DATA USERS GUIDES

1: Digital Line Graphs from 1:24,000-Scale Maps
2: Digital Line Graphs from 1:100,000-Scale Maps
3: Digital Line Graphs from 1:2,000,000-Scale Maps
4: Land Use and Land Cover from 1:250,000- and 1:100,000-Scale Maps
5: Digital Elevation Models
6: Geographic Names Information System
7: Alaska Interim Land Cover Mapping Program

Data Users Guides 1-7 generally replace the Geological Survey Circular 895.

Questions regarding availability and ordering of US GeoData (all types of digital cartographic and geographic data produced and distributed by the U.S. Geological Survey) should be addressed to:

Earth Science Information Center
U.S. Geological Survey
507 National Center
Reston, Virginia 22092
(703) 648-6045

Technical questions and comments should be addressed to:

Branch of Technical Standards
and Product Development
U.S. Geological Survey
510 National Center
Reston, Virginia 22092

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

DIGITAL ELEVATION MODELS

Data Users Guide 5

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INTRODUCTION

The Earth Science Information Center (ESIC) distributes digital cartographic/geographic data files produced by the U.S. Geological Survey (USGS) as part of the National Mapping Program. Digital cartographic data files may be grouped into four basic types. The first of these, called a Digital Line Graph (DLG), is the line map information in digital form. These data files include information on base data categories, such as transportation, hypsography, hydrography, and boundaries. The second type, called a Digital Elevation Model (DEM), consists of a sampled array of elevations for a number of ground positions at regularly spaced intervals. The third type is Land Use and Land Cover digital data which provides information on nine major classes of land use such as urban, agricultural, or forest as well as associated map data such as political units and Federal land ownership. The fourth type, the Geographic Names Information System, provides primary information for all known places, features, and areas in the United States identified by a proper name.

The digital cartographic data files from selected quadrangles currently available from ESIC include the following:

- Digital Line Graphs (DLG's)
  - 1:24,000-scale
  - 1:62,500-scale
  - 1:63,360-scale
  - 1:100,000-scale
  - 1:2,000,000-scale

- Digital Elevation Models (DEM's)
  - 7.5-minute
  - 15-minute
  - 30-minute
  - 1-degree

- Land Use and Land Cover digital data
  - 1:250,000- and 1:100,000-scale land use and land cover and associated maps
  - 1:250,000-scale Alaska Interim Land Cover Maps

- Geographic Names

The digital data are useful for the production of cartographic products such as plotting base maps and for various kinds of spatial analysis. A major use of these digital cartographic/geographic data is to combine them with other geographically referenced data, enabling scientists to conduct automated analyses in support of various decision making processes.

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This document describes five distinct digital elevation products that are distributed by the USGS in the standard DEM format:

1. 7.5-Minute DEM (30- x 30-m data spacing, cast on Universal Transverse Mercator (UTM) projection). Provides coverage in 7.5- x 7.5-minute blocks. Each product provides the same coverage as a standard USGS 7.5-minute map series quadrangle.

2. 1-Degree DEM (3- x 3-arc-second data spacing). Provides coverage in 1- x 1-degree blocks. Two products (three in some regions of Alaska) provide the same coverage as a standard USGS 1- x 2-degree map series quadrangle. The basic elevation model is produced by or for the National Imagery and Mapping Agency (NIMA), but is distributed by USGS in the DEM data record format.

3. 30-Minute DEM (2- x 2-arc-second data spacing). Consists of four 15- x 15-minute DEM blocks. Two 30-minute DEM's provide the same coverage as a standard USGS 30- x 60-minute map series quadrangle. Saleable units will be 30- x 30-minute blocks, that is, four 15- x 15-minute DEM's representing one half of a 1:100,000-scale map (30- x 60-minute coverage).

4. 15-minute Alaska DEM (2- x 3-arc-second data spacing, latitude by longitude). Provides coverage similar to a 15-minute DEM, except that the longitudinal cell limits vary from 20 minutes at the southernmost latitude of Alaska to 36 minutes at the northernmost latitude limits of Alaska. Coverage of one DEM will generally correspond to a l:63,360-scale quadrangle.

5. 7.5-minute Alaska DEM (1- x 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.

The UTM-based DEM's (7.5-minute DEM) and the geographic-based DEM's (30-minute, Alaska, and 1-degree DEM's) are identical in logical data structure but differ in sampling interval, geographic reference system, areas covered, and horizontal and vertical accuracy. Knowledge of all of these properties is essential to ensure that the user does not exceed the useful limits of the data for required applications. The 7.5-minute UTM DEM's are available for selected quadrangles, which are indicated on a status graphic published biannually by USGS. The 1-degree DEM's are available for all of the contiguous United States, Hawaii, and portions of Alaska, Puerto Rico, and the Virgin Islands. Many of the original 1-degree DEM's are being replaced with more accurate digital models through a cooperative regridding project with NIMA, scheduled for completion in 1995. As they become available, these 1-degree DEM's will replace their corresponding product. The 30-minute and Alaska DEM's are new DEM series and are available on a limited basis as projects are completed.

7.5-MINUTE DIGITAL ELEVATION MODELS

Characteristics

A 7.5-minute DEM has the following characteristics:

- The data consist of a regular array of elevations referenced horizontally in the UTM coordinate system. The reference datum may be North American Datum of 1927

(NAD 27), North American Datum of 1983 (NAD 83), Old Hawaiian Datum (OHD), or Puerto Rico Datum of 1940 (PRD).

- The unit of coverage is the 7.5-minute quadrangle. Overedge coverage is not provided.

- The data are ordered from south to north in profiles that are ordered from west to east.

- The data are stored as profiles in which the spacing of the elevations along and between each profile is 30 m.

- The profiles do not always have the same number of elevations because of the variable angle between the quadrangle's true north and the grid north of the UTM coordinate system.

- Elevations for the continental U.S. are either meters or feet referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Elevations for Hawaii and Puerto Rico are either in meters or feet referenced to local mean sea level. DEM's of low-relief terrain or generated from contour maps with intervals of 10 ft (3 m) or less are generally recorded in feet. DEM's of moderate to high-relief terrain or generated from maps with terrain contour intervals greater than 10 ft are generally recorded in meters.

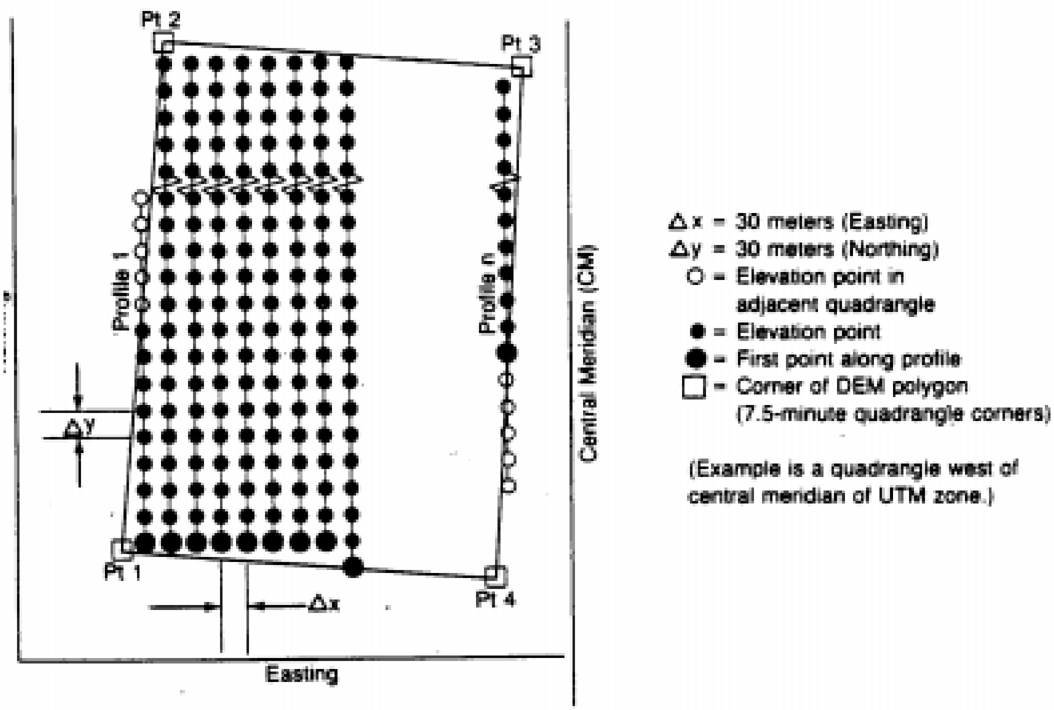
Profiles for 7.5-minute DEM's are generated by using a UTM cartesian coordinate system as a base. The profiles are clipped to the straight-line intercept between the four geographic corners of the quadrangle--an approximation of the geographic map boundary (neatline) as shown in figure 1. The resulting area of coverage for the DEM is a quadrilateral, the opposite sides of which are not parallel. (See appendix 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's are listed in the type A record, as shown in table 1, data element 11; the UTM coordinates of the starting points of each profile are listed in the type B record (profiles), table 2, 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 coordinate system, profiles intersect the east and west neatlines as well as the north and south neatlines as shown in figure 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.

Data Production

The 7.5-minute DEM data are produced in 7.5- x 7.5-minute blocks either from map contour overlays that have been digitized, or from automated or manual scanning of National Aerial Photography Program (NAPP) quarter quad-centered photographs or from the National High-Altitude Photography Program (NHAP) quad-centered photographs. The NHAP program was formally discontinued in 1988, however limited production using this scale source is permitted. The data are processed to produce a DEM having a 30-m sampling interval. The structure of a 7.5-minute DEM data file is shown in figure 1. (See tables for sample data records.)

