combined into a single zone for SPCS 83.
Nebraska	NE	Two zones used for SPCS 27 combined into a single zone for SPCS 83.
New Jersey	NJ	All projection parameters are identical to NY E zone.
New Mexico (two zones)	NM C, W	Changed SPCS 27 zone boundary because Cibola County created from westernmost four-fifths of the formerly much larger Valencia in 1981, with Cibola County in West zone and Valencia County in Central zone.
New York	NY E	All projection parameters are identical to NJ zone.
North Carolina	NC	False easting is non-exact conversion of U.S. survey feet to meters: false easting = 2,000,000.0026 sft (note coordinate discrepancy is at third decimal place).
South Carolina	SC	Two zones used for SPCS 27 combined into single zone for SPCS 83. False easting is exact metric conversion from 2,000,000 international feet = 1,999,996 sft (exact), which differs from SPCS 27 false easting of 2,000,000 sft by only 4 feet (exact).
Washington (both zones)	WA N, S	Changed SPCS 27 zone boundary in Grant County by having it follow latitude 47°30'N rather than the county boundary.
Puerto Rico & Virgin Is.	PRVI	Two zones used for SPCS 27 combined into a single zone for SPCS 83 (SPCS 27 zones identical except for false northing).
Guam	GU	Zone added in 1995, after publication of SPCS 83 manual (Stem, 1990), per Guam Annotated Code (Guam Compiler of Laws, 2017).

Appendix B. SPCS 27 Defining Parameters (134 Zones)

Table B1. Complete defining parameters for all 134 zones of the State Plane Coordinate System of 1927 (SPCS 27). All projections are defined with respect to the Clarke 1866 ellipsoid, with exact semi-major and minor axes of a = 6,378,206.4 and b = 6,356,583.8 meters, respectively (except as noted for the 1964 definition of the Michigan zones). Information in this table is available in digital format on the NGS website (geodesy.noaa.gov), including geodetic origins in decimal degrees. Table B2 gives additional information for the “Comments” column of this table. Note the following:

- Projection axis scale. Ratio values for LCC zones were computed and rounded to nearest whole number. Decimal values that are not infinitely repeating are shown as exact; repeating values are rounded to nine decimal places with ellipses indicating they are not exact.
- Origin longitude. Central meridian for LCC and TM projections. A central meridian is not defined for the OM projection (the convergence angle is zero at the local origin but does not remain zero along that meridian).
- Grid origin (*x* and *y*). Given as exact values in U.S. survey feet. Two zones defined using exact values in meters (Alaska Zone 1 and Guam), as indicated by unit abbreviation “m.”
- Abbreviations.
    - *Projections:* LCC = Lambert Conformal Conic; TM = Transverse Mercator; OM = Oblique Mercator; AE = Azimuthal Equidistant.
    - *Standard parallels (applies only to LCC projections):* S std = South standard; N std = North standard

