The UTM Grid Reference System

Peter H. Stott

The Universal Transverse Mercator ("UTM") metric grid system is a worldwide geographical reference system, which, like latitude and longitude, provides a unique coordinate reference to any point on the earth's surface.[1] The paper which follows describes the UTM grid system and its important applications to and advantages for historic site research. To encourage some facility with maps—which is an important first step in understanding the grid system—the article is introduced with the concepts of topography and map scale.

"Topography" takes its derivation from two Greek words, "topos" (meaning "place") and "graphos" (meaning "record"). Consequently, a "topographic map"—literally a "record of the place"—is "a detailed representation on paper of natural *and artificial* features."[2] Popular misconceptions to the contrary, a "topo map" is not simply a map using contour lines to show elevations above sea level; the identification of buildings, railway lines, civil boundaries, and other artificial and natural features are also important elements of topography.

In its fullest applications, the topographic survey is an inventory of all cultural and natural resources commensurate with the scale of the map. Although historic material is not always given a prominent place, topographic maps frequently note abandoned canal or railway routes and established historic sites. Less directly, contour and fence lines, limits of vegetation, and other map features will often provide evidence of the past use of a site.

Topography is a very integral part of archeology—whether above or below ground. Like topography, archeology provides a record of a place—a place that is drawn, photographed, and studied, not in isolation, but in the social and topographical context of its surroundings. To the archeologist the topographic map should be an indispensable tool: it aids him in finding a site; it allows him to study a site within the context of the natural and artificial features affecting and affected by it; and it allows him to record the location of a site for his future study and for permanent record.

The degree of detail on a topographic map is usually defined by the scale of the map. Scale is the relationship between "ground distance" and "map distance." This is represented most obviously by the simple statement "1 inch equals 2,000 feet." A more convenient form, and one not limited to conventional units of measure, is the representative fraction, written as a fraction (e.g., 1/24,000), or now more usually as a proportion or ratio (1:24,000). Both examples explain that one unit of map distance is equivalent to 24,000 of the same units on the ground. In other words,

1 inch = 24,000 inches = 2,000 feet
or
1 cm = 24,000 cm = 240 meters

[1] A number of people have very kindly agreed to review informally the text and offer their comments. Among those to whom I am particularly grateful are Alden Colvocoresses and Bill Jones of the USGS Topographic Division; David Bouse of the Canadian Office of Restoration Services, Dept. of Indian and Northern Affairs; and Wilford Cole of the National Park Service's Office of Archeology and Historic Preservation.

[2] Emile D. Chevrier and D. F. W. Aitkens, *Topographic Map & Air Photo Interpretation* (Toronto, 1970), p. 3. (Emphasis added.)

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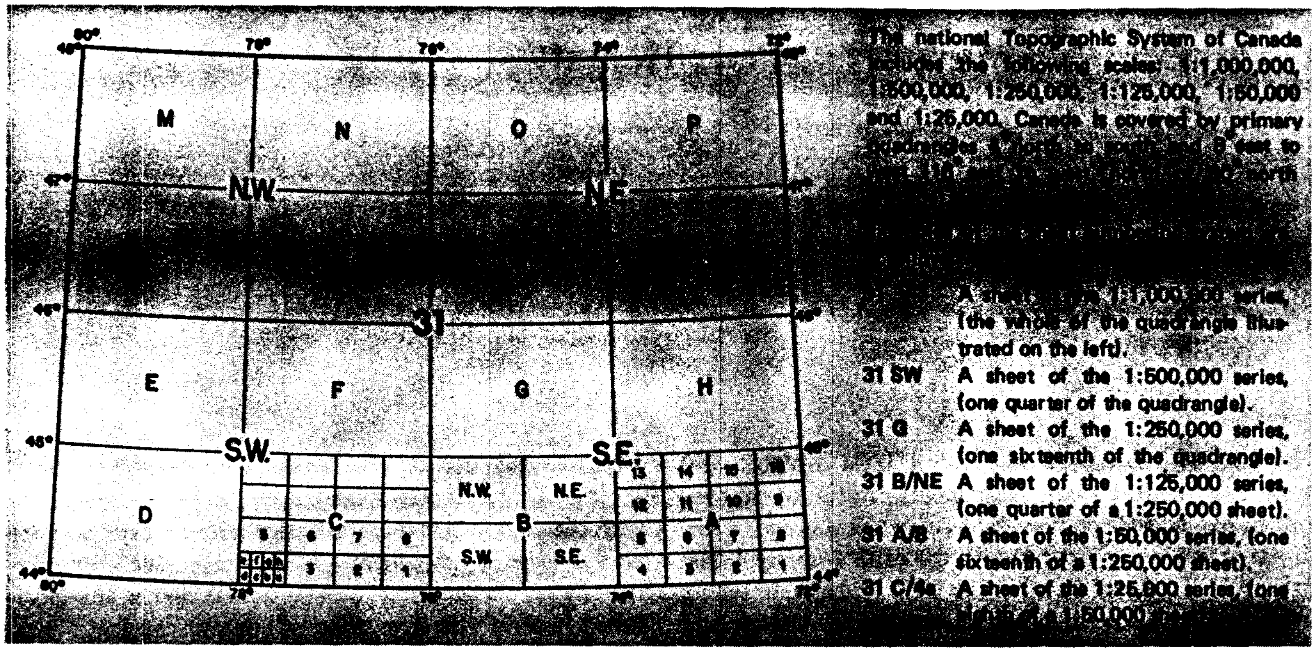


Figure 1. *Sheet numbering system of Canadian "NTS" maps. (From L.M. Sebert,* Every Square Inch. *Courtesy of the Surveys & Mapping Branch; Energy, Mines & Resources Canada)*

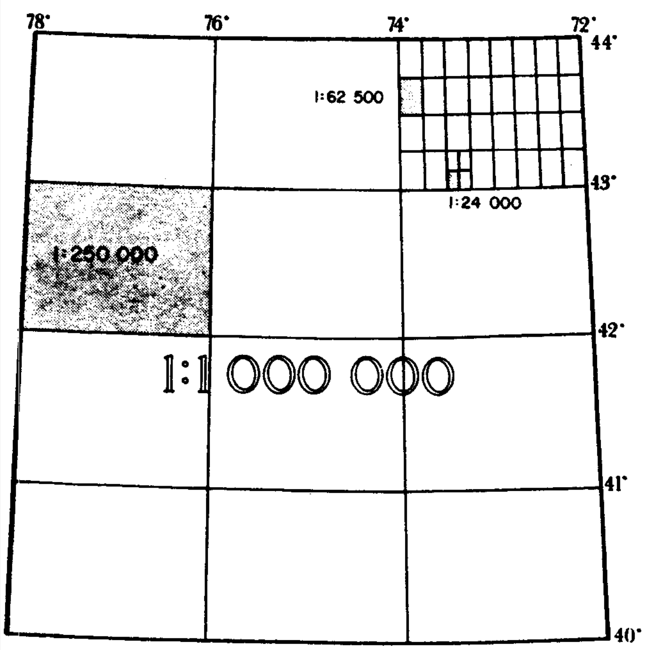


Figure 2. *Relationship of principal map scales in the National Topographic Map Series of the U.S. Geological Survey.*