Figure 1.--Structure c



The USGS has used four processes to collect the digital elevation data for production of 7.5-minute DEM's: (1) the Gestalt Photo Mapper II (GPM2), (2) manual profiling from photogrammetric stereomodels, (3) stereomodel digitizing of contours, and (4) derivation from DLG hypsography and hydrography categories or pseudo-DLG's (tagged vector contours) .

The GPM2 (now discontinued) was an automated photogrammetric system designed to produce orthophotographs, digital terrain data, and contours. An electronic image correlation component of the GPM2 measured the parallax of 2,444 points within each 9- x 8-mm area of a photogrammetric stereomodel. Of these 2,444 correlated points, subunits of 576, 1,024, or 1,600 points were collected for inclusion in the elevation model. These subunits were called patches, and the patch size was selected to accommodate various terrain conditions. The horizontal (x and y) spacing of the elevation points within each patch was approximately 182 mm at photographic scale (equivalent to a ground distance of approximately 47 ft when using photographs at 1:80,000 scale). Each of the two NHAP stereomodels used to cover a standard 7.5-minute quadrangle contained over 500,000 correlated points; these were regridded to form a DEM in the standard format. Before discontinuance, approximately 15,000 DEMs were added to the NDCDB using this autocorrelation system.

The manual profiling process uses stereoplotters, equipped with three-axis electronic digital profile recording modules, for scanning of stereomodels along successive terrain profiles. High-altitude aerial photographs are used as source material. The scan speed and distance between profiles are selected by the operator to accommodate steepness in topographic slope. The most commonly used profile separation is approximately 90-m, with elevations normally recorded every 30 m along each profile. The profiled elevation data are reformatted and regridded using a weighted four-nearest-neighbor interpolation to a regular 30-m UTM spacing, written in standard DEM format, and tested for vertical accuracy before placement in the National Digital Cartographic Data Base. Digital profile data of this type are collected as companion products during the production of orthophotographs.

For stereo model digitizing of contours (now deactivated), digital contours were acquired in digital form on stereoplotters equipped with three-axis digital recording modules. Digital data were acquired as the contours were stereocompiled for 7.5-minute quadrangle maps. The contours were assigned elevation values (attributes) during the acquisition phase. The contour data were processed into profile lines, and the elevation matrix was computed at a 30-m spacing using a bilinear interpolation.

Derivation of DEM's from DLG's or pseudo-DLG's is a process that involves the use of hardware such as scanners, manual digitizers, and (or) semiautomated line followers. The hypsography and hydrography categories of DLG or pseudo-DLG data are required as input to DEM processing. Contours and spot elevations in three-dimensional coordinates are required from the hypsographic category. Lake and shoreline data are required from the hydrographic category for water body flattening. Drainage data are also extracted from the hydrography file. Elevations are computed where contours merge with the hydrographic data. Ridge lines, the opposite of drainage lines, are normally interpolated automatically by computer programs using trends within the hypsographic overlay. If necessary, the delineation of ridge lines may be accomplished by manual inputs or sophisticated medial axis computation algorithms. The DLG or pseudo-DLG are reformatted as tagged vector line strings and are input to gridding software to interpolate gridded elevations for the DEM. A subsequent processing step involves trimming the grid along the quadrangle perimeter and formatting the data into a DEM file structure. The DEM is finally processed by the DEM Editing System to validate and test the accuracy before entry into the National Digital Cartographic Data Base.

1-DEGREE DIGITAL ELEVATION MODELS

Characteristics

A 1-degree DEM has the following characteristics:

- The product consists of a regular array of elevations referenced horizontally on the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 Datum (WGS 72) or the World Geodetic System of 1984 (WGS 84).

- The unit of coverage is a 1- x 1-degree block. Elevation data on the integer degree lines (all four sides) correspond with the same profiles on the surrounding eight blocks.

- Elevations are in meters relative to NGVD 29 in the continental U.S. and local mean sea level in Hawaii and Puerto Rico.

- The data are ordered from south to north in profiles that are ordered from west to east.

- Spacing of the elevations along each profile is 3 arc-seconds. The first and last data points are at the integer degrees of latitude. A profile will therefore contain 1,201 elevations.

- Spacing between profiles varies by latitude; however, the first and last data points are at the integer degrees of longitude. North of 50° degrees N and south of 70° N, the spacing is 6 arc-seconds with 601 profiles per product. For the remainder of Alaska north of 70° N the spacing is 9 arc-seconds with 401 profiles per product.

Data Production

The majority of the 1-degree Digital Elevation Models are produced by NIMA from cartographic and photographic sources. Under a cooperative agreement, selected 1-degree DEM's are being regridded by USGS from 7.5-minute DEM's and 30-minute DEM's. These data sets will be available upon completion of quality control and exchange between NIMA and USGS.

Elevation data from cartographic sources are collected from any map series 7.5 minute through 1 degree (1:24,000 scale through 1:250,000 scale). The hypsographic features (contours, drain lines, ridge lines, lakes, and spot elevations) are first digitized and then processed into the required matrix form and interval spacing. The structure of a 1-degree DEM data file is shown in figure 2 (see tables for sample data records).

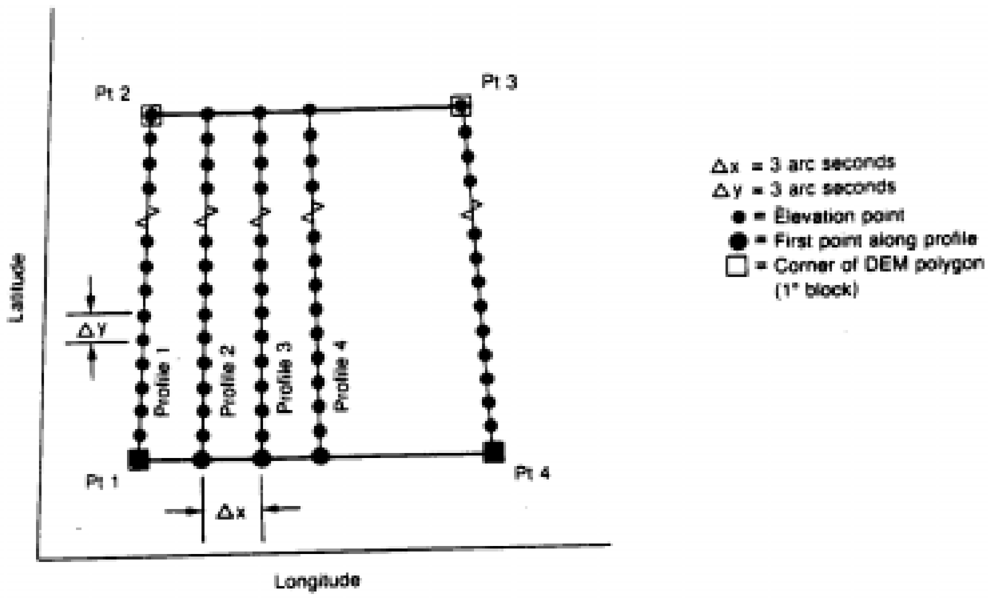


Figure 2.--Structure

Elevation data from photographic sources are collected by using manual and automated correlation techniques. Elevations along a profile are collected at 80 to 100 percent of the eventual point spacing. The raw elevations are weighted with additional information such as drain, ridge, water, and spot heights during the resampling process in which final elevations are determined for the required matrix form and interval spacing.

The digital elevation models distributed within the Department of Defense cover 1- x 1-degree blocks but are called Digital Terrain Elevation Data Level 1 (DTED-1). These blocks are referenced by their southwest corner coordinates rather than by the name of a corresponding map sheet. The header records and profile records are considerably different in their structure than those in the corresponding USGS-distributed version; however, in reformatting the product, the USGS does not change the basic elevation information.

The accuracy of the NIMA product, together with the data spacing, adequately support computer applications that analyze hypsographic features to a level of detail similar to manual interpretations of information as printed at map scales not larger than 1:250,000. The plotting of contours from the 1-degree DEM at scales larger than 1:250,000, or reliance on the elevation heights without incorporating the National Map Accuracy Standard (NMAS) horizontal error tolerance, will lead to less reliable results.

Note that NIMA 1-degree DTED-l data and USGS-distributed 1-degree DEM's are gridded by using the WGS 72 or WGS 84 datum, which is significantly different than the NAD 27 datum used by the USGS for gridding 7.5-minute DEM's. At the present time, policy issues concerning the transformation algorithms and procedures to convert to or from NAD 27 and WGS 72 to WGS 84 and (or) NAD 83 are being developed. See appendix H for additional information related to these datums.

30-MINUTE DIGITAL ELEVATION MODELS

Characteristics

A 30-minute DEM has the following characteristics:

- The product consists of a regular array of elevations referenced horizontally to the geographic (latitude/longitude) coordinate system of NAD 27 or NAD 83.

- The unit of coverage is a 30- x 30-minute block. Saleable units are four 15-minute DEM's covering a 30- x 30-minute area. Elevation data on the integer minute lines (all four sides) correspond to the same profiles on the surrounding eight blocks.

- Elevations are in meters or feet relative to NGVD 29 in the continental U.S. and local mean sea level in Hawaii and Puerto Rico.

- The data are ordered from south to north in profiles that are ordered from west to east.

- Spacing of the elevations along each profile is 2 arc-seconds. The first and last data points are at the integer 15 minutes of latitude. A 15-minute profile will therefore contain 451 elevations.