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	Projection axis scale (decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft) x	Grid origin (U.S. survey ft) y	Comments (see Table B2 for additional information)
Alabama (AL): SPCS 27												
AL E	0101	East	TM	1:25,000	0.999 96	85°50'W	30°30'N	—	—	500,000	0	
AL W	0102	West	TM	1:15,000	0.999 933 333...	87°30'W	30°00'N	—	—	500,000	0	
Alaska (AK): SPCS 27 (added ca. 1960); Zone 9 only includes islands that are referenced to three local datums other than NAD 27 (see Table B2)												
AK 1	5001	1	OM	1:10,000	0.999 9	133°40'W	57°00'N	—	—	5,000,000 m	-5,000,000 m	Skew axis azimuth = tan^{-1} (-¾)
AK 2	5002	2	TM	1:10,000	0.999 9	142°00'W	54°00'N	—	—	500,000	0	
AK 3	5003	3	TM	1:10,000	0.999 9	146°00'W	54°00'N	—	—	500,000	0	
AK 4	5004	4	TM	1:10,000	0.999 9	150°00'W	54°00'N	—	—	500,000	0	
AK 5	5005	5	TM	1:10,000	0.999 9	154°00'W	54°00'N	—	—	500,000	0	
AK 6	5006	6	TM	1:10,000	0.999 9	158°00'W	54°00'N	—	—	500,000	0	
AK 7	5007	7	TM	1:10,000	0.999 9	162°00'W	54°00'N	—	—	700,000	0	
AK 8	5008	8	TM	1:10,000	0.999 9	166°00'W	54°00'N	—	—	500,000	0	
AK 9	5009	9	TM	1:10,000	0.999 9	170°00'W	54°00'N	—	—	600,000	0	Not referenced to NAD 27
AK10	5010	10	LCC	1:6,582	0.999 848 064...	176°00'W	51°00'N	51°50'N	53°50'N	3,000,000	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale		Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft)		Comments (see Table B2 for additional information)
				(ratio)	(decimal)					x	y	
Arizona (AZ)): SPCS 27												
AZ E	0201	East	TM	1:10,000	0.999 9	110°10'W	31°00'N	—	—	500,000	0	
AZ C	0202	Central	TM	1:10,000	0.999 9	111°55'W	31°00'N	—	—	500,000	0	
AZ W	0203	West	TM	1:15,000	0.999 933 333...	113°45'W	31°00'N	—	—	500,000	0	
Arkansas (AR): SPCS 27												
AR N	0301	North	LCC	1:15,610	0.999 935 939...	92°00'W	34°20'N	34°56'N	36°14'N	2,000,000	0	
AR S	0302	South	LCC	1:12,266	0.999 918 474...	92°00'W	32°40'N	33°18'N	34°46'N	2,000,000	0	
California (CA): SPCS 27												
CA 1	0401	1	LCC	1:9,491	0.999 894 641...	122°00'W	39°20'N	40°00'N	41°40'N	2,000,000	0	
CA 2	0402	2	LCC	1:11,720	0.999 914 677...	122°00'W	37°40'N	38°20'N	39°50'N	2,000,000	0	
CA 3	0403	3	LCC	1:14,121	0.999 929 182...	120°30'W	36°30'N	37°04'N	38°26'N	2,000,000	0	
CA 4	0404	4	LCC	1:16,882	0.999 940 765...	119°00'W	35°20'N	36°00'N	37°15'N	2,000,000	0	
CA 5	0405	5	LCC	1:12,842	0.999 922 131...	118°00'W	33°30'N	34°02'N	35°28'N	2,000,000	0	
CA 6	0406	6	LCC	1:21,808	0.999 954 145...	116°15'W	32°10'N	32°47'N	33°53'N	2,000,000	0	
CA 7	0407	7	LCC	1:87,223	0.999 988 535...	118°20'W	34°08'N	33°52'N	34°25'N	4,186,692.58	4,160,926.74	LA County (added by 1945)
Colorado (CO): SPCS 27												
CO N	0501	North	LCC	1:23,174	0.999 956 848...	105°30'W	39°20'N	39°43'N	40°47'N	2,000,000	0	
CO C	0502	Central	LCC	1:15,604	0.999 935 913...	105°30'W	37°50'N	38°27'N	39°45'N	2,000,000	0	
CO S	0503	South	LCC	1:18,315	0.999 945 401...	105°30'W	36°40'N	37°14'N	38°26'N	2,000,000	0	
Connecticut (CT): SPCS 27												
CT	0600		LCC	1:59,316	0.999 983 141...	72°45'W	40°50'N	41°12'N	41°52'N	600,000	0	
Delaware (DE): SPCS 27												
DE	0700		TM	1:200,000	0.999 995	75°25'W	38°00'N	—	—	500,000	0	
Florida (FL): SPCS 27												
FL E	0901	East	TM	1:17,000	0.999 941 176...	81°00'W	24°20'N	—	—	500,000	0	
FL W	0902	West	TM	1:17,000	0.999 941 176...	82°00'W	24°20'N	—	—	500,000	0	
FL N	0903	North	LCC	1:19,393	0.999 948 436...	84°30'W	29°00'N	29°35'N	30°45'N	2,000,000	0	
Georgia (GA): SPCS 27												
GA E	1001	East	TM	1:10,000	0.999 9	82°10'W	30°00'N	—	—	500,000	0	
GA W	1002	West	TM	1:10,000	0.999 9	84°10'W	30°00'N	—	—	500,000	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft) x	y	Comments (see Table B2 for additional information)
Hawaii (HI): SPCS 27 (added ca. 1960; referenced to Old Hawaiian Datum)												
HI 1	5101	1	TM	1:30,000	0.999 966 667...	155°30'W	18°50'N	—	—	500,000	0	
HI 2	5102	2	TM	1:30,000	0.999 966 667...	156°40'W	20°20'N	—	—	500,000	0	
HI 3	5103	3	TM	1:100,000	0.999 99	158°00'W	21°10'N	—	—	500,000	0	
HI 4	5104	4	TM	1:100,000	0.999 99	159°30'W	21°50'N	—	—	500,000	0	
HI 5	5105	5	TM	Exact	1	160°10'W	21°40'N	—	—	500,000	0	
Idaho (ID): SPCS 27												
ID E	1101	East	TM	1:19,000	0.999 947 368...	112°10'W	41°40'N	—	—	500,000	0	
ID C	1102	Central	TM	1:19,000	0.999 947 368...	114°00'W	41°40'N	—	—	500,000	0	
ID W	1103	West	TM	1:15,000	0.999 933 333...	115°45'W	41°40'N	—	—	500,000	0	
Illinois (IL): SPCS 27												
IL E	1201	East	TM	1:40,000	0.999 975	88°20'W	36°40'N	—	—	500,000	0	
IL W	1202	West	TM	1:17,000	0.999 941 176...	90°10'W	36°40'N	—	—	500,000	0	
Indiana (IN): SPCS 27												
IN E	1301	East	TM	1:30,000	0.999 966 667...	85°40'W	37°30'N	—	—	500,000	0	
IN W	1302	West	TM	1:30,000	0.999 966 667...	87°05'W	37°30'N	—	—	500,000	0	
Iowa (IA): SPCS 27												
IA N	1401	North	LCC	1:18,305	0.999 945 370...	93°30'W	41°30'N	42°04'N	43°16'N	2,000,000	0	
IA S	1402	South	LCC	1:19,369	0.999 948 372...	93°30'W	40°00'N	40°37'N	41°47'N	2,000,000	0	
Kansas (KS): SPCS 27												
KS N	1501	North	LCC	1:23,177	0.999 956 853...	98°00'W	38°20'N	38°43'N	39°47'N	2,000,000	0	
KS S	1502	South	LCC	1:15,606	0.999 935 921...	98°30'W	36°40'N	37°16'N	38°34'N	2,000,000	0	
Kentucky (KY): SPCS 27												
KY N	1601	North	LCC	1:26,372	0.999 962 081...	84°15'W	37°30'N	37°58'N	38°58'N	2,000,000	0	
KY S	1602	South	LCC	1:18,316	0.999 945 404...	85°45'W	36°20'N	36°44'N	37°56'N	2,000,000	0	
Louisiana (LA): SPCS 27												
LA N	1701	North	LCC	1:11,730	0.999 914 746...	92°30'W	30°40'N	31°10'N	32°40'N	2,000,000	0	
LA S	1702	South	LCC	1:13,468	0.999 925 749...	91°20'W	28°40'N	29°18'N	30°42'N	2,000,000	0	
LASH	1703	Offshore	LCC	1:9,506	0.999 894 800...	91°20'W	25°40'N	26°10'N	27°50'N	2,000,000	0	Established in 1968

