

# Area Measurement/Water Classification

For many decades, the Bureau of the Census has provided data users with area measurement information. Typically, this has been the calculated area, in square miles or square kilometers, for selected census geographic entities; usually States, counties, and some places and MCDs. It provides this information as a component of the data presentations resulting from each decennial census. Most area measurement information pertains only to land area, but there also have been figures for water and/or total area.

In conjunction with the 1990 census, the Census Bureau, for the first time, published area measurement information for all geographic entities down to the census block level. The geographic scope of this coverage includes the entire territory of the United States, Puerto Rico, and the Outlying Areas—American Samoa, Guam, the Northern Mariana Islands, Palau, and the Virgin Islands of the United States.

## **Area Measurement Through the 1980 Census**

A primary original purpose of area measurement information, most of which pertained only to land area, was to provide a basis for calculating population density figures. In response to other needs, the Census Bureau began to provide water and/or total area measurement information. Over time, the Census Bureau has revised its area measurement figures to take into account boundary changes, revisions in shorelines, construction of artificial water bodies, the latest technology for calculating area, and better maps.

### **Censuses Before 1940**

Area measurement data first appeared in an 1850 census publication, which reported the land area of the Nation, the States and territories, five major drainage areas, and a few other selected major divisions of the United States.<sup>1</sup> Similar area measurement data appeared in the

1860 and 1870 census publications. These data, which came from sources outside the Census Office (predecessor of the Census Bureau), show only the land area of the States and territories.

The first comprehensive area measurement information was published as part of the 1880 census. The measurements were done for many more types of geographic entities than in previous censuses. There were separate land and water area figures for the Nation, the individual States and territories, and for the first time, counties. Also, the Census Office began to calculate its own area measurement values. A special publication described the measurement techniques, sources consulted, and maps used.<sup>2</sup> From 1890 through 1930 there were gradual improvements in the quality and scope of the area measurement presentations, as the Census Bureau began to provide area measurement information for geographic entities below the State and county level, such as for more populous incorporated places and minor civil divisions (MCDs).

### **The 1940 Through 1970 Censuses**

There were important new advances in conjunction with the 1940 census. For the first time, the Census Bureau provided area measurement information for every MCD regardless of its population, and every incorporated place with a population of 1,000 or more.<sup>3</sup> The Census Bureau used aeronautical charts from the U.S. Coast and Geodetic Survey (scale of 1:500,000) to derive the total area of the United States and of each State; for counties, it used the U.S. Geological Survey's (USGS) State topographic quadrangle maps (also at a scale of 1:500,000); for county subdivisions and places, it used county highway maps. It then adjusted the State totals to agree with the previously derived U.S. total, and the county totals to agree with the State totals.

The Census Bureau defined land to include all dry land, land temporarily or partially covered by water (except tidal flats), and islands more than 40 acres in size. It defined inland water as permanent streams, sloughs, estuaries, and canals except those less than one-eighth of a mile (660 feet) in width, and permanent lakes, ponds, and reservoirs except those of less than 40 acres.

Also for the first time, the Census Bureau developed guidelines for measuring waters other than inland water; that is, coastal water, large embayments, sounds, straits, and the Great Lakes.

From its 1950 through its 1970 censuses, the Census Bureau used the same techniques to obtain updated area measurement data; each decade it revised the previous figures to take into account new geographic entities, shifts or transfers of territory, new reservoirs, better maps, and reported errors and inconsistencies. To perform these updates, it used information available from Federal, State, and local governmental sources. Where necessary, it remeasured geographic areas with polar planimeters or an electromechanical scanning device, the Map Area Computer. After the 1960 census, the Census Bureau published a series of reports to update the 1940 area measurement data.<sup>4</sup> The 1940 area measurement values, at the county level, were treated as control figures for the 1950, 1960, and 1970 updates; that is, all geographic entities comprising a county had to equal the county's total area figure.

### **The 1980 Census**

For the 1980 census, there were two major changes: an improved map base and the first use of computer processing techniques to obtain updated area measurements. The Census Bureau recalculated the area of every State and county from the largest scale USGS topographic maps available, usually the 1:24,000-scale series. (For Alaska, the 1:250,000-scale maps were used.) The Census Bureau obtained the new area measurement values digitally; that is, by a process that converted boundaries on maps into x, y coordinates based on a grid network (latitude/longitude). The digitized values, stored in a computer file, were processed to provide improved area measurement figures for States and counties. To obtain measurements for other geographic entities, such as places and MCDs, and for water bodies, the Census Bureau used a variety of sources: local estimates of area, State highway maps, individual maps of places, the Metropolitan Map Series,<sup>5</sup> and the records of governmental agencies that control development of new reservoirs and similar water bodies.

