National Mapping Program
Technical Instructions

Standards for Digital Elevation Models

U. S. Department of the Interior
U.S. Geological Survey
National Mapping Division

CONTENTS

Page

1. General 1-1
   1.1 Objectives 1-1
   1.2 Product Description 1-2
   1.3 Sources 1-3
   1.4 Digital Elevation Model Structure 1-6
2. Specifications: Errors and Blunders 2-1
   2.1 Definitions 2-1
   2.2 Accuracy 2-4
   2.3 Classification Levels 2-7
   2.4 Format 2-9
   2.5 Geometry 2-10
   2.6 Areas of Constant Elevation. 2-14
   2.7 Digital Elevation Model Caveats 2-16
   2.8 Data Records 2-17
3. Quality Control 3-1
   3.1 Accuracy Verification 3-1
   3.2 Logical and Physical Format Verification 3-5
   3.3 Visual Verification 3-6
   3.4 Editing 3-7

LIST OF PAGES

A complete and current copy of the preliminary pages for the "Standards for Digital Elevation Models" consists of the pages (and most recent creation or revision dates) listed below.

Page	Date	Page	Date	Page	Date
ii	12/92				

National Mapping Program
Technical Instructions

Part 1
General

Standards for
Digital Elevation Models

U.S. Department of the Interior
U.S. Geological Survey
National Mapping Division

CONTENTS

Page

1. General 1-1
   1.1 Objectives 1-1
   1.2 Product Description 1-2
   1.3 Sources 1-3
   1.4 Digital Elevation Model Structure 1-6
      1.4.1 UTM Structured DEM 1-6
      1.4.2 Arc Second Structured DEM 1-8
Appendix 1-A References 1-11

FIGURES

Figure

1-1 Structure of a 7.5-minute digital elevation model, UTM grid 1-7

1-2 Structure of a 1-degree digital elevation model, arc second grid. .1-9

TABLES

Table

1-1 Characteristics of digital elevation models 1-4
1-2 Data production of digital elevation models 1-5

LIST OF PAGES

A complete and current copy of part 1 of Standards for Digital Elevation Models consists of the pages (and most recent creation or revision dates) listed below.

Page	Date
1-ii thru 1-iv	12/92
1-v	8/93
1-1	12/92
1-2	8/93
1-3 thru 1-11	12/92

Standards for Digital Elevation Models
Part 1: General

1. GENERAL

1.1 OBJECTIVES

The U.S. Geological Survey (USGS) has been designated as a lead Federal agency for the collection and distribution of digital cartographic data. The standards specified in this document pertain to the collection, processing, and quality control of digital elevation model (DEM) data intended for entry into the National Digital Cartographic Data Base (NDCDB).

These standards are intended to facilitate the interchange and use of DEM data. DEM collection and editing systems must produce data that are compatible with other production systems, not only in the Federal sector but also in other government and private sector organizations. Because of rapidly changing technologies in the mapping industries, these DEM standards cover a broad range of collection systems and related accuracy levels. It is the intent of this standard to set common standards that will ensure that data will be acceptable for entry into the NDCDB.

This document also provides the NDCDB manager and the quality control unit(s) within the USGS with standards for testing DEM data. Data generated by National Mapping Division (NMD) production units are collected according to the standards set forth in this document. DEM data collected by other Federal agencies, or acquired through procurement from the private sector, will be accepted for entry to the NDCDB after verification according to these same standards.

1.2 PRODUCT DESCRIPTION

The USGS produces five primary types of DEM data. This document describes these products as they are archived in the NDCDB in standard DEM format (see table 1-1 and 1-2):

1. 7.5-minute DEM (30- by 30-m data spacing, cast on Universal Transverse Mercator (UTM) projection). Provides coverage in 7.5- by 7.5-minute blocks. Each product provides the same coverage as a standard USGS 7.5-minute quadrangle without overedge. Coverage: Contiguous United States, Hawaii, and Puerto Rico.