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft) x	y	Comments (see Table B2 for additional information)
Maine (ME): SPCS 27												
ME E	1801	East	TM	1:10,000	0.999 9	68°30'W	43°50'N	—	—	500,000	0	
ME W	1802	West	TM	1:30,000	0.999 966 667...	70°10'W	42°50'N	—	—	500,000	0	
Maryland (MD): SPCS 27												
MD	1900		LCC	1:19,940	0.999 949 850...	77°00'W	37°50'N	38°18'N	39°27'N	800,000	0	
Massachusetts (MA): SPCS 27												
MA M	2001	Mainland	LCC	1:28,210	0.999 964 552...	71°30'W	41°00'N	41°43'N	42°41'N	600,000	0	
MA I	2002	Island	LCC	1:659,080	0.999 998 483...	70°30'W	41°00'N	41°17'N	41°29'N	200,000	0	
Michigan (MI): SPCS 27												
MI E	2101	East	TM	1:17,500	0.999 942 857...	83°40'W	41°30'N	—	—	500,000	0	Original SPCS 27 (1934)
MI C	2102	Central	TM	1:11,000	0.999 909 091...	85°45'W	41°30'N	—	—	500,000	0	Original SPCS 27 (1934)
MI W	2103	West	TM	1:11,000	0.999 909 091...	88°45'W	41°30'N	—	—	500,000	0	Original SPCS 27 (1934)
MI N	2111	North	LCC	1:10,292	0.999 902 838...	87°00'W	44°47'N	45°29'N	47°05'N	2,000,000	0	Used scaled ellipsoid (1964)
MI C	2112	Central	LCC	1:11,456	0.999 912 710...	84°20'W	43°19'N	44°11'N	45°42'N	2,000,000	0	Used scaled ellipsoid (1964)
MI S	2113	South	LCC	1:10,739	0.999 906 882...	84°20'W	41°30'N	42°06'N	43°40'N	2,000,000	0	Used scaled ellipsoid (1964)
Minnesota (MN): SPCS 27												
MN N	2201	North	LCC	1:10,290	0.999 902 820...	93°06'W	46°30'N	47°02'N	48°38'N	2,000,000	0	
MN C	2202	Central	LCC	1:12,825	0.999 922 025...	94°15'W	45°00'N	45°37'N	47°03'N	2,000,000	0	
MN S	2203	South	LCC	1:12,828	0.999 922 043...	94°00'W	43°00'N	43°47'N	45°13'N	2,000,000	0	
Mississippi (MS): SPCS 27												
MS E	2301	East	TM	1:25,000	0.999 96	88°50'W	29°40'N	—	—	500,000	0	
MS W	2302	West	TM	1:17,000	0.999 941 176...	90°20'W	30°30'N	—	—	500,000	0	
Missouri (MO): SPCS 27												
MO E	2401	East	TM	1:15,000	0.999 933 333...	90°30'W	35°50'N	—	—	500,000	0	
MO C	2402	Central	TM	1:15,000	0.999 933 333...	92°30'W	35°50'N	—	—	500,000	0	
MO W	2403	West	TM	1:17,000	0.999 941 176...	94°30'W	36°10'N	—	—	500,000	0	
Montana (MT): SPCS 27												
MT N	2501	North	LCC	1:35,070	0.999 971 486...	109°30'W	47°00'N	47°51'N	48°43'N	2,000,000	0	
MT C	2502	Central	LCC	1:12,823	0.999 922 018...	109°30'W	45°50'N	46°27'N	47°53'N	2,000,000	0	
MT S	2503	South	LCC	1:11,207	0.999 910 773...	109°30'W	44°00'N	44°52'N	46°24'N	2,000,000	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft) x	y	Comments (see Table B2 for additional information)
Nebraska (NE): SPCS 27												
NE N	2601	North	LCC	1:28,210	0.999 964 551...	100°00'W	41°20'N	41°51'N	42°49'N	2,000,000	0	
NE S	2602	South	LCC	1:12,833	0.999 922 075...	99°30'W	39°40'N	40°17'N	41°43'N	2,000,000	0	
Nevada (NV): SPCS 27												
NV E	2701	East	TM	1:10,000	0.999 9	115°35'W	34°45'N	—	—	500,000	0	
NV C	2702	Central	TM	1:10,000	0.999 9	116°40'W	34°45'N	—	—	500,000	0	
NV W	2703	West	TM	1:10,000	0.999 9	118°35'W	34°45'N	—	—	500,000	0	
New Hampshire (NH): SPCS 27												
NH	2800		TM	1:30,000	0.999 966 667...	71°40'W	42°30'N	—	—	500,000	0	
New Jersey (NJ): SPCS 27												
NJ	2900		TM	1:40,000	0.999 975	74°40'W	38°50'N	—	—	2,000,000	0	
New Mexico (NM): SPCS 27												
NM E	3001	East	TM	1:11,000	0.999 909 091...	104°20'W	31°00'N	—	—	500,000	0	
NM C	3002	Central	TM	1:10,000	0.999 9	106°15'W	31°00'N	—	—	500,000	0	
NM W	3003	West	TM	1:12,000	0.999 916 667...	107°50'W	31°00'N	—	—	500,000	0	
New York (NY): SPCS 27												