In conjunction with the 1980 census, the Census Bureau produced land area data for States; counties; places with a population of 2,500 or more; MCDs of 2,500 or more in 11 States (Connecticut, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Wisconsin); metropolitan areas; urbanized areas; and postcensal congressional districts. (The Census Bureau did not produce area measurement data for small-area geographic entities such as census tracts, block groups, and census blocks.) The 1980 population census reports included land area data for places to tenths of a square mile and tenths of a square kilometer; for all other entities, the area figures were rounded to whole square miles and square kilometers.

## **Area Measurements for the 1990 Census**

### **Using TIGER to Calculate Area**

For the 1990 census, the Census Bureau created the TIGER (Topologically Integrated Geographic Encoding and Referencing) System, which included a nationwide digital geographic data base, to automate the mapping and related geographic activities required to support the Census Bureau's census and survey programs. The Census Bureau calculated all areal values, for both land and water, from the specific set of boundaries recorded for each entity in the TIGER data base. As a result, there are four major differences between the 1990 census and previous ones regarding area measurements:

- The values for the 1990 census area measurements are based on the information contained in a single, consistent geographic data base rather than on a variety of maps supplemented by historical and local information. The TIGER data base is based on the U.S. Geological Survey's 1:100,000-scale maps for the coterminous 48 States, except for the areas covered by the GBF/DIME-Files,<sup>6</sup> which are based on the MMS. The TIGER data base for Alaska, Hawaii, Puerto Rico, and the Outlying Areas reflects the results of manual digitizing outside GBF/DIME-File areas using primarily 1:24,000-, 1:63,360-, and 1:250,000-scale USGS maps for Alaska and 1:20,000-, 1:24,000-, and 1:25,000-scale maps for the other entities. By integrating these various map sources into a

single data base, all coastlines and inland bodies of water were shown more currently and consistently. With the information in the TIGER data base providing a comprehensive and consistent basis for a new set of area measurement figures, all previous data have been superseded by the 1990 census figures.

- The Census Bureau has provided 1990 area measurement figures for virtually *every geographic entity* included in its standard data tabulations, down to the census block level; these figures are available in each standard data product that includes a particular class of entity. This is the first time that the Census Bureau has provided measurements for some kinds of geographic entities: the least populous places, census tracts and block numbering areas (BNAs), block groups, census blocks, American Indian reservations, and Alaska Native village statistical areas.
- Inland water includes *every* body of water that appears in the data base and *every* stream or similar hydrographic feature recorded as a double-line feature in the data base. As a result of this more accurate and complete inventory of inland water area, the 1990 measurements show an increase in the amount of inland water area when compared to 1980.
- The water areas in the standard data products of the 1990 census reflect *all* water, whereas the measurements from previous censuses applied only to inland water. As a result, the total area reported for coastal States has increased correspondingly (see section below “The 1990 Census Water Classification Scheme”).

## **Methodology**

In its TIGER data base for the 1990 census, the Census Bureau has calculated measurements for total area, land area, and four types of water areas, for every polygon in the file *except* census blocks. A census block is identified in the TIGER data base as either all land or all water. This is because *tabulation census blocks*, that is, entities for which the Census Bureau presents population and housing data, always consist of

land area only. (All bodies of water entirely or partially within a tabulation block are identified by a separate, untabulated block number—N99, where N= the block group number. As such, the water body is not part of the land block. This separate, untabulated block number exists internally within the TIGER data base, and also is included in TIGER/Line™ data products.)

In its TIGER data base, the Census Bureau has recorded the area of each polygon in square meters (1 square meter= 0.000001 square kilometer= 10.764 square feet= 0.000247 acre). The data base can accommodate a single polygon area measurement up to almost 2,150,000,000 square meters (2,150 square kilometers, or about 830 square miles). The area measurement for the land surface of any geographic entity is the sum of all polygons comprising that entity. The Census Bureau recorded the area measurement figures in the appropriate geographic reference files (but not in the TIGER data base) in thousandths of a square kilometer (0.001 square kilometer= 1,000 square meters= 10,764 square feet= 0.247 acre= 0.000386 square mile). These parameters ensured the reporting of precise area measurements in square miles and square kilometers, as well as any other appropriate measures—acres, square feet, hectares, and so forth. Where square mile figures are shown in the 1990 census data products, the conversion from square kilometers to square miles was performed first, and rounding was then applied—to six decimal places in the TIGER data base, to three in the summary tape files (STFs), and to one in the printed reports.