2. 30-minute DEM (2- by 2-arc second data spacing). Consists of four 15- by 15-minute DEM blocks. Two 30-minute DEM's provide the same coverage as a standard USGS 30- by 60-minute quadrangle. Saleable units are 30- by 30-minute blocks, that is, four 15- by 15-minute DEM's representing one half of a 1:100,000-scale map. Coverage: Contiguous United States, and Hawaii.

3. 1-degree DEM (3- by 3-arc second data spacing). Provides coverage in 1- by 1-degree blocks. Two products (three in some regions of Alaska) provide the same coverage as a standard USGS 1- by 2-degree quadrangle. The basic elevation model is produced by or for the Defense Mapping Agency (DMA), but is distributed by the USGS in the DEM data record format. Coverage: United States.

4. 7.5-minute Alaska DEM (1- by 2-arc second data spacing, latitude by longitude). Provides coverage similar to a 7.5-minute DEM, except that the longitudinal cell limits vary from 10 minutes at the southernmost latitude of Alaska to 18 minutes at the northernmost latitude limits of Alaska.

5. 15-minute Alaska DEM (2- by 3-arc second data spacing, latitude by longitude). Coverage is 15 minutes of latitude by 20 minutes of

longitude at the southernmost latitude of Alaska, to 36 minutes of longitude at the northernmost latitude limits of Alaska. Coverage of one DEM corresponds to a 1:63,360-scale quadrangle.

Note: The term "block," as used in 1, 2, and 3 above, is used to describe the physical extent of a DEM quadrangle, and implies that the DEM is trimmed to the quadrangle neatlines and that no overedge is allowed beyond the "block" boundaries.

1.3 SOURCES

The production procedures and instrumentation used for collecting raw elevation data vary depending on the production systems available to each mapping center, other agencies, or contractors. However some production processes are specified in this standard that critically affect the criteria for accepting data into the NDCDB. Those production processes specific to DEM series levels are summarized in table 1-2.

Table 1-1
Specifications for digital elevation models

	Horizontal Coordinate system	Units of coverage	Elevations	Profile spacing	Data order
7.5-minute DEM	UTM on North American Datum of 1927 (NAD 27) or North American Datum of 1983 (NAD 83).	7.5-minute quadrangle; overedge coverage is not provided.	For the continental U.S., meters or feet referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). For Hawaii and Puerto Rico, meters or feet referenced to local mean sea level.	Spacing of elevations along and between each profile is 30 meters. The profiles do not always have the same number of elevations because of the variable angle between true north and the grid north of the UTM coordinate system.	Data are ordered south to north in profiles ordered west to east.
30-minute DEM	Geographic (lat/long) on NAD 27 or NAD 83.	30- by 30-minute block. Saleable units are four 15-minute DEM's covering a 30- by 30-minute block.	Meters or feet relative to NGVD 29 in the continental U.S., and local mean sea level in Hawaii and Puerto Rico.	Spacing of elevations along and between each profile is 2 arc seconds.	Data are ordered south to north in profiles ordered west to east.
1-degree DEM	Geographic (lat/long) on World Geodetic Survey (WGS) 72 or WGS 84.	1- by 1-degree block; elevation data on the integer degree lines correspond with the profiles on the surrounding eight blocks.	Meters relative to NGVD 29 in the continental U.S. and Alaska, and in local mean sea level in Hawaii and Puerto Rico.	Spacing of elevations along each profile is 3 arc seconds. Spacing between profiles is 3 arc seconds south of 50°N latitude, 6 arc seconds between 50°N and 70°N, and 9 arc seconds north of 70°N.	Data are ordered south to north in profiles ordered west to east.
7.5-minute Alaska DEM	Geographic (lat/long) on NAD 27 or NAD 83.	7.5 by 10 minutes south of 59°N; 7.5 by 11.25 minutes between 59°N and 62°N; 7.5 by 15 minutes between 62°N and 68°N; and 7.5 by 18 minutes north of 68°N.	Meters or feet relative to NGVD 29.	Spacing of elevations along and between each profile is 1 by 2 arc seconds, respectively.	Data are ordered south to north in profiles ordered west to east.
15-minute Alaska DEM	Geographic (lat/long) on NAD 27 or NAD 83.	15 by 20 minutes south of 59°N; 15 by 22.5 minutes between 59°N and 62°N; 15 by 30 minutes between 62°N and 68°N; and 15 by 36 minutes north of 68°N.	Meters or feet relative to NGVD 29.	Spacing of elevations along and between each profile is 2 by 3 arc seconds, respectively.	Data are ordered south to north in profiles ordered west to east.