NY E	3101	East	TM	1:30,000	0.999 966 667...	74°20'W	40°00'N	—	—	500,000	0	
NY C	3102	Central	TM	1:16,000	0.999 937 5	76°35'W	40°00'N	—	—	500,000	0	
NY W	3103	West	TM	1:16,000	0.999 937 5	78°35'W	40°00'N	—	—	500,000	0	
NY L	3104	Long Island	LCC	1:196,102	0.999 994 901...	74°00'W	40°30'N	40°40'N	41°02'N	2,000,000	100,000	
North Carolina (NC): SPCS 27												
NC	3200		LCC	1:7,849	0.999 872 598...	79°00'W	33°45'N	34°20'N	36°10'N	2,000,000	0	
North Dakota (ND): SPCS 27												
ND N	3301	North	LCC	1:15,587	0.999 935 844...	100°30'W	47°00'N	47°26'N	48°44'N	2,000,000	0	
ND S	3302	South	LCC	1:15,589	0.999 935 854...	100°30'W	45°40'N	46°11'N	47°29'N	2,000,000	0	
Ohio (OH): SPCS 27												
OH N	3401	North	LCC	1:16,432	0.999 939 143...	82°30'W	39°40'N	40°26'N	41°42'N	2,000,000	0	
OH S	3402	South	LCC	1:15,603	0.999 935 911...	82°30'W	38°00'N	38°44'N	40°02'N	2,000,000	0	
Oklahoma (OK): SPCS 27												
OK N	3501	North	LCC	1:18,319	0.999 945 411...	98°00'W	35°00'N	35°34'N	36°46'N	2,000,000	0	
OK S	3502	South	LCC	1:15,612	0.999 935 946...	98°00'W	33°20'N	33°56'N	35°14'N	2,000,000	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	(decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft) x	y	Comments (see Table B2 for additional information)
Oregon (OR): SPCS 27												
OR N	3601	North	LCC	1:9,486	0.999 894 587...	120°30'W	43°40'N	44°20'N	46°00'N	2,000,000	0	
OR S	3602	South	LCC	1:9,489	0.999 894 612...	120°30'W	41°40'N	42°20'N	44°00'N	2,000,000	0	
Pennsylvania (PA): SPCS 27												
PA N	3701	North	LCC	1:23,171	0.999 956 842...	77°45'W	40°10'N	40°53'N	41°57'N	2,000,000	0	
PA S	3702	South	LCC	1:24,692	0.999 959 502...	77°45'W	39°20'N	39°56'N	40°58'N	2,000,000	0	
Rhode Island (RI): SPCS 27												
RI	3800		TM	1:160,000	0.999 993 75	71°30'W	41°05'N	—	—	500,000	0	
South Carolina (SC): SPCS 27												
SC N	3901	North	LCC	1:18,323	0.999 945 422...	81°00'W	33°00'N	33°46'N	34°58'N	2,000,000	0	
SC S	3902	South	LCC	1:14,844	0.999 932 630...	81°00'W	31°50'N	32°20'N	33°40'N	2,000,000	0	
South Dakota (SD): SPCS 27												
SD N	4001	North	LCC	1:16,424	0.999 939 114...	100°00'W	43°50'N	44°25'N	45°41'N	2,000,000	0	
SD S	4002	South	LCC	1:10,738	0.999 906 874...	100°20'W	42°20'N	42°50'N	44°24'N	2,000,000	0	
Tennessee (TN): SPCS 27												
TN	4100		LCC	1:19,381	0.999 948 404...	86°00'W	34°40'N	35°15'N	36°25'N	2,000,000	100,000	
Texas (TX): SPCS 27												
TX N	4201	North	LCC	1:11,221	0.999 910 880...	101°30'W	34°00'N	34°39'N	36°11'N	2,000,000	0	
TXNC	4202	North Central	LCC	1:7,851	0.999 872 629...	97°30'W	31°40'N	32°08'N	33°58'N	2,000,000	0	
TX C	4203	Central	LCC	1:8,457	0.999 881 750...	100°20'W	29°40'N	30°07'N	31°53'N	2,000,000	0	
TXSC	4204	South Central	LCC	1:7,313	0.999 863 251...	99°00'W	27°50'N	28°23'N	30°17'N	2,000,000	0	
TX S	4205	South	LCC	1:9,506	0.999 894 800...	98°30'W	25°40'N	26°10'N	27°50'N	2,000,000	0	
Utah (UT): SPCS 27												
UT N	4301	North	LCC	1:23,171	0.999 956 843...	111°30'W	40°20'N	40°43'N	41°47'N	2,000,000	0	
UT C	4302	Central	LCC	1:9,884	0.999 898 825...	111°30'W	38°20'N	39°01'N	40°39'N	2,000,000	0	
UT S	4303	South	LCC	1:20,534	0.999 951 299...	111°30'W	36°40'N	37°13'N	38°21'N	2,000,000	0	
Vermont (VT): SPCS 27												
VT	4400		TM	1:28,000	0.999 964 286...	72°30'W	42°30'N	—	—	500,000	0	
Virginia (VA): SPCS 27												
VA N	4501	North	LCC	1:19,375	0.999 948 388...	78°30'W	37°40'N	38°02'N	39°12'N	2,000,000	0	
VA S	4502	South	LCC	1:18,316	0.999 945 404...	78°30'W	36°20'N	36°46'N	37°58'N	2,000,000	0	