Data Production

The USGS uses two processes to collect the digital elevation data for production of 30-minute DEM's: (1) derivation from DLG contours of any map series 7.5 minute to 30 x 60 minute (1:24,000 scale to 1:100,000 scale), (2) resampling from digital elevation models with a source spacing equal to or less than 2-arc second sampling interval (if the data is resampled from preexisting DEMs, it is arbitrarily archived as level 1). DEM data for this series are tested according to level 2 (see Level 2, p. 14) accuracy specifications.

The accuracy of the DEM data, together with the data spacing, adequately support computer applications that analyze hypsographic features to a level of detail similar to manual interpretations of information as printed at map scales not larger than 1:100,000. The plotting of contours from 30-minute DEM data at scales larger than 1:100,000, or reliance on the elevation heights without incorporating the NMAS horizontal error tolerance, will lead to less reliable results.

15-MINUTE ALASKA DIGITAL ELEVATION MODELS

Characteristics

15-minute Alaska DEM's have the following characteristics:

- The product consists of a regular array of elevations referenced horizontally on to the geographic (latitude/longitude) coordinate system of NAD 27 or NAD 83.

- The unit of coverage corresponds to four basic quadrangle sizes for 1:63,360-scale graphics (depending on latitude):

  Cell size limits

15 x 36 minutes	State of Alaska north of 68° N latitude
15 x 30 minutes	Between 62° N and 68° N latitude
15 x 22.5 minutes	Between 59° N and 62° N latitude
15 x 20 minutes	State of Alaska south of 59° N latitude

- The longitudinal limits of these cells are computed east and west of the -150 degree meridian. The north-south cell limits conform to even multiples of 15 minutes of latitude.

- The data are collected with a 2- x 3-arc-second spacing in latitude, and longitude, respectively. The first and last data points along a profile are at the integer degrees of latitude. A profile will therefore contain 451 elevations.

- Elevation data on the quadrangle neatlines (all four sides) share edge profiles with the surrounding eight quadrangles.

- Elevations are in meters or feet relative to NGVD 29.

- The data are ordered from south to north in profiles that are ordered from west to east.

Data Production

The 15-minute Alaska DEM data are produced to match the spatial format of the 1:63,360-scale source contours. The primary process used for production of Alaska DEM's is to combine digitized hypsographic and hydrographic data from 1:63,360-scale graphics. Processing can include all of the scanning, resampling, and contour interpolation programs previously mentioned. Data production for this series, if derived from hypsography overlays, is classified according to level 2 specifications.

The accuracy of the DEM data, together with the data spacing, adequately support computer applications that analyze hypsographic features to a level of detail similar to manual interpretations of information as printed at map scales not larger than 1:63,360. The plotting of contours from the 15-minute Alaska DEM's at scales larger than 1:63,360, or reliance on the elevation heights without incorporating the NMAS horizontal error tolerance, will lead to less reliable results.

7.5-MINUTE ALASKA DIGITAL ELEVATION MODELS

Characteristics

7.5-minute Alaska DEM's have the following characteristics:

- The product consists of a regular array of elevations referenced horizontally to the geographic (latitude/longitude) coordinate system of NAD 27 or NAD 83.

- The unit of coverage corresponds to four basic quadrangle sizes for 1:24,000- and 1:25,000-scale graphics (depending on latitude):

Cell size limits

7.5 x 18 minutes	State of Alaska north of 68° N latitude
7.5 x 15 minutes	Between 62° N and 68° N latitude
7.5 x 11.25 minute	Between 59° N and 62° N latitude
7.5 x 10 minutes	State of Alaska south of 59° N latitude

- The longitudinal limits of these cells are computed east and west of the -150 degree meridian. The north-south cell limits conform to even multiples of 7.5 minutes of latitude.

- The data are collected with a 1- x 2-arc-second spacing in latitude and longitude, respectively. The first and last data points along a profile are at the integer degrees of latitude. A profile will therefore contain 451 elevations.

- Elevation data on the quadrangle neatlines (all four sides) share edge profiles with the surrounding eight quadrangles.

- Elevations are in meters or feet relative to NGVD 29.

- The data are ordered from south to north in profiles that are ordered from west to east.

Data Production

The 7.5-minute Alaska DEM data are produced to match the spatial format of the 1:24,000- and 1:25,000-scale source contours. The collection of elevation data is primarily by raster-to-vector digitizing of map separates and gridding the resultant vectors. Data production for this series, if derived from hypsography overlays, is classified according to level 2 specifications.

The accuracy of the DEM data, together with the data spacing, adequately support computer applications that analyze hypsographic features to a level of detail similar to manual interpretations of information as printed at map scales not larger than 1:24,000. The plotting of the contours from the Alaska DEM's at scales larger than 1:24,000, or reliance on the elevation heights without incorporating the NMAS horizontal error tolerance will lead to less reliable results.

GEOMETRY

Profiles are the basic building blocks of DEM's and are defined as one-dimensional arrays, that is, arrays of dimension in m rows x 1 column, where m is the length of the profile (variable length for 7.5-minute DEM's or fixed length for 30-minute, Alaska, and 1-degree DEM's).

Figure 3 provides an example of the computation for the first data point inside the quadrilateral representing a 7.5-minute DEM west of the UTM central meridian. Figure 4 provides a similar example for a quadrangle east of the central meridian.

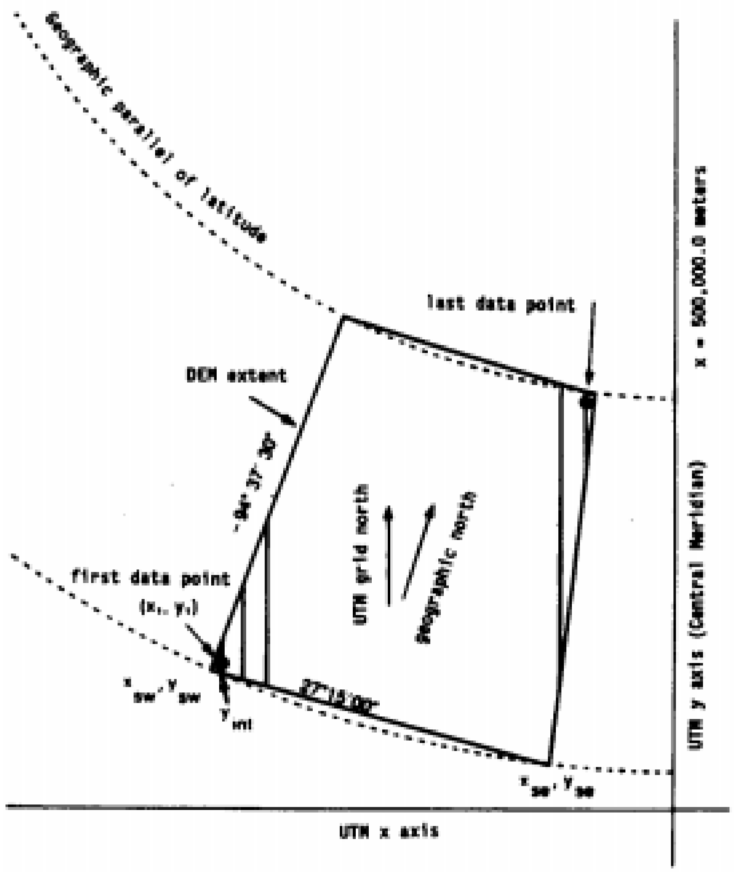
Figure 5, formula 1, illustrates the internal horizontal relationship (x_p, y_p) of elevations ordered as profiles in which the spacing of the elevations along each profile is Δy and the spacing between profiles is Δx. Figure 5, formula 2, relates the internal array structure to actual ground coordinates (x_{gp}, y_{gp}) based on an origin of the DEM at the lower left corner (x_{go}, y_{go}), and a rotation angle measured from quadrangle north, if any. The rotation angle of 7.5-minute DEM's is normally set to zero (see record A, element 13 in table 1). The rotation angle for a 1-degree DEM is always set to zero (see record A, element 13, in table 4). In general the mathematics is simpler for a 1-degree DEM. Each 1-degree DEM profile is composed of the same number of elevations per profile and the array is a square or rectangle. Therefore, the equations of figure 5 are greatly simplified.

ACCURACY

The accuracy of a DEM is dependent upon the level of detail of the source and the grid spacing used to sample that source. The primary limiting factor for the level of detail of the source is the scale of the source materials. The proper selection of grid spacing determines the level of content that may be extracted from a given source during digitization. For example, 1:250,000-scale topographic maps are the primary source of 1-degree DEM's. Larger scale maps, such as 1:100,000 and 1:24,000, are used to generate higher accuracy DEM's. Scales smaller than 1:250,000 have not been used as a DEM source.

Another factor is the horizontal and vertical dimension of the DEM. Horizontal accuracy of DEM data depends on the horizontal spacing of the elevation matrix. Within a standard DEM, most terrain features are generalized by being reduced to grid nodes spaced at regular intersections in the horizontal plane (7.5-minute DEM interval is 30 m; 1-degree DEM interval is 3 arc-seconds). This generalization reduces the ability to recover positions of specific features less than the internal spacing during testing and results in a de facto filtering or smoothing of the surface during gridding.

Vertical accuracy of DEM data depends on the spatial resolution (horizontal grid spacing), quality of the source data, collection and processing procedures, and digitizing systems. As with horizontal accuracy, the entire process, beginning with project authorization, compilation of the source data sets, and the final gridding process, must satisfy accuracy criteria customarily applied to each system. Each source data set must qualify to be used in the next step of the process. Errors are compounded in each step of the process. For this reason, significant effort is expended in each phase of the production process to minimize errors.