## **The 1990 Census Water Classification Scheme**

All water in the TIGER data base is classified in one of four types:

- Inland water
- Coastal water
- Territorial sea
- Great Lakes

### **Inland Water**

Within the interior of the United States, Puerto Rico, and the Outlying Areas, with the exception of the Great Lakes, inland water includes all lakes, reservoirs, ponds, rivers, streams, creeks, or similar bodies of water recorded in the TIGER data base as a two-dimensional feature (rather than as a single line). Rivers and bays that empty into large embayments, the Great Lakes, the oceans, the Caribbean Sea, the Gulf of Mexico, and the Bering Sea are treated as inland water from the point at which they are narrower than one nautical mile across.

### **Coastal Water**

Coastal water refers to any embayments across which one can draw a closure line from 1 to 24 nautical miles in length (inland from the point at which the closure line is one mile or less, the water is treated as inland water). This line separates the coastal water from the territorial sea. For example, the coastal water of the Chesapeake Bay extends from this closure line towards the shoreline, and ends where the bay and its tributaries narrow to less than one nautical mile, where the water becomes classified as inland water.

### **Territorial Sea**

The territorial sea consists of water located between the 3-mile limit and the shoreline or the line that represents the extent of either inland or coastal water. It includes portions of the oceans, the Gulf of Mexico, the Caribbean Sea, and the Bering Sea, but does not include the Great Lakes.

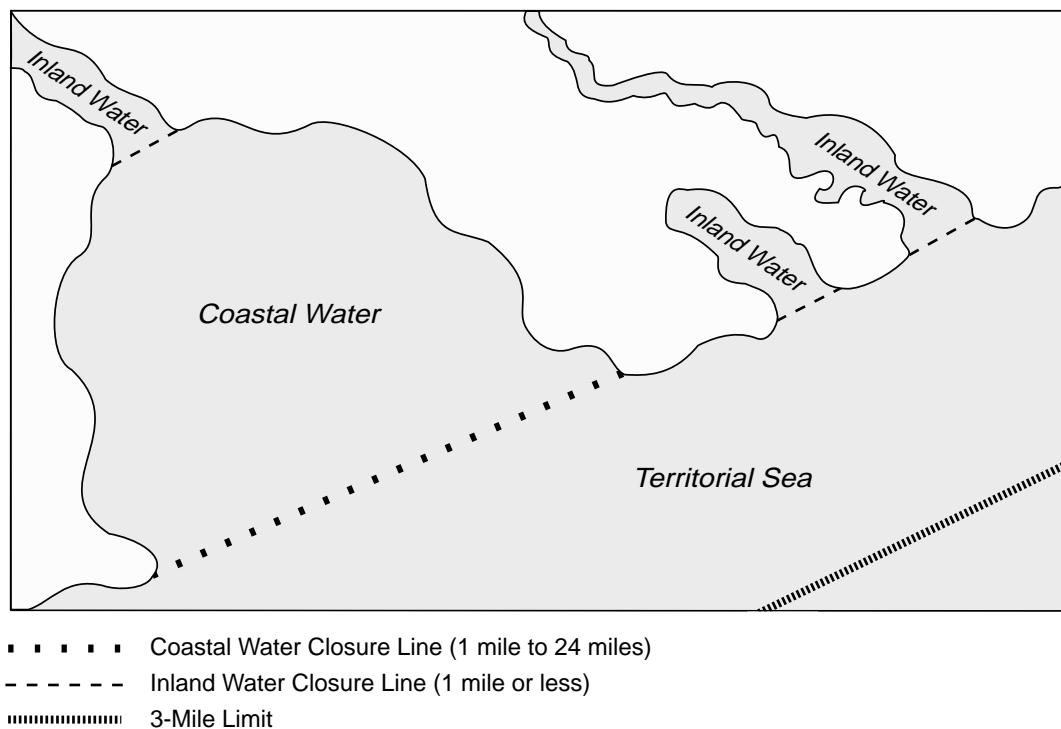
### **Great Lakes Water**

This includes the five Great Lakes and Lake St. Clair. Inland water also includes embayments of the Great Lakes, using the same criteria that distinguish it from coastal and territorial waters.

Figure 15-1 illustrates the geographic relationships between inland water, coastal water, and the territorial sea.

The use of the TIGER data base enhanced the Census Bureau's measurements of water area. Inland water was measured more accurately because the totals for inland water include bodies of water much smaller than those ever measured previously. This also is true for coastal water, where figures were limited to selected coastal water areas in the publications of previous censuses. The use of the TIGER data base also led to improvements in the area totals for Great Lakes water, and enabled the Census Bureau to provide measurements for a new water classification category, territorial sea.

Figure 15-1. **The Water Classification for 1990**



### Using Area Measurement Information

With the availability of area measurement information by census block, any data user can sum these figures to obtain the land area for any geographic entity composed of whole 1990 census blocks. (However, determining the area of an entity that does not comprise whole census blocks



requires the digitization of that entity into the TIGER data base and an independent summation of its component polygons.)