- *1:1,000,000 International Map of the World series, 6° x 4°*
- *1:250,000, 1/12th of the IMW series, 2° x 1°*
- *1:62,500, 1/32nd of the 1:250,000 series, 15 minutes on a side*
- *1:24,000, 1/4th of the 1:62,500 series, 7.5 minutes on a side*

Small-scale maps (those which depict a large portion of the earth's surface) include the 1:1,000,000-scale International Map of the World[3] (about 16 miles to the inch); and 1:250,000-scale maps (about 4 miles to the inch), the largest scale at which both Canada and the U.S. are completely mapped. Most large-scale mapping in Canada is at 1:50,000 (about .8 miles to the inch). At this scale most of the country's settled areas have been completely covered, as well as certain strategic areas of the far north. Mapping at a scale of 1:25,000 is limited to densely settled areas.[4] Figure 1 portrays the system of sheet lines used in Canada's National Topographic System (except in the far north), based on quadrangles 8 degrees wide by 4 degrees high.

In the continental U.S. the equivalent mapping scales are 1:62,500 (about 1 mile to the inch) and 1:24,000 (1 inch = 2,000 feet). Maps at the smaller scale are 15 minutes (one quarter of a degree) on a side; larger-scale maps at 1:24,000 are 7½ minutes on a side. These "quadrangles" are usually

[3] The "IMW" is an international map series first proposed in 1891 by the German geographer Albrecht Penck (1858-1945) to map completely the land areas of the world to internationally controlled cartographic standards at a scale of 1:1,000,000. The program is today administered by the United Nations Cartography Section. North American maps in the series may be obtained from the agencies discussed below; most others may be obtained through the Defense Mapping Agency Topographic Center, 6500 Brooks Lane, Washington, D.C. 20315.

[4] L.M. Sebert, *Every Square Inch: The Story of Canadian Topographic Mapping* (Ottawa, 1970), p. 12.

designated as being either 7½-minute or 15-minute. Figure 2 illustrates the relationship between these two scales and the smaller scales.

In the United States the agency charged with the production of a topographic survey is the U.S. Geological Survey.[5] Large-scale topo maps are available directly from the USGS for $1.25 each (and from many booksellers and stationers for somewhat more). The USGS Branch of Distribution for maps east of the Mississippi is at 1200 South Eads Street, Arlington, VA 22202; the branch for maps west of the Mississippi is at Federal Center, Building 41, Denver, CO 80225. State indexes to mapping (gratis) may be ordered from either office.[6]

In Canada the corresponding agency is the Surveys and Mapping Branch (Dept. of Energy, Mines, and Resources). Public inquiries and sales are handled though the Canada Map Office, 615 Booth Street, Ottawa, Ontario K1A OE9. Prices range from 75 cents to $1.50 for large-scale maps. Index maps (gratis) are arranged according to lines of latitude and longitude; requests should specify the locality desired.[7]

Referencing systems–the way of communicating a particular location–may take any number of forms. A street address is one form; so is an atlas or road-map grid, by which, for example, the reader is referred to "A-3." Much of the U.S. and Canada is covered by a series of township and range lines developed for the disposition of government lands; these lines are still widely used as a referencing system. Various organizations have developed other systems.

For practical reasons, however, we limit the discussion which follows to those systems compatible with all topographic maps.[8] These include non-cartographic systems such as street addresses (e.g., 31 Mulberry Street) or landmark orientation (1500 feet west of the railway station). The disadvantage of these systems is that they provide convenience and precision only in proportion to the user's familiarity with the area. These systems are also virtually impossible to standardize either for computerization or general inventory purposes.[9]

On U.S. topographic maps[10] there are three cartographic referencing systems in general use: geographic coordinates, in degrees, minutes, and seconds; state plane coordinates, in units of feet; and UTM coordinates, in metric units. Modern Canadian topographic maps show geographic coordinates and full UTM grid.

Geographic, or spherical, coordinates were a direct consequence of the first attempts to visualize the shape and size of the earth. Eratosthenes (c.276-195? B.C.), Curator of the Library at Alexandria, is generally credited with their first application, later refined by the 2nd-century A.D. geographer Ptolemy.[11] In principle the system of geographic coordinates is the simplest of systems since its three-dimensional network of grid lines (the "gratticule") conforms neatly to the shape of the earth. But even aside from the ancient problems associated with transferring a global image to a plane surface without distortion, the non-rectilinear configuration of the grid makes the coordinates unwieldy both in computation and in print.

The state plane and UTM coordinate systems are both examples of a two-dimensional rectangular grid of evenly spaced lines superimposed on a map surface. Every point on that surface then has an identity determined by its distance from two major "axes." This concept, sometimes called Cartesian coordinates after its inventor, the philosopher/mathematician René Descartes (1596-1650), is now a familiar feature of elementary mathematics.

The development of the present plane coordinate system coincided with the development of long-range artillery.

[5] The term "Geological Survey" may be misleading. Although the organization was founded in 1879 to facilitate the exploration of mineral and water resources, it was quickly realized that a topographic survey should take precedence, and today, of the various mapping programs undertaken by the Survey, the National Topographic Mapping Program is by far the most extensive.

[6] A request for "Special Handling" generally assures a response within one week.

[7] Four to six weeks should be allowed for delivery.

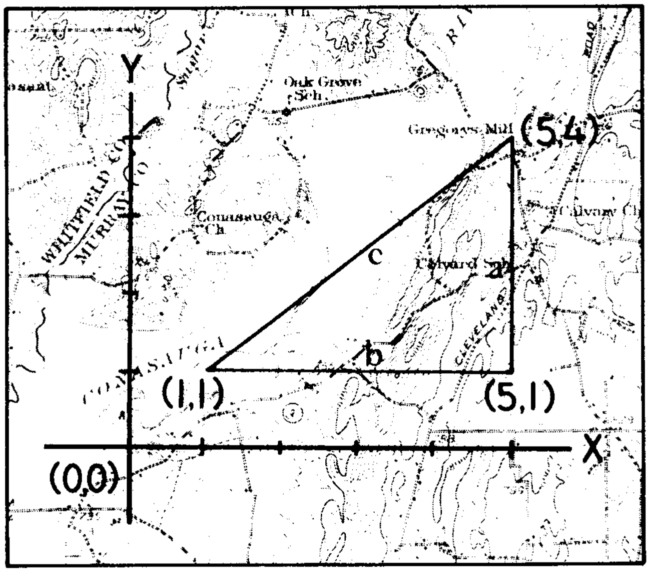
[8] For an examination of other referencing systems see Alden P. Colvocoresses, "A Unified Plane Co-ordinate Reference System" in *World Cartography* 9 (1969): 9-65. This article provides a very thorough argument for the use of plane coordinate systems by national topographic surveys throughout the world.