Example computation of UTM coordinates (x_1, y_1) of the first data point in a 7.5-minute DEM west of the central meridian.

The southwest corner of the 7.5-minute DEM in this example is at latitude 27°15'00", longitude -94°37'30" (x_{sw} = 339117.761, y_{sw} = 3015001.964). The southeast corner is at latitude 27° 15'00", longitude -94° 30'00" (x_{se} = 351495.041, y_{se} = 3014847.375).

Compute x coordinate (x_1) of the first profile. The first profile is offset to the next integer multiple of 30 m east of the southwest corner.

$$\frac{x_{sw}}{30m} = \frac{339117.761m}{30m}$$

$$= 11303.9 \text{ (round up)}$$

$$= 11304$$

$$x_1 = 11304\ (30m)$$

$$= 339120m$$

Compute y coordinate (y_1) of the first data point on the first profile. The first data point is offset to the next integer multiple of 30 m north of the intercept (y_{int}) of the first profile with the southern latitude line of the 7.5-minute quadrangle.

a) Use the slope intercept formula y = mx + b to compute y_{int}.

$$m = (y_{se} - y_{sw}) / (x_{se} - x_{sw})$$

$$= -154.589/12377.280$$

$$= -.0124897$$

$$b = y_{sw} - mx_{sw}$$

$$= 3015001.964 - (-.0124897)(339117.761)$$

$$= 3019237.443m$$

$$y_{int} = b + mx_1$$

$$= (-.0124897)\ (339120) + 3019237.443$$

$$= 3015001.934m$$

b) Compute y_1

$$\frac{y_{int}}{30m} = \frac{3015001.934m}{30m}$$

$$= 100500.06 \text{ (round up)}$$

$$y_1 = 100501\ (30m)$$

$$= 3015030m$$

Figure 3.--Computation of first data point in a 7.5-minute Digital Elevation Model west of the central meridian.

xample computation of UTM coordinates (x_1, y_1) of the first data point
 a 7.5-minute DEM east of the central meridian.

he southwest corner of the 7.5-minute DEM in this example is at
titude 27°07'30", longitude -92°30'00" (x_{sw} = 549553.918m,
$_{sw}$ = 3000211.052). The northwest corner is at latitude 27°15'00",
ngitude -92°35'00" (x_{nw} = 549498.713m, y_{nw} = 3014056.068m).

ompute x coordinate (x_1) of the first profile. The first profile is
ffset to the next integer multiple of 30 m east of the northwest corner.

$$\frac{x_{nw}}{30m} = \frac{549498.713m}{30m}$$

$$= 18316.6 \text{ (round up)}$$

$$= 18317$$

$$x_1 = 18317\ (30m)$$

$$= 549510m$$

ompute y coordinate (y_1) of the first data point on the first profile.
he first data point is offset to the next integer multiple of 30 m north
of the intercept (y_{int}) of the first profile with the western longitude
line of the 7.5-minute quadrangle.

(a) Use the slope intercept formula $y = mx + b$ to compute y_{int}.

$$m = (y_{nw} - y_{sw})/(x_{nw} - x_{sw})$$

$$= 13845.016/-55.205$$

$$b = y_{sw} - mx_{sw}$$

$$= 3000211.052m - [(-250.79)(549553.919)]$$

$$= 140822838.147m$$

$$y_{int} = b + mx_1$$

$$= 140822838.147m + [(-250.79)(549510m)]$$

$$= 3011225.247m$$

(b) Compute y_1

$$\frac{y_{int}}{30m} = \frac{3011225.247m}{30m}$$

$$= 100374.175 \text{ (round up)}$$

$$y_1 = 100375\ (30m)$$

$$= 3011250m$$

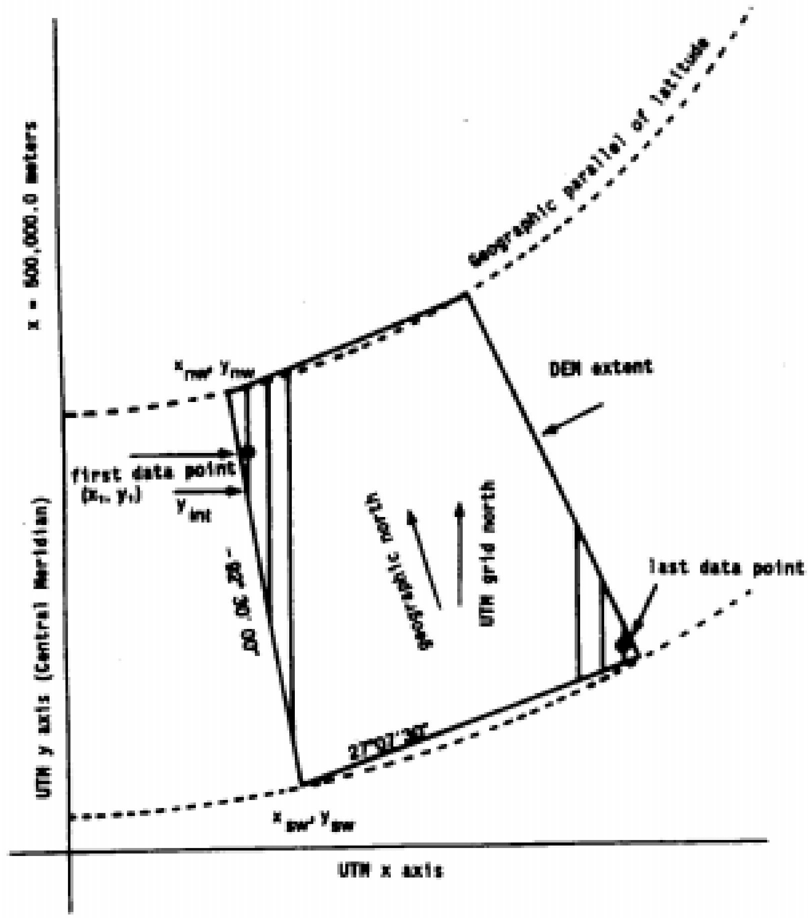
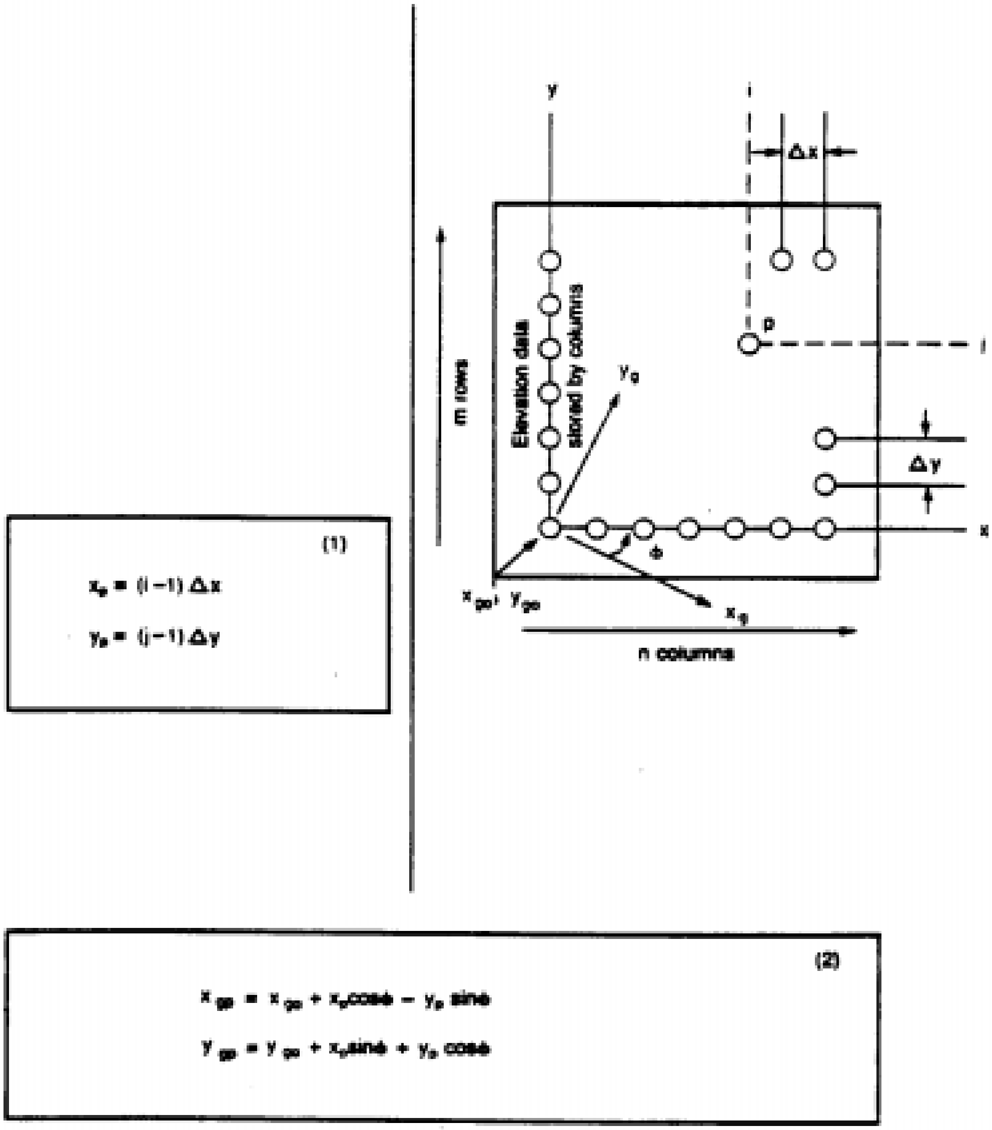


Figure 4.-- Computation of first data point in a 7.5-minute Digital Elevation Model east of the central meridian.