Table 1-2

Data production of digital elevation models

DEM level**	DEM series*	Production process	Instructions and comments
Level 1	7.5-minute DEM 30-minute DEM	DEM created by auto correlation or manual profiling from aerial photographs. Source photography is typically from National Aerial Photography Program or National High Altitude Photography Program. Depending on the specific production process used, a given DEM shall meet the maximum 7-meter root mean square error (RMSE) or may have an RMSE less than one-half of the contour interval of the corresponding topographic series map. Level 1 30-minute DEM's may be derived or resampled from level 1 7.5-minute DEM.	May be derived from a wide variety of sources using any of a number of USGS approved techniques and instrumentation. The primary objective is that the resulting product meet the minimum accuracy requirements required to support production of orthophotos at a scale of 1:24,000. This DEM product must also meet minimum RMSE test standards as specified in part 2, sections 2.1.4 and 2.3.1.
Level 2	All series*	DEM created from digital line graph (DLG) contours or equivalent, from any USGS map series up to 1:100,000 scale.	The accuracy and data spacing are intended to support computer applications that analyze hypsographic features to a level of detail similar to manual interpolations of information from printed source maps.
Level 3	7.5-minute DEM	DEM created from DLG that have been vertically integrated with all categories of hypsography, hydrography, ridge line, break line, drain files, and all vertical and horizontal control networks.	Requires a system of logic incorporated into the software interpolation algorithms that clearly differentiates and correctly interpolates between the various types of terrain, data densities, and data distribution.

* This table is exclusive of 1-degree DEM's that are produced for or by DMA according to DMA program requirements. Level designation is referenced in a different context than that used by the USGS. The DMA designation of digital terrain data (DTED) "level" is similar to the USGS designation of DEM "series." Under a cooperative agreement, selected 1-degree DEM's are being regridded by the USGS from 7.5-minute DEM's and 30-minute DEM's. These DEM's are subject to quality control procedures as specified in a Memorandum of Understanding between the two agencies.

** DEM levels are defined in section 2.3.

1.4 DIGITAL ELEVATION MODEL STRUCTURE

Two types of grids, UTM and arc second, are used for the USGS DEM program.

1.4.1 UTM Structured DEM

A typical 7.5-minute UTM DEM is shown in figure 1-1. The 7.5-minute DEM profiles are clipped to the straight line intercept between the four geographic corners of the quadrangle, an approximation of the geographic map boundary (neatline). The resulting area of coverage for the DEM is a quadrilateral, the opposite sides of which are not parallel. (See appendix 2-D for an example of UTM coordinates describing a 7.5-minute quadrilateral figure.)

The UTM coordinates of the four corners (bounds) of the DEM are listed in the type A record, as shown in appendix 2-A, data element 11; the UTM coordinates of the starting points of each profile are listed in the type B record (profiles), appendix 2-B, data element 3. These coordinates describe the shape of the quadrilateral and the variable x, y starting position of each profile. Because of the variable orientation of the quadrilateral in relation to the UTM grid, profiles intersect the east and west neatlines as well as the north and south neatlines as shown in figure 1-1. In addition, DEM's have profile easting values that are continuous from one DEM to the adjoining DEM only if the adjoining DEM is contained within the same UTM zone. Profiles that pass within the bounds of the DEM quadrilateral, but are void of elevation grid points, are not represented in the DEM (Referred to as "missing profile condition." This condition occurs occasionally and is always the first or last profile of the DEM. Typically such a profile intersects the DEM corner, but there is no grid node within the quad bounds).