The Census Bureau tabulates and publishes demographic data for land blocks only. Because the TIGER data base identifies all water bodies with a separate series of unique numbers, the water area of a census block is always zero. The Census Bureau reports water area only for entities at the block group level and larger.

Land area measurements may disagree with the information displayed on the Census Bureau's maps and in the TIGER data base because, for area measurement purposes, features identified as *intermittent water* and *glacier* are reported as land area. For this reason, it may not be possible to derive the land area for an entity (as opposed to its total area) by summing the land area of its component census blocks.

In addition, the water area measurement figures reported for some geographic areas include water, while those for some lower-level geographic entities do not. This occurs, for example, where water is associated with a county but is not within the legal boundary of any MCD, or the water is associated with a State but is not within the legal boundary of any county. Therefore, because water area values are contained only in the totals for higher-level geographic entities, summing the water measurements for all component lower-level geographic entities will not necessarily yield the water area of that higher-level entity. Therefore, at any given higher level of geography, there may be water area that is not part of a particular lower-level geographic entity.

Some census tracts, BNAs, and census blocks are classified as *crews-of-vessels* entities, populated entirely by people aboard one or more civilian or military ships. Such entities do not encompass territory (the ships are assumed to be docked and part of the adjacent land block for this purpose) and therefore have no separate area measurement value.

Also, because ZIP Codes are not true geographic entities (they are collections of addresses that share a common numeric identifier) it is not possible to determine the extent of territory they cover with any precision. Therefore, the Census Bureau does not provide area measurement values for them, even though the 1990 STF 3B ZIP Code data tabulations are based on whole census blocks.

The accuracy of any area measurement data is limited by the inaccuracy inherent in (1) the location and shape of the various boundary features in the TIGER data base, (2) rounding affecting the last digit in all operations that compute and/or sum the area measurement values of individual polygons, and (3) conversion from square meters to other measures. Furthermore, it is preferable to sum the areas of polygons, or census blocks and/or tabulated block groups, rather than to perform an independent measurement of an entire large area, because independent area measurement values tend to become inaccurate for very large geographic entities. Although the effects of these limitations tend to be insignificant, especially since they affect measurements represented in very small units (square meters), users of the data should be aware that these inaccuracies exist.

## **Future Improvements**

As updated USGS files and other more accurate map bases replace current information in the TIGER data base, and as the GBF/DIME-File features there are replaced by new USGS or local records, the water and land content of the TIGER data base will become more accurate. Basing the TIGER records for Alaska on a data base similar to the one used for the coterminous 48 States will improve the land and water definition considerably, and can be expected to change the area measurement figures for portions of this State significantly. The result will be further changes to the area measurement figures of the United States and its component geographic entities when the 2000 census figures are calculated—changes that may have nothing to do with any changes to the areal configuration of the United States or those entities.

## Notes and References

- <sup>1</sup> DeBow, J.D.B., *The Seventh Census of the United States, 1850. An Appendix*, Washington [DC], 1853; reprinted in Proudfoot, Malcolm J., *Measurement of Geographic Area*, (Washington, DC), Bureau of the Census, 1946, Appendix C, pp. 69-70.
- <sup>2</sup> Gannett, Henry, *The Areas of the United States, the Several States and Territories, and their Counties, an Extra Census Bulletin*, Washington [DC], 1881, reprinted in Proudfoot, *op. cit.*, Appendix F, pp. 83-106. Also of interest is another publication by Henry Gannett, prepared to reconcile the differences between the 1881 Census Office publication and an 1899 report from the Commissioner of the General Land Office: *The Areas of the United States, the States, and the Territories*, U.S. Geological Survey Bulletin No. 302, Washington [DC], 1906; reprinted in Proudfoot, *op. cit.*, Appendix G, pp. 109-113.
- <sup>3</sup> U.S. Bureau of the Census, *Sixteenth Census of the United States: 1940/Areas of the United States, 1940*, Washington, DC, 1942.
- <sup>4</sup> U.S. Bureau of the Census, *Area Measurement Reports* (Series GE-20), Nos. 1-52, Washington, DC, 1963-1970.
- <sup>5</sup> The Metropolitan Map Series (MMS) was a set of maps developed by the Census Bureau using the 1:24,000-scale map series of the USGS and extensive local assistance. They were used for the 1970 and 1980 censuses. Each MMS covered the urbanized core of a metropolitan area.
- <sup>6</sup> The Census Bureau's GBF/DIME-Files (Geographic Base File/Dual Independent Map Encoding Files) are a series of geographic base files representing the MMS on a segment basis. They contain the segment name, address range, and ZIP Code if applicable; census geographic entity codes for both sides of each segment; feature intersection node numbers; and x, y coordinate information for each record in the file. The file contains information describing an urban street network.