[9] An exception to this statement, David Bouse has pointed out to me, is provided by the "geocode" of the Canadian Inventory of Historic Buildings. Fifteen digits are used to break down a site's location according to province, town, street, and number according to an intricate coding scheme. The system has also been adapted for rural sites, with a corresponding increase in complexity.

[10] The Canada Map Office has for some years given the UTM a prominent place on its maps and in its publications. See particularly Sebert, above.

[11] G. C. Dickinson, *Maps and Air Photographs* (London, 1969), pp. 2-3.

Figure 3. *Plane coordinate axes laid out over topographic map detail. Distance "c" computed from Pythagorean Theorem as* $\sqrt{(5\text{-}1)^2 \text{ x } (4\text{-}1)^2} = 5$.



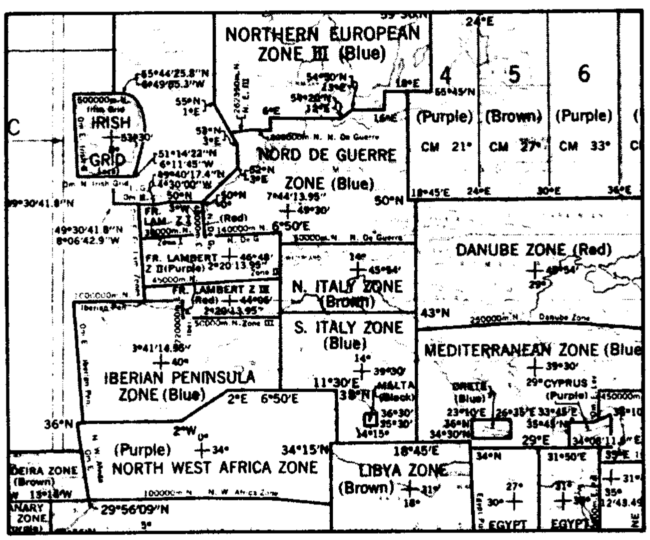


Figure 4. *Plane Coordinate grids in use during World War Two.*[14]

Until World War I, heavy ordnance was generally aimed by a system of trial and error known as "shooting in." In 1914 the use of the "French 75" with a firing range of 5 miles made this impossible; it was no longer possible to see the target.[12] Using the geographic coordinates of the gun and the target to determine distance and angle proved excessively complicated and time-consuming, and the French General Staff turned to rectangular coordinates. By superimposing a plane coordinate grid on military field maps, each point could be given coordinates which expressed its horizontal and vertical distances from the origin of the grid. (See figure 3.) Using the Pythagorean Theorem (that the square of the hypoteneuse was equal to the sum of the squares of the other two sides), it was a simple matter to determine the distance between any two points on the grid. The angle of fire could be determined from elementary trigonometric functions. The grid developed by the French General Staff became famous as the *Nord de Guerre* and was in service until the end of World War II.

With high expectations, similar grids were proposed for civil use after the war. Suggested one geographer in 1924:

> The ordinary citizen will not get use to it all at once of course, and he may even look askance at it to begin with. It will be some time, I think, before the soldier can with confidence invite his young lady to meet him at 206.793 at 2020 hours. But that will come in time.[13]

The problem with rectangular grids, however, was that it was impossible to extend a grid very far without creating serious distortion in the planar grid over the curved surface of the earth. (Try wrapping graph paper around a grapefruit.) So a multitude of grids proliferated, and by the opening of World War II, the medium and small-scale maps of Europe were a mass of conflicting grids (figure 4). At the conclusion of the war the U.S. Army Map Service assembled

[12] Jacob Skop, "The Evolution of Military Grids," *The Military Engineer* 43 (1951): 15-18.

[13] Sir John T. Burnett Stuart, at a session of the Royal Geographical Society "The Choice of a Grid for British Maps," *Geographical Journal* 63 (1924): 105. At another meeting in 1933 an advocate confidently predicted the day when grid references would be on everyone's notepaper and visiting cards. The noted geographer A. R. Hinks suggested that the time was not far off "when every lamppost in London would have on it its rectangular coordinates, so that if one was lost in a fog or anything of that sort, one would be enabled to discover one's exact locality." *(Geographical Journal* 82 [1933]: 43-44, 51.)

[14] From "Index of American and British Mapping, March 1945." U.S. Army Map Service, *Grids and Magnetic Declinations. AMS Memorandum 425* (4th ed., Washington, D.C., 1945).

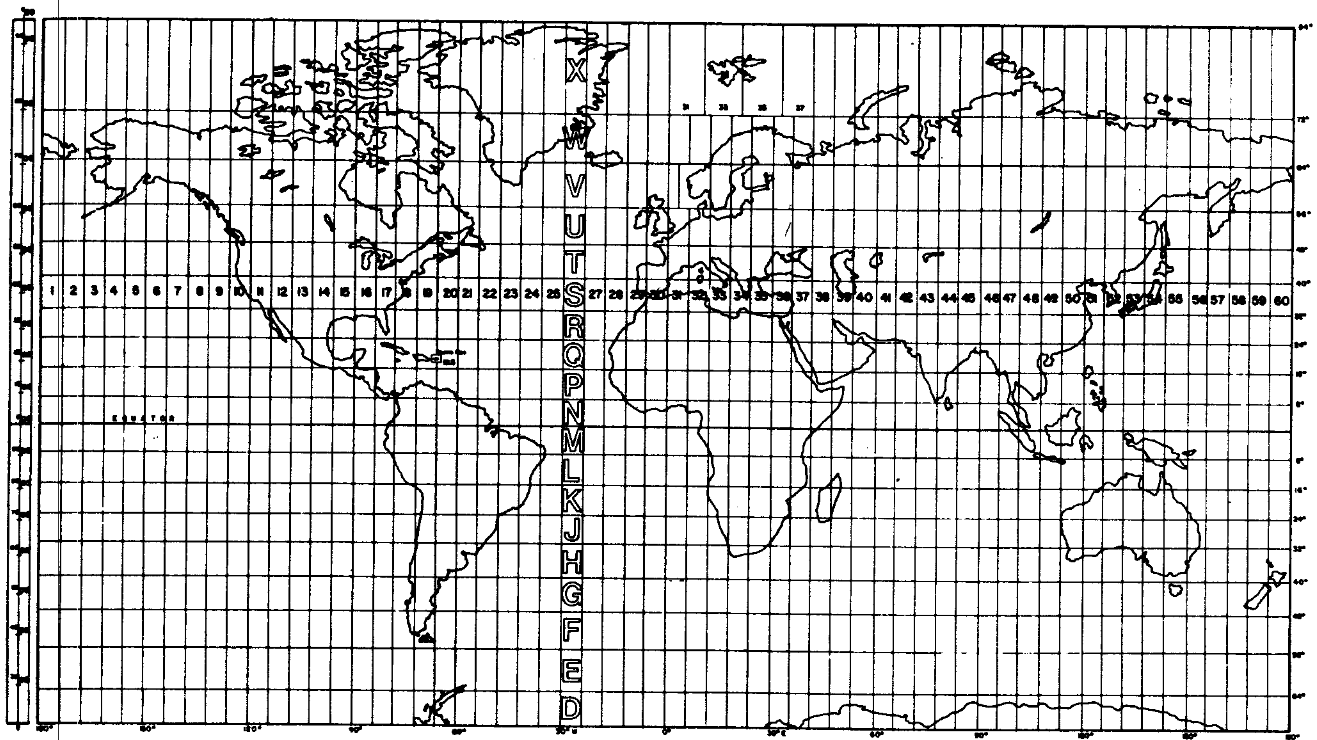


Figure 5. *Map of the world showing zones and rows. An additional zone is shown at left marked with the 500-km central meridian and 1000-km ticks.*