Zone abrev	Zone code	Zone designation	Type	Projection axis scale (ratio)	Projection axis scale (decimal)	Origin longitude	Origin latitude	S std parallel	N std parallel	Grid origin (U.S. survey ft) x	Grid origin (U.S. survey ft) y	Comments (see Table B2 for additional information)
Washington (WA): SPCS 27												
WA N	4601	North	LCC	1:17,318	0.999 942 255...	120°50'W	47°00'N	47°30'N	48°44'N	2,000,000	0	
WA S	4602	South	LCC	1:11,710	0.999 914 601...	120°30'W	45°20'N	45°50'N	47°20'N	2,000,000	0	
West Virginia (WV): SPCS 27												
WV N	4701	North	LCC	1:16,876	0.999 940 744...	79°30'W	38°30'N	39°00'N	40°15'N	2,000,000	0	
WV S	4702	South	LCC	1:13,456	0.999 925 682...	81°00'W	37°00'N	37°29'N	38°53'N	2,000,000	0	
Wisconsin (WI): SPCS 27												
WI N	4801	North	LCC	1:18,297	0.999 945 347...	90°00'W	45°10'N	45°34'N	46°46'N	2,000,000	0	
WI C	4802	Central	LCC	1:16,865	0.999 940 707...	90°00'W	43°50'N	44°15'N	45°30'N	2,000,000	0	
WI S	4803	South	LCC	1:14,826	0.999 932 550...	90°00'W	42°00'N	42°44'N	44°04'N	2,000,000	0	
Wyoming (WY): SPCS 27												
WY E	4901	I	TM	1:17,000	0.999 941 176...	105°10'W	40°40'N	—	—	500,000	0	
WYEC	4902	II	TM	1:17,000	0.999 941 176...	107°20'W	40°40'N	—	—	500,000	0	
WYWC	4903	III	TM	1:17,000	0.999 941 176...	108°45'W	40°40'N	—	—	500,000	0	
WY W	4904	IV	TM	1:17,000	0.999 941 176...	110°05'W	40°40'N	—	—	500,000	0	
United States Territories												
Puerto Rico and U.S. Virgin Islands (PR and VI): SPCS 27 (added between 1945 and 1974; referenced to Puerto Rico Datum of 1940)												
PRZ1	5201	Zone 1	LCC	1:165,150	0.999 993 945...	66°26'W	17°50'N	18°02'N	18°26'N	500,000	0	
VISX	5202	St. Croix	LCC	1:165,150	0.999 993 945...	66°26'W	17°50'N	18°02'N	18°26'N	500,000	100,000	
American Samoa (AS): SPCS 27 (added between 1945 and 1974; referenced to American Samoa Datum of 1962)												
AS	5300		LCC	Exact	1	170°00'W	14°16'S	14°16'S		500,000	312,234.65	One parallel LCC
Guam (GU): SPCS 27 (referenced to 1963 Guam Datum)												
GU	5400		AE	Not applicable	Not applicable	144°44'55.50254"E 13°28'20.87887"N		—	—	50,000 m	50,000 m	"Approximate" Azimuthal Equidistant projection (meters)