Figure 5.--Geometry and



The method of determining 7.5-minute DEM accuracy involves computation of the root-mean-square error (RMSE) for linearly interpolated elevations in the DEM and corresponding "true" elevations from the published maps. Test points are well distributed, are representative of the terrain, and have "true" elevations well within the DEM accuracy criteria.

Test points are located on contour lines, bench marks, or spot elevations. A minimum of 28 test points per DEM is required (20 interior points and 8 edge points). Collection of test point data and comparison of the DEM to the quadrangle hypsography are conducted by the quality-control units within the USGS.

The broad NIMA production objective for a 1-degree DTED-1 is to satisfy an absolute horizontal accuracy (feature to datum) of 130 m, circular error at 90-percent probability; and an absolute vertical accuracy (feature to mean sea level) of ±30 m, linear error at 90-percent probability. The relative horizontal and vertical accuracy (feature to feature on the surface of the elevation model), although not specified, will in many cases conform to the actual hypsographic features with higher integrity than indicated by the absolute accuracy.

CLASSIFICATION LEVELS

The following is a description of the general data characteristics used to classify DEM's into one of three levels of quality. There are varying methods of data collection and degrees of editing available for DEM data. Classification levels are indicated in the DEM record A (appendix A).

Level 1

Level 1 DEM's are elevation data sets in a standardized format. The intent is to reserve this level for 7.5-minute DEM's or equivalent that are derived from scanning National High-Altitude Photography Program, National Aerial Photography Program, or equivalent photography.

A vertical RMSE of 7 m is the desired accuracy standard. A RMSE of 15 m is the maximum permitted. The intent for 7.5-minute DEM data at this level is that an absolute elevation error tolerance of 50 m (approximately three times the 15-meter RMSE) be set for blunders for any grid node when compared to the true elevation, or that an array of points not encompass more than 49 contiguous elevations and be in error by more than 21 m (three times the 7-m RMSE). Systematic errors within the stated accuracy standards are tolerated at this level.

DEM data acquired photogrammetrically by using manual profiling or image correlation techniques are restricted to the level 1 category. DEM's with a RMSE of from 7 to 15 meters in elevation are being retained as an intermediate product and eventually will be replaced by higher accuracy DEM's. The DEM record C (appendix C) contains the RMSE accuracy statistics acquired during quality control.

A 30-minute DEM product has been produced by regridding level 1 or level 2 source 7.5-minute DEM data. These grid derivative DEM's are arbitrarily labeled as level 1 DEM's and carry a measured RMSE in record C. A tolerance has not been set for this RMSE, as a minimum level of accuracy has been satisfied previously with the data sets origin in the 7.5-minute DEM program. Alternatively, 30-minute DEM's are labeled as level 2 if gridded from 1:100,000-scale hypsography and hydrography stable base separates. The tolerance for level 2, 30-minute DEM's, is one-half contour interval (see level 2 specifications, below).

Level 2

Level 2 DEM's are elevation data sets that have been processed or smoothed for consistency and edited to remove identifiable systematic errors. DEM data derived from hypsographic and hydrographic data digitizing, either photogrammetrically or from existing maps, are entered into the level 2 category after review on a DEM Editing System. An RMSE of one-half contour interval is the maximum permitted. There are no errors greater than one contour interval in magnitude. The DEM record C contains the accuracy statistics acquired during quality control.

Level 3

Level 3 DEM's are derived from DLG data by using selected elements from both hypsography (contours, spot elevations) and hydrography (lakes, shorelines, drainage). If necessary, ridge lines and hypsographic effects of major transportation features are also included in the derivation. A RMSE of one-third of the contour interval is the maximum permitted. There are no errors greater than two-thirds contour interval in magnitude. The DEM record C contains the accuracy statistics acquired during quality control.

DIGITAL ELEVATION MODEL CAVEATS

The majority of the 7.5-minute DEM's produced to date are level 1. The current priority for authorization of 7.5-minute DEM production is now oriented to level 2, interpolation from digital contours. The USGS does not currently produce level-3 DEM data.

All 30-minute DEM's derived from contours are level 2. All 30-minute DEM's derived from 7.5-minute DEM's are level 1.

All 1-degree NIMA DTED-l's have been classified as level 3 because the hypsographic information, when plotted at 1:250,000 scale is consistent with the planimetric features normally found on 1:250,000-scale topographic maps. Inconsistencies may exist, but these are regarded as isolated cases to be tempered by the 90-percent confidence level for the overall product. NOTE: The USGS classification of "level 3" for 1-degree DEM's is not to be confused with the NIMA'S "DTED level 1." In the NIMA, the term "level" is related to the spatial resolution of the data and not to the source of the data. For example, DTED level 2 (which the USGS does not distribute) would have an array spacing of 1 x 1 arc-second for latitudes south of 50° N.

DATA RECORDS

A DEM file is organized into a series of three logical records are formatted as shown in appendixes A, B, and C. Because of the restructuring of new elements within what was formerly defined as element 1, record type A, the element counts of old record type A elements 2-15 (see table 1) have been incremented by one to elements 3-16 (see appendix A). A one-to-one correspondence still exists between the informational content of byte positions of elements in the old and new records. Therefore, DEM programs that expected elements 2-15 in specific byte positions in the DEM file will find the same information in those byte positions in the new files. In essence, this change is transparent to old DEM applications programs. Also, new data elements 17-29 have been appended to the end of the record A (see appendix A). These elements are contained in the end of the previously blank filled portion of the 1,024 byte record. This change is also expected to be transparent to existing DEM programs.

Appendixes D-G consist of code definitions that are needed to interpret various data elements in the three records. The type A record contains information defining the general characteristics of the DEM, including descriptive header information relating to the DEM's name, boundaries, units of measurement, minimum and maximum data values, number of type B records, and projection parameters. There is only one type A record for each DEM file, and it appears as the first record in the data file. The type B record contains elevation data and associated header information. All type B records of the DEM files are made up of data from one-dimensional arrays called profiles. The number of complete profiles covering the DEM area is synonymous with the number of type B records in the DEM. In a UTM structured DEM, an occasional profile that exists within the bounds of the DEM quadrilateral but is void of elevation grid points is not represented in the DEM. (This is called the "missing profile condition" and occurs occasionally as the first or last hypothetical profile of the DEM.) The type C record contains statistics on the accuracy of the data in the file.

The physical structure of the DEM distributed to the user is as follows:

- Data recorded in fixed-block format on unlabeled or ANSI-labeled 9-track magnetic tape at 1,600 or 6,250 bpi density.

- Logical record size of 1,024 bytes. No more than one logical record type (A, B, or C) recorded in any 1,024-byte record. However, more than one 1,024-byte record is usually required to store a single record type B. The logical record is padded with blanks if necessary to fill to the end of the logical record. Bytes 1,021-1,024 of each logical record are padded with blanks.

- Physical record size of 4,096 bytes; that is, 4 logical records per physical record.

- Data written as ANSI-standard ASCII characters.

Sample Data Records

Following are sample sets of A, B, and C records, corresponding to a typical 7.5-minute DEM (tables 1, 2, and 3), and sample sets of A and B records for a typical 1-degree DEM (tables 4 and 5). Included in these samples are literal ASCII listings of records directly from DEM distribution tapes. Following the literal listings are tabular explanations of each element in the type A, B, and C records. The tabular explanations may be used as direct references between the literal listings and the logical record type formats shown in appendixes A-C. Appendixes D-G consist of code definitions that are needed to interpret various data elements in the three records.

SAMPLE APPLICATIONS

The DEM files may be used in the generation of graphics such as isometric projections displaying slope, direction of slope, and terrain profiles between designated points. They may also be combined with other data types such as stream locations and weather data to plan forest fire control, or with remote sensing data to classify vegetation. Many nongraphic applications such as modeling terrain gravity data for use in locating energy resources, determining the volume of proposed reservoirs, calculating the amount of material removed during strip mining, and determining landslide probability have also been developed. Figures 6 and 7 show two graphic applications of DEM's.

Table 1.--Sample DEM Type A Logical Record--Mannboro, Virginia, Quadrangle (7.5 minute)

```
MANNBORO,VA                Free form information field ------------|Blank Filler field -----------------------------------|
3    EMC     2     1     1    18   0.0                  0.0                   0.0                   0.0                   0.0
                 0.0                   0.0                   0.0                   0.0                   0.0
      0.0                   0.0                   0.0                   0.0                   0.0                    2
 2    4   0.244998676000000D+06   0.412627656700000D+07   0.245420930000000D+06   0.414014832600000D+07   0.256491863000000D+06   0.4
13981850700000D+07   0.256087907000000D+06   0.412594681300000D+07   0.470000000000000D+02   0.114000000000000D+03   0.0
        10.300000E+020.300000E+020.100000E+01     1   383    00   10163008908I5 0 2 1   1
```

Data Element	Content	Explanation
1	MANNBORO, VA	Quadrangle name field.
TEXT		Bytes 41-80, free format textual information
FILLER		Bytes 81-135 reserved for future use.
PROCESS	3	Indicates DEM was made from a DLG hypso overlay
FILLER		Byte 137, blank fill
SECTIONAL INDICATOR		Bytes 138 -140 specific to 30-minute DEM, left blank for 7.5-minute DEM
2	EMC	Mapping Center origin code indicating that DEM was created in Eastern Mapping Center.
3	2	DEM level code indicating DEM level 2, synonymous with file created from DLG to DEM interpolation software.
4	1	Pattern code indicating either a regular or random elevation pattern; 1 indicates a regular pattern.
5	1	Planimetric reference system code; 1 indicates UTM coordinate system.
6	18	Code defining the zone in the ground planimetric reference system (i.e., UTM zone 18).