a task force to examine and evaluate all grids then in use and make recommendations for a single unified system. Their recommendation, now adopted by most of the world for military purposes, was the Universal Transverse Mercator grid system, based on the international unit, the meter.

The U.S. experience followed a similar pattern. At the end of the first World War, a yard grid using overlapping zones was established for military maps of the U.S. It was not until the 1930s, however, that civil grids were established. The foot grid developed by the U.S. Coast & Geodetic Survey was not quite as rational as the Army grids. Separate zones were established for each state, and it often happened that some states had three, four, or sometimes five distinct zones. While these state plane coordinate grids provided a perfectly acceptable way for local surveyors to tie in to the national triangulation, the use of the myriad irregular grids was unacceptable for national or international use, where the maps usually cross many of these grid zones. The state foot grids are still in wide use, though the UTM has entirely replaced the old yard grid.

The smallest-scale map in general use was the Millioneth-Scale International Map of the World. To keep zone lines from appearing on this series required that the zones be at least 6 degrees in width, the width of the IMW sheets. This meant that 60 zones were required to circle the earth completely. The zones also took over the numbering of the IMW sheets, with Zone 1 at the International Date Line, and progressing eastwardly around the world until reaching Zone 60 on the other side of the date line. Figure 5 illustrates this progression of zones. Zone 18, for instance, between the 72-degree and 78-degree meridians, covers much of the U.S. east coast and Ontario. Because the grid system, based on the Transverse Mercator map projection, covered the entire earth (except for the polar zones), it was called the Universal Transverse Mercator grid system.[15]

How It Works

Like the simple geometric X and Y axes alluded to above (and in figure 3), each grid reference has both an X coordinate (the "easting") and a Y coordinate (the "northing").

[15] The grid was established only for the non-polar regions. North of the 84° N parallel and south of the 80° S parallel the Universal Polar Stereographic (UPS) Grid is used. The only major land mass to which the UPS is applicable, however, is Antarctica. It is discussed in full in the U.S. Army's Field Manual, *Map Reading* (FM21-26), available from the U.S. Government Printing Office, Washington, D.C. 20402.

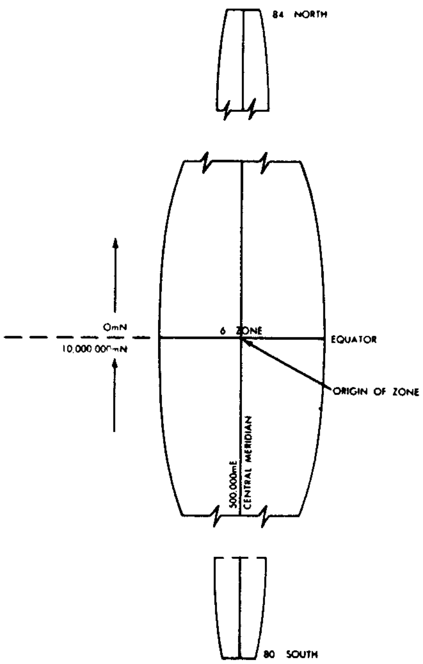


Figure 6. *A grid zone illustrated with reference to its major axes, the equator and a central meridian. At the equator each zone is approximately 668-km wide. (From U.S. Dept of the Army Field Manual,* Map Reading, *(FM 21-26)*

Delaware Aqueduct, Lackawaxen, Pa. (1847-1848). The longest of the four suspension aqueducts built by John A. Roebling for the Delaware & Hudson Canal Co. (SHOHOLA, PA 012921). (Library of Congress photo by Jack E. Boucher for the Historic American Engineering Record, April 1971)

The origin of each zone's grid is on the equator on the central meridian of each zone. Because this would mean that references to the left or below the axes would have at least one negative number for a coordinate, the central meridian was given an arbitrary value of 500 kilometers (500,000 meters). In the northern hemisphere the equator was given a value of 0 km; in the southern hemisphere it assumed a 10,000-km value. Thus coordinates to the left of the central meridian would have a value less than 500 km, while those to the right would have a value greater than 500 km.[16] (See figure 6.) Because the central meridian and the equator are the major axes of the grid, they are also the *only* grid lines which coincide with meridians and parallels. For example, the central meridian of Zone 18 is the 75-degree meridian.[17]

Now turn to figure 7, a corner from a U.S. Geological Survey quadrangle. In one corner is a grid reference box, which schematically diagrams the process of determining a grid reference. It has been devised for this example for the sake of clarity, but it is absent from most USGS maps. It is frequently included, however, wherever grid lines are printed in full, as in Canada. On the large scale maps of the U.S. and Canada (1:24,000 and 1:25,000 scales) grid lines are each one kilometer apart (1000 meters, or approximately 3280 feet). Where they are not shown in full, grid lines are located in the margin by blue "tick" marks. UTM figures labeling the ticks or grid lines are composed of one or two small superscript digits (called "anterior digits") and usually two "principal digits."[18]