Table B2. Additional information for "Comments" column of Table B1 for SPCS 27 zones.

State or Territory	Zones	Additional information
Alaska	AK 1	Skew axis azimuth = $\tan^{-1}(-3/4)$ = -36°52'11.6315250385". SPCS 27 Fortran code in subroutine "akspec.f" (NGS, 2003) defines grid origin as exactly 3.28083333333 × (±5,000,000) = ±16,404,166.66665 sft. The grid origin is defined at the "natural" origin on the equator of the "aposphere", an intermediate surface of rotation with constant total curvature derived from the ellipsoid at the central point (local origin) of the projection. The ellipsoid is conformally projected onto the aposphere before final projection onto the plane. See NGS (1986) and Snyder (1987).
Alaska	AK 9	Entire zone consists of islands in the Bering Sea too far from the mainland for connection to the NAD 27 datum. Four islands each have their own astronomically determined local horizontal datums: the St. Lawrence, St. Matthew, St. Paul, and St. George datums of 1952 (see Figure 3).
California	CA 7	Initially developed in 1938 and added to SPCS 27 by 1945. Grid origin selected such that coordinates were as close as possible to those of a Polyconic projection referenced to NAD 27 that had been previously defined for part of Los Angeles County. For SPCS 83, this zone was eliminated and its area included in CA Zone 5.
Louisiana (offshore)	LASH	The included area of the Gulf of Mexico was defined as being within 200 miles of the state of Louisiana by state law. The extents of the zone by positive grid coordinates covers all of the Gulf of Mexico north of 25°40'N latitude, with its south margin approximately 220 miles (350 kilometers) south of the southernmost part of the Louisiana coast. For SPCS 83, the south edge of the zone was moved to 25°30'N latitude, approximately 230 miles (370 kilometers) south of the Louisiana coast.
Michigan (all zones)	MI E, C, W	TM zones created in original 1934 definition, superseded by three LCC zones in 1964.
Michigan (all zones)	MI N, C, S	LCC zones created in 1964 by scaling Clarke 1866 ellipsoid semi-major axis by a factor of exactly 1.0000382 with its flattening held constant (yields scaled ellipsoid axes of a = 6,378,450.047484 meters and b = 6,356,826.621501 meters). The scale factor was based on a height of 800 feet at 44° latitude to create a reference ellipsoid surface near the topographic surface for Michigan. The objective was to keep linear distortion ***at ground*** within ±100 parts per million (1:10,000) over the entire state.
American Samoa	AS	One-parallel LCC with false northing of 312,234.65 corresponds to single standard parallel (where scale is exactly 1).
Guam	GU	Non-conformal "approximate" Azimuthal Equidistant projection. Origin coordinates of latitude 13°28'20.87887"N and longitude 144°44'55.50254"E are for station *Agana Monument* 1945 based on Guam Datum of 1963 (Claire 1968, p. 35).

