

# Field Validation of the UTM Gridded Map

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## Abstract

Testing was conducted to evaluate the benefits of the UTM coordinate system and a fully gridded map for land-navigation and coordinate measurement tasks. Under field conditions, 20 of 22 test participants preferred the UTM coordinate system to the latitude/longitude (lat/long) system, and all participants favored maps with the full UTM grid to maps on which the grid is represented as marginal tick marks. A full UTM grid allowed coordinates to be measured quickly with a pocket-size coordinate reader to accuracies of approximately 10 m, as compared to 100 m when the map has only marginal UTM tick marks. In order to facilitate the integrated use of maps with GPS and GIS technologies, it is recommended that full UTM grids be printed on all 1:24,000-scale maps.

## Introduction

The most accurate large-scale base maps of the United States (with the exception of Alaska) are the U.S. Geological Survey (USGS) 7.5-minute, 1:24,000-scale topographic map series. Some 53,689 sheets are available for the contiguous 48 states and Hawaii and each year the USGS sells between three and four million copies of the 1:24,000-scale maps (J.T. Harman, personal communication, 7 July 1992; C. O'Brien, customer memorandum, 23 January 1996; C. O'Brien, personal communication, 15 November 1996). These maps are used by police and military organizations, resource agencies, developers, hunters, fishermen, planners, hikers, and other groups or individuals who require accurate spatial information.

A great benefit of the paper (or plastic) map is that it is inexpensive, is easily carried, and does not require a power supply. You can fold it, drop it, soak it, even shoot a hole through it, and still use it without undue difficulty. Paper maps when used in conjunction with a modern Global Positioning System (GPS) unit and compass, provide an integrated set of land-navigation tools. To efficiently utilize these tools, however, the map should be fully gridded in a standard rectangular coordinate system. The most widely accepted rectangular map coordinate system is the Universal Transverse Mercator (UTM) grid (Terry, 1996). This paper provides some recent background on the UTM gridding of the 1:24,000-scale maps, and describes tests conducted to evaluate the utility of gridded 1:24,000-scale maps for land-navigation/positioning tasks.

## Background

While acknowledging the need for continued use of coordinate reference systems such as latitude/longitude (lat/long), the State Plane Coordinate System (SPCS), and the Public Land Survey System (PLSS), in 1974 the USGS adopted the UTM grid as the preferred plane coordinate reference system (USGS, 1974a; USGS, 1974b). The UTM coordinate system was chosen because of its compatibility with future trends in mapping, its use of metric units, and its relatively small number of grid zones. Consequently, in 1975, the USGS began

adding a full fine-line UTM coordinate grid to the 1:24,000-scale map series. By July 1992, 13,567 quadrangles of the 1:24,000 map series (~25 percent) had been gridded (J.T. Harman, personal communication, 7 July 1992).

However, in 1992, at a time when both GPS and geographic information system (GIS) technologies were becoming fully integrated in mapping operations, the USGS reversed their decision of 1974 and began replacing full UTM grids on the 1:24,000-scale map series with marginal tick marks along the neat line. This decision was based on the reported concerns of the U.S. Forest Service (USFS) that the UTM grid lines caused clutter and confusion with PLSS lines when monochromatic reproductions of the lithographed quadrangles were used in western State operations. Unfortunately, the advantages of the full fine-line grid in survey, positioning, or land-navigation tasks involving GPS or GIS were largely overlooked.

After implementing this decision, a common complaint from the map user community was that the lack of a full UTM grid hindered the ability to quickly and accurately locate map positions. As a consequence, a study was conducted by the USGS to determine whether there is a significant difference in accuracy between UTM coordinate pairs determined without regard to speed from fully gridded maps and from tick-mark maps (Donato, 1994). This test, was conducted under *office conditions*, employing techniques that would not be available to map users in the field (K.C. Wortman, personal communication, 21 March 1996). Given that field use should be considered in the design of map products, and that the speed and ease of position location are important for many applications, the author of this paper undertook a field evaluation of fully gridded and tick-mark maps for land-navigation and coordinate measurement tasks.