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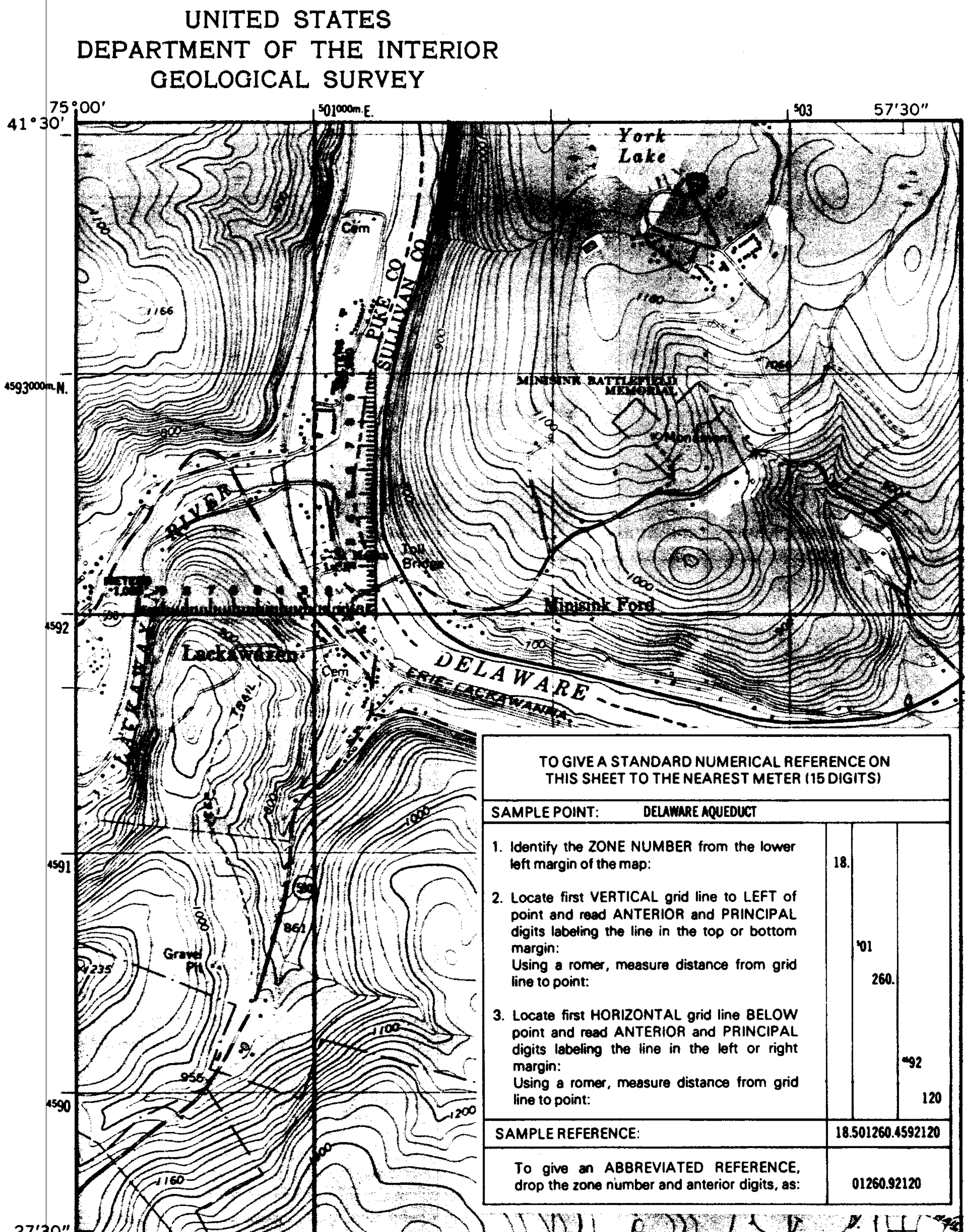
[16] Some values of course are impossible. The maximum width of a zone (at the equator) is approximately 668 km, giving a maximum range of approximately 165 to 834 km. A noticeable exception is when the width of a zone is artificially broadened. The New York State Transverse Mercator System is an example of such a zone extension, in use on maps issued by the State Department of Transportation. Though western New York normally lies in zone 17, to keep the state entirely within one zone, the grid lines of zone 18 were simply mathematically extended to the western edge of the state. Consequently, all grid lines and grid coordinates west of the 78-degree meridian on NY DOT quads bear no useful relationship to standard UTM coordinates.

In certain circumstances, maps will show two or more zones, sometimes overlapping. When determining coordinates under these circumstances, it is important to choose the grid zone in which the site would *normally* fall. Otherwise the reference will not be easily adaptable to all map series.

[17] This particular central meridian happens to be the west edge of the SHOHOLA, PA quadrangle (figure 7). The figure $^{5}00$ is not shown on the quad because of congestion at the corner, but the figure $^{5}01$ is exactly one kilometer east.

The material in this paragraph is thoroughly and clearly discussed in *Map Reading* (note 15).

[18] It is the practice of U.S. and Canadian map agencies (and many others as well) to give the full meter readings–6 or 7 digits–only at the northwest and southeast corners of the map. In addition, grid ticks are unlabeled where the digits would conflict with other lettering.



TO GIVE A STANDARD NUMERICAL REFERENCE ON THIS SHEET TO THE NEAREST METER (15 DIGITS)	
SAMPLE POINT: DELAWARE AQUEDUCT	
1. Identify the ZONE NUMBER from the lower left margin of the map:	18.
2. Locate first VERTICAL grid line to LEFT of point and read ANTERIOR and PRINCIPAL digits labeling the line in the top or bottom margin:	501
Using a romer, measure distance from grid line to point:	260.
3. Locate first HORIZONTAL grid line BELOW point and read ANTERIOR and PRINCIPAL digits labeling the line in the left or right margin:	4592
Using a romer, measure distance from grid line to point:	120
SAMPLE REFERENCE:	18.501260.4592120
To give an ABBREVIATED REFERENCE, drop the zone number and anterior digits, as:	01260.92120

Figure 7. *A corner of the U.S. Geological Survey 7.5-minute quadrangle SHOHOLA, PA (1965 edition, photo revised 1973). Thousand-meter grid lines have been added. The Delaware Aqueduct is marked by the words "Toll Bridge."*

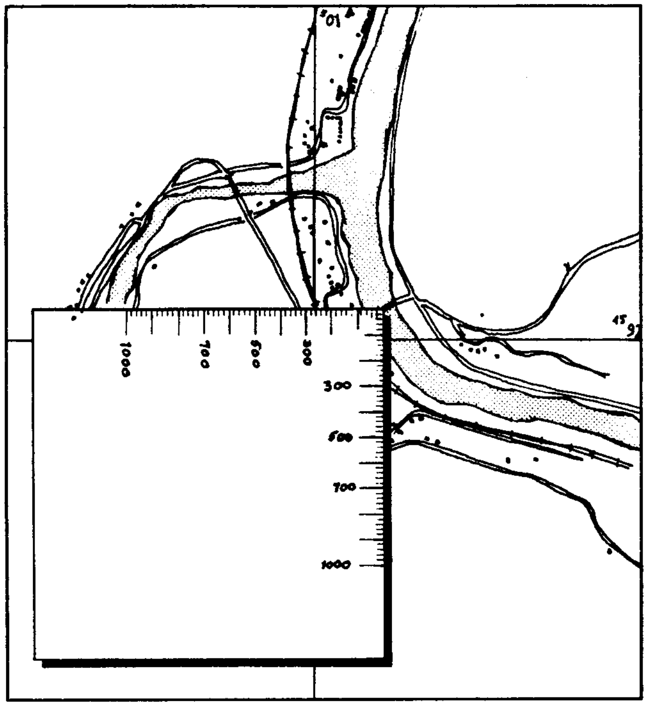


Figure 8. *Use of a handmade paper romer to determine coordinates to the nearest meter.*

Date	County	Quadrangle	Grid Reference
1867	Albany	ALBANY	98330/20860
1870	Columbia	CLAVERACK	04880/74230
c.1860	Fulton	PECK LAKE	50370/60980
?	Lewis	BRANTINGHAM	70080/33080
?	Lewis	PORT LEYDEN	70195/20075
1869	Montgomery	RANDALL	50110/55860