Table 1.--Sample DEM Type A Logical Record--Mannboro, Virginia
Quadrangle (7.5 minute)--continued

Data Element	Content	Explanation
7	0.0 (15 sets of 0.0)	Map projection parameters; all 15 fields are set to zero for the UTM coordinate system and should be ignored.
8	2	Units code; 2 represents meters as the unit of measure for ground planimetric coordinates throughout this file.
9	2	Units code; 2 represents meters as the unit of measure for elevation coordinates throughout this file.
10	4	Number (n) of sides in the polygon which defines the coverage of the DEM file (usually equal to 4).
11	0.2449986...D+06	A 4,2 array containing the ground coordinates of the four corners of the DEM. Translation to decimal format yields: 244998.7, 4126276.6; 245420.9, 4140148.3; 256491.9, 4139818.5; 256087.9 4125946.8.
12	0.47.....D+02 0.114....D+03	Minimum and maximum elevations for the DEM.
13	0.0	Counterclockwise angle (in radians) from the primary axis of ground planimetric reference to the primary axis of the DEM local reference system.
14	1	Accuracy code; 1 indicates that a record of accuracy exists and is contained in record type C.
15	0.3000000E+02 0.3000000E+02 0.1000000E+01	A three-element array containing DEM spatial resolution (x, y, z); usually set to 30, 30, 1.
16	1 383	A two-element array containing the number of rows and columns of profiles in the DEM. The row value m is usually set to 1 as an indication that the arrays are actually one-dimensional profiles. The column value n equaling 383 indicates that the DEM file consists of a total of 383 profiles.

Table 1.--Sample DEM Type A Logical Record--Mannboro, Virginia Quadrangle (7.5 minute)--continued

Data Element	Content	Explanation
17	0	Indicates no largest contour interval.
18	0	Contour interval (set to 0 if previous data field is 0).
19	10	Smallest contour interval; indicates a standard 10-foot contour interval for the source quadrangle.
20	1	Contour units; 1 represents foot contours in multiples specified in the previous data field.
21	63 00	Data source date; this DEM was generated from contours which were compiled photogrametrically in 1963. Numbers 00 indicate month is not specified. The quadrangle was photorevised in 1987; however, no significant changes were made to the contours, therefore the date of 1963 takes precedence.
22	89 08	Data inspection date; this DEM was tested and inspected on the DES on August 1989.
23	I	Inspection/revision flag; in this case, this is a new data set which has been inspected but not revised.
24	5	Data validation flag; qualitative and quantitative tests appropriate to DEM level 2 data have been performed.
25	0	Suspect/void flag; 0 indicates none.
26	2	Vertical datum; 2 indicates DEM vertical datum is National Geodetic Vertical Datum 1929 (NGVD 29).
27	1	Horizontal Datum; 1 indicates DEM horizontal datum is North American Datum of 1927 (NAD 27).
28	1	Data edition; 1 indicates this is the first edition.
29	Percent void, element 25 is 0, therefore this field is blank.	

Table 2.--Sample DEM Type B Logical Record--Mannboro, Virginia
Quadrangle (7.5 minute)

```
    1     4   111     1   0.245100000000000D+06   0.412629000000000D+07   0.0
0.540000000000000D+02  0.870000000000000D+02    78    79    79    80    80    79    80    79    76    73
  73    77    80    80    81    81    81    81    82    83    83   83    83    83    82    82    83    84
   84    84    84    84    85    86    86    87    87    87    87    87    87    87    86    85   85    84
   83    82    82    82    82    82    83    84    85    85    84    83    83    82    82    80    76
75    74    75    74    74    73    71    68    68    65    64    61    60    60    61    60    58    58
  57    57    57    56    56    55    55    55   55    55    54    55    55    55    55    56    56    56
   56    57    57    57    58    58    60    61    61    61    61    61
```

Data Element	Content	Explanation
1	1 4	Row and column identification number of the profile contained in this record; 1, 4 represents row 1, column 4, in the DEM data set.
2	111 1	Number of rows (elevations) and column in this profile; 111, 1 indicates there are 111 elevations and 1 column in this profile.
3	0.245100...D+06 0.4126290...D+07	Translated to the decimal, 245100.0 and 4126290.0 are the ground planimetric coordinates (UTM) of the first elevation in the profile.
4	0.0	Elevation of local datum for the profile.
5	0.54....D+02 0.87....D+02	Minimum and maximum elevations for the profile.
6	78 79... ....61 61	An array of m x n elevations (m=111, n=1) for the profile expressed in units of measure of meters (record A, element 9, indicates meters as units of measure) above or below the local datum (record A, element 26).

Table 3.--Sample DEM Type C Logical Record--Mannboro, Virginia Quadrangle (7.5 minute)

1 0 0 3 0 1 0 0 1 23

Data Element	Content	Explanation
1	1	Availability code; 1 indicates that an absolute accuracy estimate does exist for this file.
2	0 0 3	Absolute accuracy RMSE estimate (in x, y, and z); the first two zeros indicate that the x and y relative statistics are not available. A 3 in this field indicates that a vertical solution of 3 meters or less was computed for the source data control network.
3	0	A 0 implies that this test occurred prior to and is independent of the DEM collection process and that the number of test points is irrelevant.
4	1	Availability code; 1 indicates that statistics are available in the next element.
5	0 0 1	RMSE of DEM data relative to datum (in x, y, and z); the first two zeros indicate that the x and y relative statistics are not available. The value 1 meaning 1-meter RMSE indicates that the DEM met relative vertical (z) accuracy criteria for the 7-meter data base.
6	23	Sample size code; 23 indicates that the relative statistic of element 5 is based on 23 vertical test points.

Table 4.--Sample DEM Type A Logical Records--Reno, Nevada-California, Quadrangle (West Half) (1 degree)

```
NJ11-01W
     3    1    0    0   0.0                 0.0                 0.0                 0.0                 0.0
          0.0                 0.0                 0.0                 0.0                 0.0
  0.0                 0.0                 0.0                 0.0                 0.0                 3
 2    4  -0.428400000000000D+06   0.140400000000000D+06  -0.428400000000000D+06   0.144000000000000D+06  -0.424800000000000D+06   0.1
44000000000000D+06  -0.424800000000000D+06   0.140400000000000D+06   0.999000000000000D+03   0.264100000000000D+04   0.0
       00.300000E+010.300000E+010.100000E+01     1  1201
```

Data Element	Content	Explanation
1	NJ11-01W	Quadrangle name field (144 characters); NJ11-01W is the designation for the DEM covering the west half of the Reno, Nevada-California, sheet.
2	3	DEM level code; 3 reflects processing by NIMA which includes registration to planimetric features appearing on the source 1-degree topographic map.
3	1	Pattern code; 1 indicates a regular elevation pattern.
4	0	Planimetric reference system code; 0 indicates geographic coordinate system.
5	0	Zone code; there are no zones in the geographic system. Therefore, the zone code is set to zero.
6	0.0 (15 sets of 0.0)	Map projection parameters; all 15 fields are set to zero for the geographic system and should be ignored. Presence of non-zero parameters are not related to the geographic coordinate system and should also be ignored.
7	3	Units code; 3 represents arc-seconds as the unit of measure for ground planimetric coordinates throughout the file.
8	2	Units code; 2 represents meters as the unit of measure for elevation coordinates throughout the file.
9	4	Number (n) of sides in the polygon which defines the coverage of the DEM file (usually equal to 4).

Table 4.--Sample DEM Type A Logical Records--Reno, Nevada-California,

Quadrangle (West Half) (1 degree)--continued

Data Element	Content	Explanation
10	-0.4284...D+06, 0.1404...D+06 .... -0.4248...D+06 0.1404...D+06	A 4,2 array containing the ground coordinates of the four corners of the DEM. In this case translation from arc-seconds to degrees, minutes, and seconds yields: -119 00 00, 39 00 00; -119 00 00, 40 00 00; -118 00 00, 40 00 00; -118 00 00, 39 00 00.
11	0.9990...D+03 0.2641...D+04	Minimum and maximum elevations for the DEM.
12	0.0	Counterclockwise angle from the primary axis of ground planimetric reference to the primary axis of the DEM local reference system.
13	0	Accuracy code; 0 indicates that a record of accuracy does not exist and that no record type C will follow.
14	0.3000000E+01 0.3000000E+01 0.1000000E+01	A three-element array containing DEM spatial resolution (x, y, z); set to 3, 3, 1; or 3, 6, 1; or 3, 9, 1 depending on the latitude of the product.
15	1 1201	A two-element array containing the number of rows and columns of profiles in the DEM. The row value m is usually set to 1 as an indication that the arrays are actually one-dimensional profiles. The column value n set to 1,201 indicates that the DEM file consists of a total of 1,201 profiles.