Appendix C. SPCS 83 Legislation and Foot Version Adopted by States and Territories

Table C1. State Plane Coordinate System of 1983 (SPCS 83) legislation as adopted for U.S. states, districts, territories, and commonwealths, and Federal Register Notices (FRNs) regarding official version of the foot if not defined by state statute. Information in this table is available in digital format on the NGS website (geodesy.noaa.gov). Figure 4 shows the jurisdictions with SPCS 83 legislation and the type of foot adopted.

All legislation and FRNs include embedded hyperlinks to websites. Whenever possible, state legislation hyperlinks are to the relevant government website for the jurisdiction. However, for some jurisdictions the only available or practical links were through commercial websites, as indicated in the table endnotes. While every effort was made to provide complete and correct information, website addresses can change, and in those cases the legislation citation text in the table can be used for online searches. All hyperlinks in this table were last checked on **February 25, 2018**.

The two types of feet are defined as:

- **U.S. survey foot** (sft) ≡ 1200 / 3937 meter (exact); 1 meter = 3.280833333333… sft; the sft is *longer* than the ift by 2 parts per million.
- **International foot** (ift) ≡ 0.3048 meter (exact); 1 meter = 3.280839895013… ift; the ift is *shorter* than the sft by 2 parts per million

State, district, or territory	Type of foot	State Plane Coordinate System of 1983 legislation	Federal Register Notices on SPCS 83 linear units
Alabama (a)	None	None	
Alaska	None	Alaska Statutes, Title 38, Chapter 20, §38.20.010 to §38.20.110	
Arizona	International	Arizona Revised Statutes, Title 33, Chapter 1, Article 3, §33-131 to §33-138	
Arkansas (b)	U.S. survey	Arkansas Code Annotated, Title 15, Subtitle 2, Chapter 21, Subchapter 3, §15-21-301 to §15-21-310	
California	U.S. survey	California Law, Public Resource Code, Division 8, Chapter 1, §8801 to §8819	
Colorado (b)	U.S. survey	Colorado Revised Statutes, Title 38, Article 52, §38-52-101 to §38-52-107	
Connecticut	U.S. survey	General Statutes of Connecticut, Volume 4, Title 13a, Chapter 241, §13a-255	
Delaware	U.S. survey	Delaware Code, Title 6, Subtitle III, Chapter 55, §5501 to §5508	
Florida	U.S. survey	Florida Statutes, Title XII, Chapter 177, §177.151	
Georgia (b)	U.S. survey	Official Code of Georgia Annotated, Title 44, Chapter 4, Article 2, §44-4-20 to §44-4-31	
Hawaii	None	None	
Idaho	U.S. survey	Idaho Statutes, Title 55, Chapter 17, §55-1701 to §55-1709	71 FR 58804 (10/05/2006)
Illinois	U.S. survey	Illinois Compiled Statutes, Chapter 765, ICLS 225/1 to 225/8	