Known Surviving Examples of Bowstring-Truss Bridges Following the 1841 Whipple Patent (All New York State)

Figure 9. *Example of abbreviated references used in an inventory of Whipple Bowstring-Truss Bridges.*[21]

In the example illustrated by figure 7 we wish to determine the grid reference for the Delaware Aqueduct, built by John Roebling for the Delaware and Hudson Canal, 1847-1849. To do so we must identify the southwest corner of the kilometer square in which the aqueduct lies. This corner is bounded by the grid lines labeled $^{5}01^{000\text{m.}}$ E. (501,000 meters east of the "false" origin of the zone's grid) and $^{45}92$ (4,592,000 meters north of the origin). Horizontal coordinates (the eastings) are always read first, followed by the vertical (northing) coordinates. The military mnemonic expression is **"read right-up."**[19]

It then simply remains to measure the distances north and east from the grid lines to the point and add these values to those of the grid lines. This may be done either by estimation (using the metric scale in the margin as a guide) or by measuring. The grid reference box in this example uses a measured distance. To measure the distance accurately requires a tool called a "romer." Transparent romers are available commercially,[20] but they can also be very simply drawn on the corner of a 3x5 card. To use a romer, place the upper right corner on the point whose reference is to be determined and read the values where the romer crosses the grid lines. (See figure 8.)

The coordinates are then assembled into a full numerical grid reference by separating the two parts with a decimal point (sometimes a slash), and prefixing the pair with the zone number, derived from the bottom left-hand margin of the map—e.g.,

zone easting northing
18.^{5}01260.^{45}92120

It is this 15-digit form that is at the moment most common in the U.S., having been adopted by the National Park Service's Office of Archeology and Historic Preservation as well as each of the State Historic Preservation Offices. It is difficult, however, to determine from the grid reference the approximate location or map name, and there is a variety of established means of including this information and shortening the grid reference. In the abbreviated form noted in the grid reference box, both the zone number and the anterior digits have been dropped—e.g.,

~~18.5~~01260.~~45~~92120

[19] *Map Reading* (note 15), p. 12.

[20] They are available for $5.25 each from the Keuffel & Esser Company, 1521 North Danville Street, Arlington, VA 22201 (Attn: Vince Cascio), with discounts for bulk orders. The romer was named after its inventor, Capt. Romer of the British army.

[21] From Chamberlin, W.P., "History of Road and Bridge Building Technology in New York State," A Report of Progress on Research Project 80-14 through March 31, 1975, Engineering Research & Development Bureau, NYS DOT, Albany; and from Division for Historic Preservation, NYS OPR.

Although this figure is not unique,[22] it is a very useful form for local inventories or other circumstances where the quadrangle name or approximate locality is known. (See figure 9.) By prefixing this reference with the quadrangle name, uniqueness is restored, with the added advantage of the map name built into the grid reference—e.g., SHOHOLA, PA 01260/92120.

For large unmistakable structures, an estimated reference to the nearest 100 meters is sufficient, shortening the grid reference still further. Following the practice of the alphanumeric form (see below), short references are usually run together—e.g., SHOHOLA 012921. Similarly, a reference to the nearest 1000 meters would be only 4 digits long (SHOHOLA 0192).[23]

Alphanumeric Form

The above descriptions outline what is known as the numerical or "civilian" form of grid reference. However, the recommendation of the Army Map Service, and the form adopted by military and many civilian mapping agencies (including the Canada Map Office), is the alphanumeric, "military" form of grid reference. In this usage the abbreviated reference is run together without break and prefixed, not by the map name, but by a letter code derived from the anterior digits. The grid reference box on each map indicates the correct letter codes (figure 10). Each pair of letters designates a square 100 kilometers on a side.[24] The zone number is retained and followed by a "row number," designating one of several strips, each usually eight degrees in latitude as shown in figure 5.

Thus translated, the military grid reference for the Delaware Aqueduct would be 18T WA 01260/92110 (though the standard grid reference box would give only the estimated reference to the nearest 100 m, 18T WA 012921).

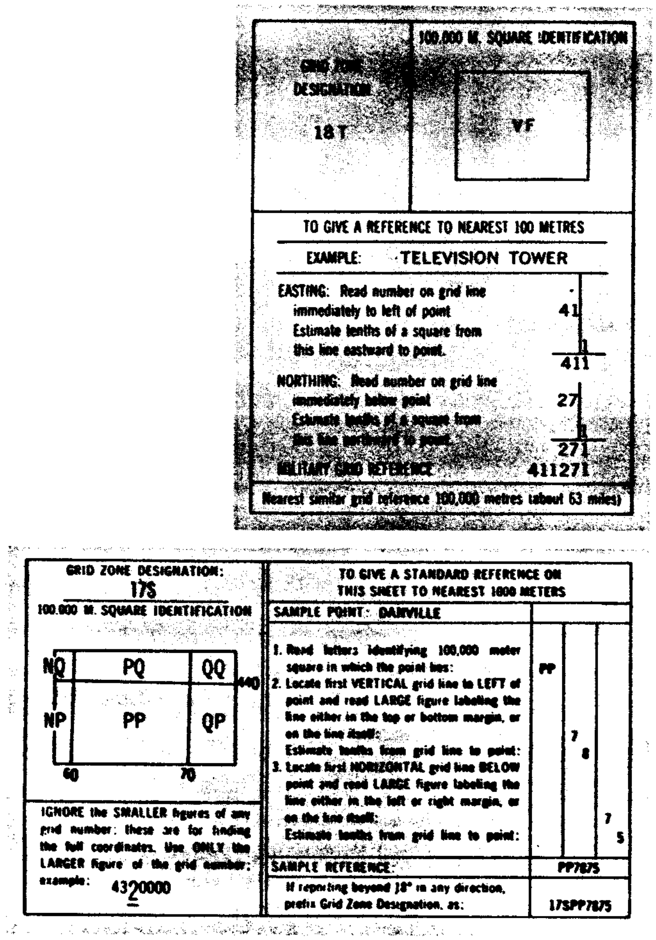


Figure 10. *Grid reference boxes used (above) on the Canadian 1:50,000 series and (below) on the U.S. 1:250,000 series. Both examples use the alphanumeric form of grid reference. Note that the right example, covering a much larger land area than that on the left, uses grid lines that are 10 km apart. The lines are indicated by coordinates with* single *principal digits* ($^{43}2$, $^{43}3$) *instead of the more usual double digits* ($^{43}20$, $^{43}30$).