Table 5.--Sample DEM Type B Logical Record--Reno, Nevada-California, Quadrangle (West Half) (1 degree)

```
     1     1  1201     1  -0.428400000000000D+06   0.140400000000000D+06   0.0
0.121200000000000D+04  0.177200000000000D+04  1538  1539  1539  1534  1529  1520  1513  1508  1501  1493
1488  1483  1479  1475  1474  1473  1472  1469  1469  1467  1466  1464
```

(As per 7.5-minute DEM's, element 6 contains elevations for the NIMA DEM. This field always contains 1,201 data elements per record. See Data Element 6.)

```
                                                                1422  1417  1412  1405  1401  1396  1391  1392
 1394  1397  1398  1397  1398  1398  1397  1394  1390  1386  1383  1380  1377  1374  1372  1369  1367
1366  1367  1368  1368  1369  1369  1370  1371  1371  1371  1371  1370  1371  1372  1370  1373  1373  1372
 1376  1375  1374  1374  1372  1372  1374  1374  1374  1374  1376  1378  1381
```

Data Element	Content	Explanation
1	1 1	Row and column identification number of the profile contained in this record; 1, 1 represents row 1, column 1, in the DEM data set.
2	1201 1	Number of rows (elevations) and columns in this profile; 1201, 1 indicates there are 1,201 elevations and 1 column in this profile.
3	-0.4284...D+06 0.1404...D+06	Translated to the decimal, -428400.0 and 1404000.0 are the ground planimetric coordinates (arc-seconds) of the first elevation in the profile, thus computed equal to -119 and 39 degrees.
4	0.0	Elevation of local datum for the profile. Always zero for 1-degree DEM, the reference is mean sea level.
5	0.1212...D+04 0.1772...D+04	Minimum and maximum elevations for the profile.
6	1538 1539... ....1378 1381	An array of m x n elevations (m=1201, n=1) for the profile expressed in units of measure of meters (record A, element 8, indicates meters as units of measure) above or below the local datum (record a, element 4).

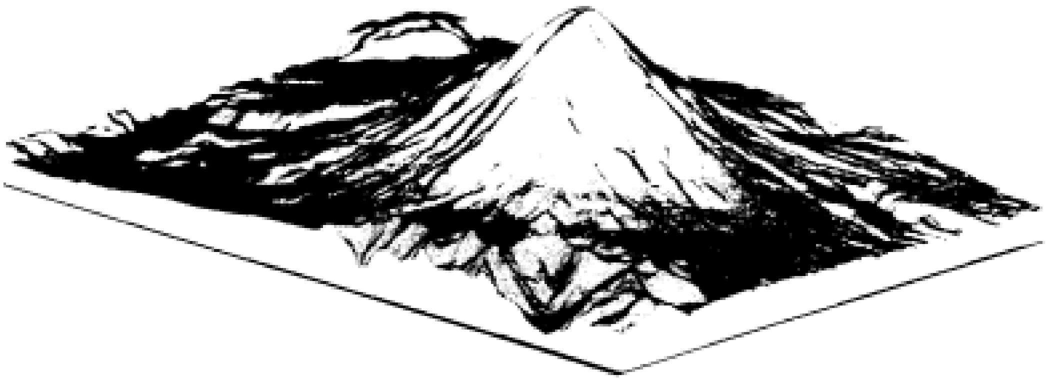


Figure 6.--Preeruption isometric plot of Mount St. Helens 7.5-minute Digital Elevation Models generated from data obtained from July 15, 1979, photographs. View is from the northeast at a 45° altitude angle; vertical exaggeration is 3:1.

Figure 7.--Posteruption isometric plot of Mount St. Helens 7.5-minute Digital Elevation Models generated from data obtained from September 6, 1980, photographs. View is from the northeast at a 45° altitude angle; vertical exaggeration is 3:1.

APPENDIXES

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
1	File name	ALPHA	A40	1	40	Authorized DEM quadrangle name.
	Free Format Text	ALPHA	A40	41	80	Free format descriptor field, contains useful information related to digital process such as digitizing instrument, photo codes, slot widths, etc.
	Filler	---	---	81	135	
	Process Code	ALPHA	A1	136		Code 1=GPM 2=Manual Profile 3=DLG2DEM (includes any DLG type process such as CTOG or LINETRACE) 4=DCASS
	Filler	---	---	137		
	Sectional Indicator	ALPHA	A3	138	140	This code is specific to 30-minute DEM's. Identifies 1:100,000-scale sections. Formatted as XNN, where X is "s"=7.5-minute, "F"=15-minute, and NN is a two-digit sequence number.
2	MC origin code	ALPHA	A4	141	144	Mapping Center origin Code. Valid codes are EMC, WMC, MCMC, RMMC, FS, GPM2.
3	DEM level code	INTEGER*2	I6	145	150	Code 1=DEM-1 2=DEM-2 3=DEM-3
4	Code defining elevation pattern (regular or random)	INTEGER*2	I6	151	156	Code 1=regular 2=random is reserved for future use.

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
5	Code defining ground planimetric reference system	INTEGER*2	I6	157	162	Code 0=Geographic 1=UTM 2=State plane For codes 3-20, see appendix F. Code 0 represents the geographic (latitude/longitude) system for 30-minute, 1-degree and Alaska DEM's. Code 1 represents the current use of the UTM coordinate system for 7.5-minute DEM's.
6	Code defining zone in ground planimetric reference system	INTEGER*2	I6	163	168	Codes for State plane and UTM coordinate zones are given in appendixes D and E for 7.5-minute DEM's. Code is set to zero if element 5 is also set to zero defining data as geographic.
7	Map projection parameters (see appendix F)	REAL*8	15D24.15	169	528	Definition of parameters for various projections is given in appendix F. All 15 fields of this element are set to zero and should be ignored when geographic, UTM, or State plane coordinates are coded in data element 5.
8	Code defining unit of measure for ground planimetric coordinates throughout the file	INTEGER*2	I6	529	534	Code 0=radians 1=feet 2=meters 3=arc-seconds Normally set to code 2 for 7.5-minute DEM's. Always set to code 3 for 30-minute, 1-degree, and Alaska DEM's.

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
9	Code defining unit of measure for elevation coordinates throughout the file	INTEGER*2	I6	535	540	Code 1=feet 2=meters Normally code 2, meters, for 7.5-minute, 30-minute, 1-degree, and Alaska DEM's.
10	Number (n) of sides in the polygon which defines the coverage of the DEM file	INTEGER*2	I6	541	546	n=4.
11	A 4,2 array containing the ground coordinates of the four corners for the DEM	REAL*8	4(2D24.15)	547	738	The coordinates of the quadrangle corners are ordered in a clockwise direction beginning with the southwest corner. The array is stored row-wise as pairs of eastings and northings.
12	A two-element array containing minimum and maximum elevations for the DEM	REAL*8	2D24.15	739	786	The values are in the unit of measure given by data element 9 in this record.
13	Counterclockwise angle (in radians) from the primary axis of ground planimetric reference to the primary axis of the DEM local reference system	REAL*8	D24.15	787	810	See figure 5. Set to zero to align with the coordinate system specified in element 5.

Data Element		Type (FORTRAN Notation)	Physical Record Format: ASCII Format	Starting byte	Ending byte	Comment
14	Accuracy code for elevations	INTEGER*2	I6	811	816	Code 0=unknown accuracy 1=accuracy information is given in logical record type C.
15	A three-element array of DEM spatial resolu-tion for x, y, z. Units of measure are consistent with those indicated by data elements 8 and 9 in this record	REAL*4	3E12.6	817	852	These elements are usually set to; 30, 30, 1 for 7.5-minute DEM's; 2, 2, 1 for 30-minute DEM's; 3, 3, 1 for 1-degree DEM's. 2, 1, 1 for high resolution DEM's in Alaska 3, 2, 1 for low resolution DEM's in Alaska. 7.5-minute DEM'S will eventually be converted to geographics, i.e., 1,1,1.
16	A two-element array containing the num-ber of rows and columns (m,n) of profiles in the DEM	INTEGER*2	2I6	853	864	When the row value m is set to 1 the n value describes the number of columns in the DEM file. Raw GPM data files are set to m=16, n=16.
Note:	*Old format stops here*					
17	Largest primary contour interval	INTEGER*2	I5	865	869	Present only if two or more primary intervals exist.
18	Source contour interval units	INTEGER*1	I1	870		Corresponds to the units of the map largest primary contour interval 0=N.A., 1=feet, 2=meters.
19	Smallest primary	INTEGER*2	I5	871	875	Smallest or only primary contour interval
20	Source contour interval units	INTEGER*1	I1	876		Corresponds to the units of the map smallest primary contour interval. 1=feet, 2=meters.

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
21	Data source date	INTEGER*2	I4	877	880	YYMM two-digit year and two-digit month MM = 00 for source having year only.
22	Data inspection/ revision date	INTEGER*2	I4	881	884	YYMM two-digit year and two-digit month.
23	Inspection/ revision flag	ALPHA*1	A1	885		"I" or "R"
24	Data validation flag	INTEGER*1	I1	886		0= No validation performed. 1=TESDEM (record C added) no qualitative test (no DEM Edit System [DES] review). 2=Water body edit and TESDEM run. 3=DES (includes water edit) no qualitative test (no TESDEM). 4=DES with record C added, qualitative and quantitative tests for level 1 DEM. 5=DES and TESDEM qualitative and quantitative tests for levels 2 and 3 DEM's.
25	Suspect and void area flag	INTEGER*1	I2	887	888	0=none 1=suspect areas 2=void areas 3=suspect and void areas

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
26	Vertical datum	INTEGER*1	I2	889	890	1=local mean sea level 2=National Geodetic Vertical Datum 1929 (NGVD 29) 3=North American Vertical Datum 1988 (NAVD 88)
27	Horizontal datum	INTEGER*1	I2	891	892	1=North American Datum 1927 (NAD 27) 2=World Geodetic System 1972 (WGS 72) 3=WGS 84 4=NAD 83 5=Old Hawaii Datum 6=Puerto Rico Datum 7=NAD 83 Provisional (shifts in horizontal coordinates are computed, but old DEM nodes are not resampled)
28	Data Edition	INTEGER*2	I4	893	896	01-99 Primarily a NIMA specific field.
29	Percent Void	INTEGER*2	I4	897	900	If element 25 indicates a void, this field (right justified) contains the percentage of nodes in the file set to void (-32,767).