The use of UTM coordinates to define the horizontal grid spacing of DEM's is restricted at this time to the 7.5-minute DEM program.

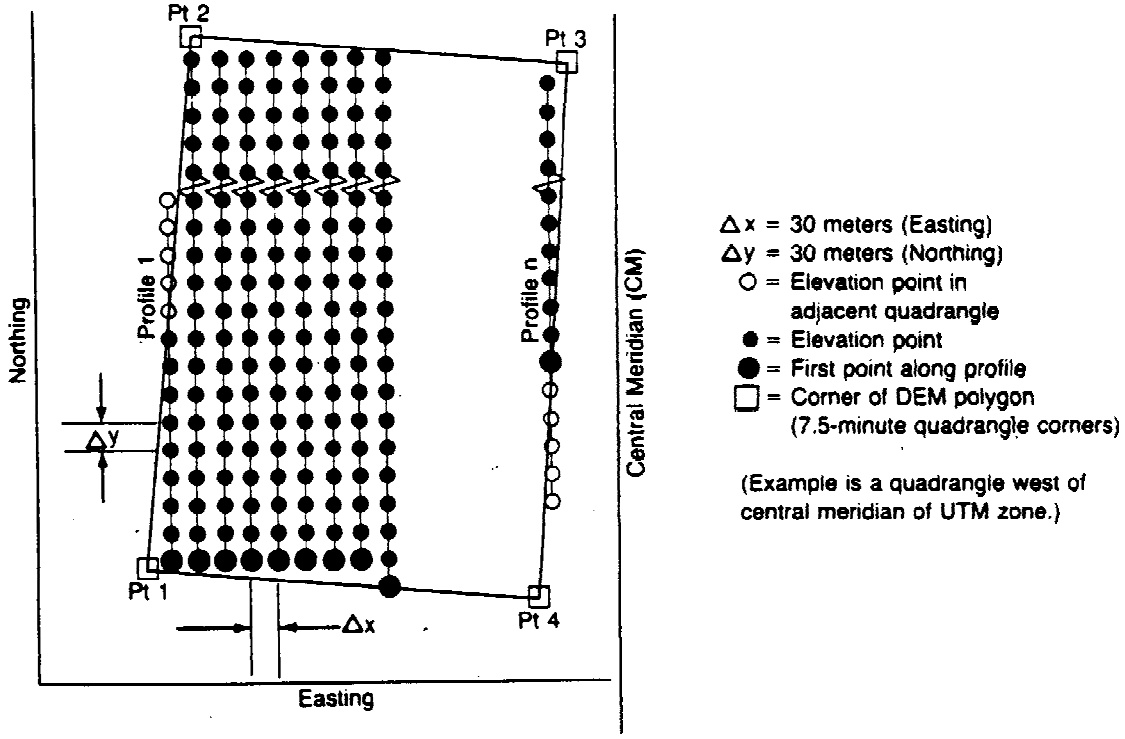

Figure 1-1
Structure of a 7.5-minute digital elevation model, UTM meter grid

1.4.2 Arc second structured DEM

A typical 1-degree arc second DEM is shown in figure 1-2. The 1-degree DEM west-and-east profiles are coincident with the west and east neat-lines respectively. The distribution of elevation data is as illustrated in figure 1-2. The resulting area of coverage for the DEM is a geographic rectangle.

The arc second coordinates of the four corners (bounds) of the DEM are listed in the type A record, as shown in appendix 2-A, data element 11; the arc second coordinates of the starting points of each profile are listed in the type B record (profiles), appendix 2-B, data element 3. These coordinates describe the shape of the geographic rectangle and the x, y starting position of each profile.