State, district, or territory	Type of foot	State Plane Coordinate System of 1983 legislation	Federal Register Notices on SPCS 83 linear units
Indiana	U.S. survey	Indiana Code, Title 32, Article 19, Chapters 1 to 4 (IC 32-19-1 to IC 32-19-4)	
Iowa	U.S. survey	Iowa Code, Chapter 355, §355.16 to §355.19	71 FR 58805 (10/05/2006)
Kansas	U.S. survey	Kansas Statutes, Chapter 58, Article 20a, §58-20a01 to §58-20a07	71 FR 67857 (11/24/2006)
Kentucky	U.S. survey	Kentucky Revised Statutes, Chapter 1.020	
Louisiana	U.S. survey	Louisiana Revised Statutes, Title 50, Chapter 1	
Maine	U.S. survey	Maine Revised Statutes, Title 33, Chapter 13, §801 to §807	72 FR 70575 (12/12/2007)
Maryland	U.S. survey	Annotated Code of Maryland, Article - Real Property, Title 14, Subtitle 4, §14-401 to §14-407	
Massachusetts	U.S. survey	General Laws of Massachusetts, Part 1, Title XV, Chapter 97, §8 to §17	
Michigan	International	Michigan Complied Laws, Public Act 9 of 1964, §54.231 to §54.239	
Minnesota	U.S. survey	Minnesota Statutes, Chapter 505, §505.18 to §505.28	72 FR 32287 (06/12/2007)
Mississippi (b)	U.S. survey	Mississippi Code of 1972 Annotated, Title 89, Chapter 6, §89-6-1 to §89-6-19	
Missouri	None	Revised Statutes of Missouri, Title VI, Chapter 60, §60.401 to §60.491	
Montana	International	Montana Code Annotated, Title 70, Chapter 22, Part 2, §70-22-201 to §70-22-210	
Nebraska	U.S. survey	Nebraska Revised Statutes, Chapter 76, §76-2501 to §76-2506	72 FR 73771 (12/28/2007)
Nevada	U.S. survey	Nevada Revised Statutes, Chapter 327, §327.005 to §327.090	71 FR 42817 (07/28/2006)
New Hampshire	U.S. survey	New Hampshire Statutes, Title 1, Chapter 1-A, §1-A:1 to §1-A:5	
New Jersey (c)	U.S. survey	New Jersey General and Permanent Statutes, Title 51, §51:3-7 to §51:3-10	71 FR 42816 (07/28/2006)
New Mexico (c)	U.S. survey	New Mexico Statutes Annotated, Chapter 47, Article 1, §47-1-49 to §47-1-56	
New York (c)	U.S. survey	Laws of New York, 1995, Chapter 605 *[link is to 1995 act showing edits from previous 1938 law]*	
North Carolina	U.S. survey	North Carolina General Statutes, Chapter 102, §102-1 to §102-17	
North Dakota	International	North Dakota Century Code, Title 47, Chapter 20.2, §47-20.2-01 to §47-20.2-09	
Ohio	U.S. survey	Ohio Revised Code, Title 1, Chapter 157, §157.01 to §157.11	72 FR 9737 (03/05/2007)
Oklahoma	U.S. survey	Oklahoma Statutes, Title 60, §60-1001 to §60-1008	
Oregon (d)	International	Oregon Revised Statutes, Volume 3, Chapter 93, §93.320 to §93.380	
Pennsylvania	U.S. survey	Pennsylvania Coordinate System Law - Omnibus Amendment, P.L. 1224, No. 161, Cl. 76	

State, district, or territory	Type of foot	State Plane Coordinate System of 1983 legislation	Federal Register Notices on SPCS 83 linear units
Rhode Island	U.S. survey	State of Rhode Island General Laws, Title 34, Chapter 8, §34-8-1 to §34-8-10	
South Carolina	International	South Carolina Code of Laws, Title 27, Chapter 2, §27-2-10 to §27-2-110	
South Dakota	U.S. survey	South Dakota Codified Laws Title 43, Chapter 22, §43-22-1 to §43-22-14	
Tennessee	U.S. survey	Tennessee Code Annotated, Title 66, Chapter 6, §66-6-101 to §66-6-106	
Texas	U.S. survey	Texas Statutes, Natural Resources Code, Title 2, Chapter 21, Subchapter D, §21.071 to §21.079	
Utah	U.S. survey	Utah Code, Title 57, Chapter 10, §57-10-1 to §57-10-11	74 FR 34557 (07/16/2009)
Vermont	U.S. survey	Vermont Statutes, Title 1, Chapter 17, §671 to §679	
Virginia	U.S. survey	Code of Virginia, Title 55, Chapter 17, §55-287 to §55-297	
Washington	U.S. survey	Revised Code of Washington, Title 58, Chapter 20, §58.20.110 to §58.20.901	
West Virginia	U.S. survey	West Virginia Code, Chapter 1, Article 1, §1-1-5	72 FR 46214 (08/17/2007)
Wisconsin	U.S. survey	Wisconsin Statutes, Chapter 236, Subchapter III, §236.18	
Wyoming	U.S. survey	Wyoming Statutes, Title 34, Chapter 25, §34-25-101 to §34-25-108	72 FR 9737 (03/05/2007)
United States Districts, Territories, and Commonwealths			
Washington D.C. [(e)]	None	None	
Puerto Rico [(b)]	None	Laws of Puerto Rico Unannotated, Title 23, Part VII, Chapter 203, Subchapter V, §7722 to §7722c	
U.S. Virgin Islands	None	None	
American Samoa	None	None	
Guam	None	Guam Code Annotated, Title 21, Division 2, Chapter 60, Article 5, §60516	
Northern Marianas	None	None	

[(a)] No SPCS 83 legislation, but SPCS 27 legislation exists (see Code of Alabama, Title 35, Chapter 2, Article 1, §35-2-1 to §35-2-9).

[(b)] Government website for statute redirects to *LexisNexis* portal. If difficult to access, select jurisdiction from list at http://www.lexisnexis.com/hottopics/michie/.

[(c)] Hyperlink is to commercial website; no direct access via hyperlink to statute through government website.

[(d)] Coordinate systems also defined in Oregon Administrative Rules, Chapter 734, Division 5, §734-005-0005 to §734-005-0015.

[(e)] State Plane Coordinate System of 1927 or 1983 never defined for Washington D.C.; intent was that Maryland or Virginia North zones be used.