## Evaluation of the UTM Gridded Map

A two-part testing program was developed to study the value of portraying the UTM coordinate system on maps as either full-line grids or ticks. It was also decided to assess the relative merits of lat/long coordinates for land-navigation tasks. The increased demand for spatial information for large-scale positioning has stirred discussions over whether UTM or lat/long coordinates are preferred by the user community (FCC, 1996).

### Test 1: Land Navigation

In Test 1, ten Marine Corps officers, highly qualified in conventional land navigation (i.e., without GPS), were given the UTM and lat/long coordinates for orienteering stations in Prince William Forest Park, near Quantico, Virginia. This Park is split by two USGS 1:24,000-scale quadrangles. The Quantico, Virginia quadrangle (1966 edition, photorevised

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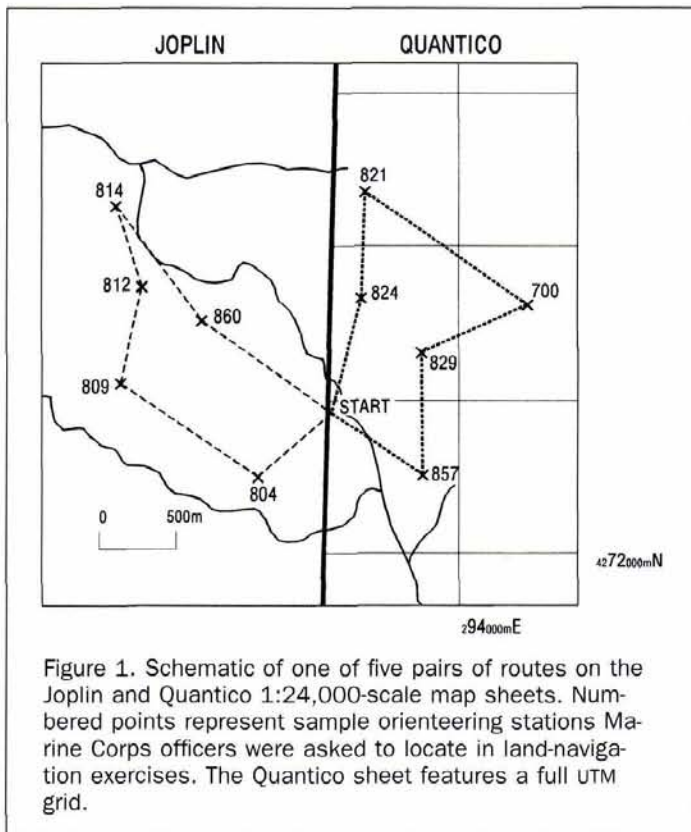


Figure 1. Schematic of one of five pairs of routes on the Joplin and Quantico 1:24,000-scale map sheets. Numbered points represent sample orienteering stations Marine Corps officers were asked to locate in land-navigation exercises. The Quantico sheet features a full UTM grid.

1983) is fully gridded, whereas the Joplin, Virginia sheet (1966 edition, photorevised 1971) has marginal tick-marks.

The locations of the orienteering stations were obtained using an AN/PSN-11 (military) GPS receiver which provided UTM coordinates to within  $\pm 10$  m of their true position using the Precise Positioning Service. These stations were located within an area of approximately 3 by 4 km spanning both maps. Five separate routes of five stations each were developed for each of the two maps. A typical pair of routes (each about 5 km in length) are depicted in Figure 1. Two officers were assigned to each pair of routes, that is, a route on the gridded map (Quantico) and a route on the tick-mark map (Joplin). One officer of the pair was given the orienteering station positions in UTM coordinates and the other officer was provided with lat/long coordinates for the same course. The first officer of the pair (using UTM coordinates) was asked to undertake the course on the gridded map (Quantico) in a 4-hour morning session and locate the five orienteering stations shown (see Figure 1). He was asked to run the companion course on the tick-mark (Joplin) sheet in the afternoon. His teammate (using lat/long coordinates) was asked to run the tick-mark map course in the morning and the gridded map course in the afternoon.