The use of arc second coordinates to define the horizontal grid spacing of DEM's is mandatory for all DEM series, except for 7.5-minute UTM DEM's.

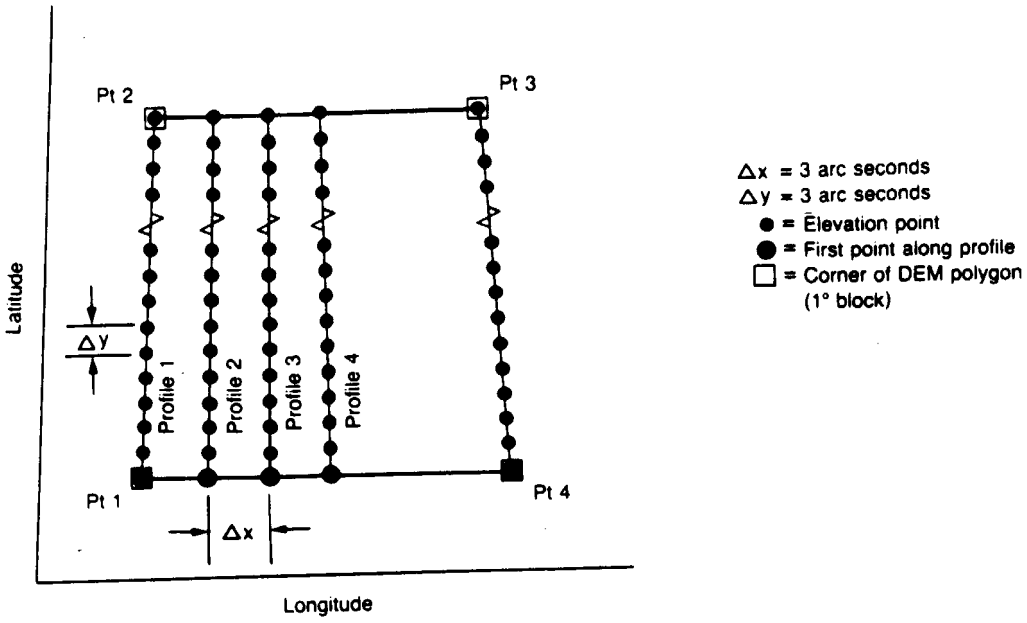

Figure 2.
Structure of a 1-degree digital
elevation model, arc second grid.

APPENDIX 1-A
REFERENCES

Caruso, V., 1987, Standards for Digital Elevation Models, in 1987 ASPRS-ACSM Annual Convention: Falls Church, Virginia, American Society for Photogrammetry and Remote Sensing and American Congress on Surveying and Mapping, v. 4, 159-166.

Allder, W. R., Caruso, V., Pearsall, R., and Troup, M., 1983, An overview of Digital Elevation Model production at the U.S. Geological Survey, in Fifth International Symposium on Computer-Assisted Cartography, Auto-Carto 5: Falls Church, Virginia, American Society of Photogrammetry and American Congress on Surveying and Mapping, 23-32.

Brunson, E. B., and Olsen, R. W., 1978, Digital Elevation Model Data Collection Systems." In Digital Terrain Models Symposium. Falls Church, Virginia, American Society of Photogrammetry.

De Gree, M., and McCausland, R.G., 1985, Digital Elevation Model Image Display and Editing, in International Symposium on Computer-Assisted Cartography, Auto-Carto 7: Falls Church, Virginia, American Society of Photogrammetry and American Congress on Surveying and Mapping, 142-151.

Kelly R.E., McConnell, P.R.H., and Mildenberger, S.J., 1977, The Gestalt Photomapping System: Photogrammetric Engineering and Remote Sensing, v. 43, no. 11, 1407-1417.

Olsen, R., 1979, Analysis of digital terrain profile data: U.S. Geological Survey unpublished report.

U.S. Geological Survey, 1978, Evaluation of Digital Elevation Model data: U.S. Geological Survey Research Project Report #WMC-21.