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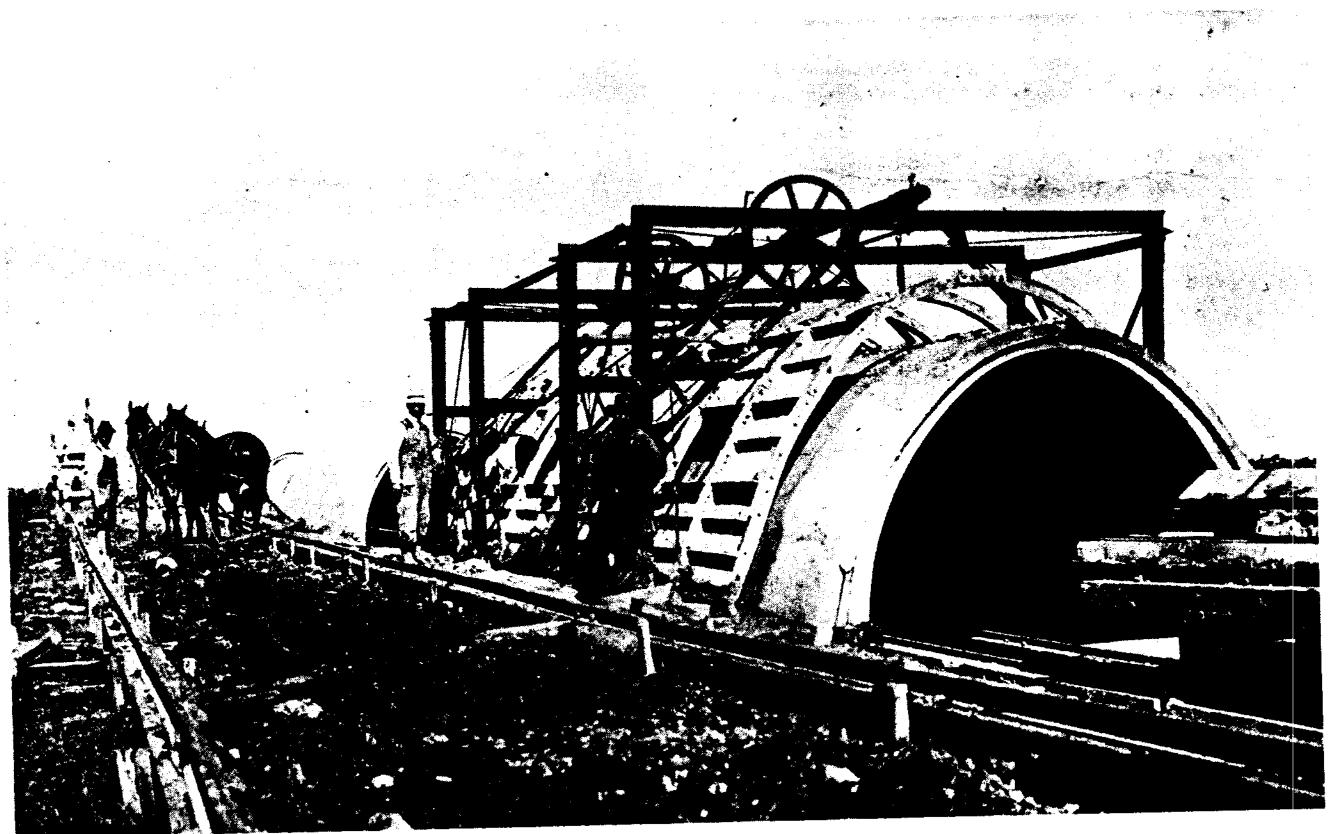
[22] This grid reference will be repeated at 100-kilometer intervals (about every 62 miles) in four directions.

[23] This is often the best estimated accuracy obtainable on a medium-scale map series, like that at 1:250,000. Figure 10 shows a grid reference box at that scale.

[24] The first letter is derived from the easting anterior digit; the second from the northing anterior digits. The appendix gives instructions for calculating one form from another.



Construction of the Winnipeg Aqueduct, Shoal Lake to Winnipeg, Manitoba (1913-1919). The Water District Railway paralleling the water-supply aqueduct was completed in 1914 for construction and maintenance of the aqueduct, which is 110 miles in length [EAST KILDONAN (62H/14h) 368278 to WAUGH (52E/11 east) 414987]. (Photo courtesy of Canadian Engineering Heritage Record)

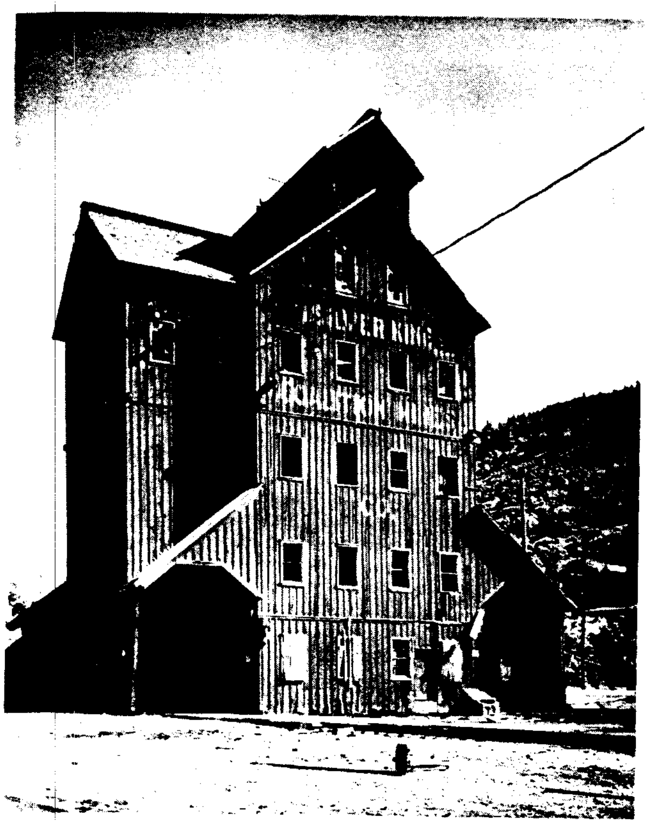
Who Should Use Grid References and Why

The universal use of a grid reference system is an important element in furthering public awareness of industrial archeology, and indeed of historic sites in general. Journal or newsletter articles may proliferate about a site but the greatest obstacle to public visitation (and hence a demonstrable popular preservation cause) is the lack of a precise location. All have experienced the frustration of trying to locate a relatively obscure site in a small town, and spending perhaps half a morning wandering local roads. Unfamiliar territory is made no more familiar by the addition of a street name.