Before undertaking the courses, the officers were provided with the Quantico and Joplin map sheets. Those asked to use lat/long coordinates with a fully gridded map were furnished sheets on which the 2.5-minute graticule tick marks had been connected to create a lat/long "grid." A USGS lat/long interpolator was issued to test participants conducting routes on the lat/long gridded map sheets, and a USGS CR-2 grid reader was provided to the officers working with UTM coordinates.

As shown in Table 1, under actual field conditions, maps with a full grid significantly increased the probability of finding point locations. Correspondingly, the uncertainty of attempting to estimate point locations from marginal tick

marks is clearly evident. All but two of the participants preferred to use the UTM coordinate system for land-navigation tasks. All participants preferred fully gridded maps to those with tick marks.

#### Test 2: Measurement of Map Coordinates

Test 2 sought to quantify the ability of people to precisely measure coordinate values when using simple tools that might be available for field use with maps having (1) a full lat/long "grid," (2) a full UTM grid, or (3) UTM ticks. The 1:24,000-scale Vienna, Virginia quadrangle (1982 edition), featuring a full UTM grid, and the adjacent Fairfax, Virginia sheet (1982 edition) with marginal tick marks were selected for this experiment. A full 2.5-minute lat/long "grid" was added to the sheets employed to collect lat/long values, and test participants were provided with USGS lat/long interpolators (200 mm by 150 mm in size) and USGS CR-2 UTM grid readers (about 55 mm by 55 mm) to aid the measurement of map coordinates.

The 12 participants in this test included five professional firefighters from Prince George's County, Maryland Fire Department, and seven civilian hikers and backpackers who use maps recreationally. Due to a lack of experience in coordinate measurement among several of the participants, training was provided on how to read and measure both UTM and lat/long coordinates from 1:24,000-scale maps. By the time the test was run, all participants could precisely measure coordinates in both UTM and lat/long coordinate systems.

Each participant was asked to measure coordinate values for five points on both maps for each of the three conditions (full lat/long grid, full UTM grid, and UTM ticks). Coordinates recorded by the participants were compared to "true" values obtained by measuring the coordinates from the map sheets with an Altek digitizer ( $\sigma = \pm 2$ m). Criteria to evaluate positional accuracy included the time required to complete the tasks and the level of accuracy achieved (Table 2). In determining the average positional accuracy, blunders of 150 m or greater were discounted. The results in Table 2 clearly demonstrate that maps with full UTM grids allow coordinates to be quickly determined to accuracies of about 10 m, and that the determination of lat/long coordinates requires more time and is likely to produce greater measurement errors. Positions determined from marginal tick marks in a "field" situation often produced errors of 100 m or more.

#### Conclusion

This study supports the original decision by the USGS in 1974 to add full UTM grids to the 1:24,000-scale map series. Although both the lat/long and UTM coordinates are of value, the map user involved in land-navigation and coordinate measurement tasks is better served by the rectangular UTM coordinate system depicted as a full grid. Fully gridded maps allow point features to be located quickly to accuracies of approximately 10 m using a small ruler or coordinate reader. With increased use of GPS receivers and GIS software, the integration of map, GPS, and GIS data will be greatly facilitated by maps on which a full UTM grid is printed. Consequently, it is recommended that the USGS expedite gridding of all 1:24,000-scale topographic quadrangles.

TABLE 1. RESULTS OF TEST 1 SHOWING THE PERCENTAGE OF ORIENTEERING STATIONS LOCATED USING MAPS WITH FULL GRIDS AND MARGINAL TICK MARKS.

Coordinate System	Maps with Full Grids	Maps with Tick Marks
UTM	80%	58.3%
Latitude/Longitude	90%	20%

TABLE 2. RESULTS OF TEST 2. A FULL UTM GRID ALLOWED TEST PARTICIPANTS TO QUICKLY MEASURE MAP COORDINATES TO AN ACCURACY OF ABOUT 10 M, WITH FEW BLUNDERS.

Type of map	Percentages of samples with < 150 m positional error	Average positional error (metres) <sup>1</sup>	Average time for participants to finish
Full lat/long grid	69%	32 m	14 min., 47 sec.
Full UTM grid	86%	10 m	9 min., 43 sec.
UTM ticks	34%	100 m	8 min., 00 sec.

<sup>1</sup>Blunders of >150 m were not included.

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