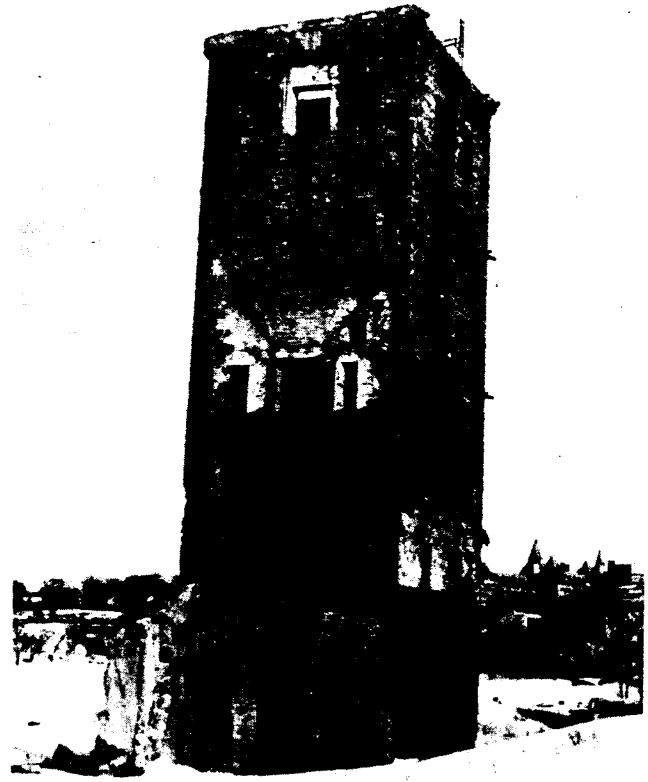
Now, provided with a grid reference and map (even the 1:250,000-scale is often sufficient, and these can be purchased for large areas of the country without enormous expense), the enthusiastic archeologist can head directly for the Coke Ovens of Cascade, WV (MASONTOWN 010795), the ruins of the Harmony Borax Works in Death Valley, CA (FURNACE CREEK 113370), or the Baillie-Grohman Canal in Canal Flats, British Columbia (CANAL FLATS 82J/4W840554).[25]

Here, then, is a popular need. But the need is equally present for professional historians and archeologists. The site (an artifact located in space) is the primary document of a particular aspect of cultural history. As such it demands the same rigorous documentation given to a primary bibliographic source. A precise grid reference guarantees that when all other landmarks have been demolished, hills laid

[25] Those who collect topographic maps for field trips and other uses may find a 4-hole, 14-inch ring binder convenient, an idea for which the author is indebted to the SIA's Robert M. Vogel, Curator of Mechanical and Civil Engineering, Smithsonian Institution. Quadrangles for northern latitudes will conveniently fit if trimmed, cut in half horizontally, and each half folded. The 1:250,000-scale maps may also be stored in this fashion, though the cut should be a vertical one.



Silver King Coalition Mines Co. Ore Loading Station, Park City, Utah (1900-1901). Terminus for an aerial tramway which transported silver ore from the Silver King mine to tracks of the D&RGW RR in Park City (PARK CITY EAST 579995). (Photo by Jack E. Boucher for the Historic American Engineering Record, August 1971)



E.B. Eddy Digester Tower, Hull, Quebec (1901). Possibly the first vertical digester applied to the sulphite pulping process, permitting the economical manufacture of a higher quality paper [OTTAWA (31G/5) 446305]. (Photo courtesy of Canadian Engineering Heritage Record)

plain, streets discontinued, and buildings replaced, the site is still retrievable.

With these thoughts in mind, the following guidelines are proposed for citing grid references of U.S. and Canadian sites:

For the main subject of a journal article:

Topographic map name + full grid reference to nearest meter

SHOHOLA, PA 18.501260.4592120
CANAL FLATS, BC (82J/4W) 11U NF 84000/55400

For less important sites in the same article, newsletter references, and photograph indentifications (where not mentioned in text):[26]

Topographic map name + abbreviated estimated reference to nearest 100 meters

SHOHOLA, PA 012921
CANAL FLATS, BC (82J/4W) 840554

USGS topographic maps should be cited by name only; Canada Map Office maps should include the map number in parentheses. Where the locality is the same as the map name, and has already been mentioned in the text, the map name need not be repeated in giving a grid reference.

Full grid references should be placed in footnotes, but abbreviated references may often be conveniently placed within the text in parentheses.

In April 1975 the U.S. Geological Survey announced that in the future all maps at scales of 1:1,000,000 (the IMW) and larger would carry a full fine-line UTM grid. The grid has already appeared on specialized maps and many of the 1:250,000-scale maps. However, it will be some time before

[26] Not all sites mentioned in an article need be referenced, of course. It will generally be unnecessary to reference familiar landmarks, noted only in passing.

each large-scale map can be reprinted. Some old quadrangles printed before 1959[27] and all of them published before 1953 lack the blue UTM ticks. In this case there are several possible remedies. The easiest solution is to determine the coordinates of the corners of the map using the U.S. Army's Technical Manual TM 5-241-11, "Coordinates for 7½-minute Intersections," and by having those, establish the location of critical ticks. Coordinates may also be determined directly from geographic coordinates by using Technical Manual TM 5-241-4/1, "Transformation of Coordinates from Geographic to Grid."[28]

There are areas of the U.S. and Canada where no large-scale mapping has been completed. Although 1:250,000-scale maps will exist for the area, that scale may well be insufficient. The next-best resource is generally the state or provincial mapping agencies. In the U.S., "General Highway Maps" are published by each state's transportation or highway department under federal guidelines, usually at a scale of 1:62,500 on a county-by-county basis.[29] Some states also publish other map series and inquiries should be directed to those offices.

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[27] The printing date of a map is marked in the lower right hand corner, just below the neatline (the line bordering the map proper). The date included with the map name is the edition date.

[28] Both technical manuals are available from the U.S. Army A G Publications Center 1655 Woodson Road, St. Louis, MO 63114.

[29] Maps of the New York State Dept. of Transportation are an exception. That office produces USGS-based quadrangle maps in black and white at 1:24,000 and other scales, but see above, note 16.

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Appendix

Determination of 100-kilometer Square Designations for the UTM Kilometer Grid System

The designation for each 100-kilometer square is a two-letter combination determined from zone number and the anterior digits of eastings and northings. Using the tables below, it will be seen that an EASTING value of 500 km (i.e., anterior digit "5" in the top margin) in zone 18 will become "W." A NORTHING value of 4500 km in the same zone will become "A."

Like the full grid reference itself, the easting value must always precede the northing value; thus the 100-km square for the Delaware Aqueduct is designated by the two letter combination "WA."

Table A: Easting Values

Hundreds of km	*Zones: 7,10 13,16,19,11...*	*Zones: 8,11 14,17,20,23...*	*Zones: 9,12, 15,18,21,24...*
1	A	J	S
2	B	K	T
3	C	L	U
4	D	M	V
5	E	N	W
6	F	P	X
7	G	Q	Y
8	H	R	Z

Table B: Northing Values

Hundreds of km	*Even Nbr'd Zones*	*Odd Nbr'd Zones*
...	...	...
60	R	L
59	Q	K
58	P	J
57	N	H
56	M	G
55	L	F
54	K	E
53	J	D
52	H	C
51	G	B
50	F	A
49	E	V
48	D	U
47	C	T
46	B	S
45	A	R
44	V	Q
43	U	P
42	T	N
41	S	M
40	R	L
39	Q	K
38	P	J
37	N	H
36	M	G
35	L	F
...	...	...