APPENDIX B.--Digital Elevation Model Data Elements
Logical Record Type B

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
1	A two-element array containing the row and column identification number of the DEM profile contained in this record	INTEGER*2	2I6	1	12	See figure 5. The row/column numbers may range from 1 to m and 1 to n. The row number is normally set to 1. The column identification is the profile sequence number.
2	A two-element array containing the number (m, n,) of elevations in the DEM profile	INTEGER*2	2I6	13	24	See figure 5. The first element in the field corresponds to the number of rows and columns of nodes in this profile. The second element is set to 1, specifying 1 column per B record.
3	A two-element array containing the ground planimetric coordinates (X_{go},Y_{go}) of the first elevation in the profile	REAL*8	2D24.15	25	72	See figure 5.
4	Elevation of local datum for the profile	REAL*8	D24.15	73	96	The values are in the units of measure given by data element 9, logical record type A.

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
5	A two-element array of minimum and maximum elevations for the profile	REAL*8	2D24.15	97	144	The values are in the unit of measure given by data element 9 in logical record type A.
6	A m,n array of elevations for the profile. Elevations are expressed in units of resolution	INTEGER*2	mn(I6)	6x(146 or 170) 146 = max for first block. 170 = max for subsequent blocks		See data element 15 in appendix A. A value in this array would be multiplied by the spatial resolution value and added to the elevation of the local elevation datum for the element profile (data element 4 in this record) to obtain the elevation for the point. The planimetric ground coordinates of the point X_{gp}, Y_{gp}, are computed according to the formulas in figure 5.

APPENDIX C.--Digital Elevation Model Data Elements
Logical Record Type C

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
1	Code indicating availability of statistics in data element 2	INTEGER*2	I6	1	6	Code 1=available 0=unavailable
2	RMSE of file's datum relative to absolute datum (x, y, z)	INTEGER*2	3I6	7	24	In same units as indicated by elements 8 and 9 of logical record type A.
3	Sample size on which statistics in data element 2 are based	INTEGER*3	I6	25	30	If 0, then accuracy will be assumed to be estimated rather than computed.
4	Code indicating availability of statistics in data element 5	INTEGER*2	I6	31	36	Code 1=available 0=unavailable
5	RMSE of DEM data relative to file's datum (x, y, z)	INTEGER*2	3I6	37	54	In same units as indicated by elements 8 and 9 of logical record type A.
6	Sample size on which statistics in element 5 are based	INTEGER*2	I6	55	60	If 0, then accuracy will be assumed to be estimated rather than computed.

APPENDIX D.--Sample Quadrilateral Coordinates

Quad Corner No.	Geographic Coordinates		UTM Coordinates	
	Latitude	Longitude	Easting	Northing
1	35°30’	107°37′30"	261897	3931463
2	35°37′30"	107°37′30"	262267	3945330
3	35°37′30"	107°30′	273590	3945036
4	35°30′	107°30′	273238	3931169

APPENDIX E.--Codes for State Plane Coordinate Zones

Alabama, East (AL)	0101
Alabama, West	0102
Alaska (AK)	5001
	thru 5010
Arizona, Central (AZ)	0203
Arizona, East	0201
Arizona, West	0202
Arkansas, North (AR)	0301
Arkansas, South	0302
California (CA)	0401
	thru 0407
Colorado, Central (CO)	0502
Colorado, North	0501
Colorado, South	0503
Connecticut (CT)	0600
Delaware (DE)	0700
District of Columbia (DC)	1900
Florida, East (FL)	0901
Florida, North	0903
Florida, West	0902
Georgia, East (GA)	1001
Georgia, West	1002
Hawaii (HI)	5101
	thru 5105
Idaho, Central (ID)	1102
Idaho, East	1101
Idaho, West	1103
Illinois, East (IL)	1201
Illinois, West	1202
Indiana, East (IN)	1301
Indiana, West	1303
Iowa, North (IA)	1401
Iowa, South	1402
Kansas, North (KS)	1501
Kansas, South	1502
Kentucky, North (KY)	1601
Kentucky, South	1602
Louisiana, North (LA)	1701
Louisiana, Off Shore	1703
Louisiana, South	1702
Maine, East (ME)	1801
Maine, West	1802
Maryland (MD)	1900
Massachusetts, Island (MA)	2002
Massachusetts, Mainland	2001
Michigan, Central (MI)	2102
Michigan, Central (Lambert)	2112
Michigan, East	2101
Michigan, North (Lambert)	2111
Michigan, South (Lambert)	2113
Michigan, West	2103
Minnesota, Central (MN)	2202
Minnesota, North	2201
Minnesota, South	2203
Mississippi, East (MS)	2301
Mississippi, West	2302
Missouri, Central (MO)	2402
Missouri, East	2401
Missouri, West	2403
Montana, Central (MT)	2502
Montana, North	2501
Montana, South	2503
Nebraska, North (NE)	2601
Nebraska, South	2602
Nevada, Central (NV)	2702
Nevada, East	2701
Nevada, West	2703
New Hampshire (NH)	2800
New Jersey (NJ)	2900
New Mexico, Central (NM)	3002
New Mexico, East	3001
New Mexico, West	3003
New York, Central (NY)	3102
New York, East	3101
New York, Long Island	3104
New York, West	3103
North Carolina (NC)	3200
North Dakota, North (ND)	3301
North Dakota, South	3302
Ohio, North (OH)	3401
Ohio, South	3402
Oklahoma, North (OK)	3501
Oklahoma, South	3502
Oregon, North (OR)	3601
Oregon, South	3602
Pennsylvania, North (PA)	3701
Pennsylvania, South	3702
Rhode Island (RI)	3800
South Carolina, North (SC)	3901
South Carolina, South	3902
South Dakota, North (SD)	4001
South Dakota, South	4002
Tennessee (TN)	4100
Texas, Central (TX)	4203
Texas, North	4201
Texas, North Central	4202
Texas, South	4205
Texas, South Central	4204

Utah, Central (UT)	4302
Utah, North	4301
Utah, South	4303
Vermont (VT)	4400
Virginia, North (VA)	4501
Virginia, South	4502
Washington, North (WA)	4601
Washington, South	4602
West Virginia, North (WV)	4701
West Virginia, South	4702
Wisconsin, Central (WI)	4802
Wisconsin, North	4702
Wisconsin, South	4803
Wyoming, Zone I, East (WY)	4901
Wyoming, Zone II, East Central	4902
Wyoming, Zone III, West Central	4903
Puerto Rico (PR)	5301
Virgin Islands, St. Croix (VI)	5202
Virgin Islands, St. John, St. Thomas	5201
American Samoa (AS)	5300
Guam (GU)	5400

source: Federal Information Processing Standard (FIPS) Publication 70-1, 1986

APPENDIX F.--Universal Transverse Mercator Zone Locations and Central Meridians

Zone	C.M.	Range	Zone	C.M.	Range
01	177W	180W-174W	31	003E	000E-006E
02	171W	174W-168W	32	009E	006E-012E
03	165W	168W-162W	33	015E	012E-018E
04	159W	162W-156W	34	021E	018E-024E
05	153W	156W-150W	35	027E	024E-030E
06	147W	150W-144W	36	033E	030E-036E
07	141W	144W-138W	37	039E	036E-042E
08	135W	138W-132W	38	045E	042E-048E
09	129W	132W-126W	39	051E	048E-054E
10	123W	126W-120W	40	057E	054E-060E
11	117W	120W-114W	41	063E	060E-066E
12	111W	114W-108W	42	069E	066E-072E
13	105W	108W-102W	43	075E	072E-078E
14	099W	102W-096W	44	081E	078E-084E
15	093W	096W-090W	45	087E	084E-090E
16	087W	090W-084W	46	093E	090E-096E
17	081W	084W-078W	47	099E	096E-102E
18	075W	078W-072W	48	105E	102E-108E
19	069W	072W-066W	49	111E	108E-114E
20	063W	066W-060W	50	117E	114E-120E
21	057W	060W-054W	51	123E	120E-126E
22	051W	054W-048W	52	129E	126E-132E
23	045W	048W-042W	53	135E	132E-138E
24	039W	042W-036W	54	138E	138E-144E
25	033W	036W-030W	55	147E	144E-150E
26	027W	030W-024W	56	153E	150E-162E
27	021W	024W-018W	57	159E	156E-162E
28	015W	018W-012W	58	165E	162E-168E
29	009W	012W-006W	59	171E	168E-174E
30	003W	006W-000E	60	177E	174E-180W

APPENDIX G.--Parameters Required for Definition of Map Projections

Parameter	(00)* Geographic	(01)** Universal Transverse Mercator (UTM)	(02) State Plane	(03) Albers Conical Equal Area / (04) Lambert Conformal
1	***	Longitude of any point within the zone	***	Semimajor axis of ellipsoid. If this field is left blank (=0), the value for Clarke's 1866 spheroid in meters will be assumed.
2	***	Latitude of any point within the UTM zone	***	Eccentricity squared of ellipsoid (e^2). If field is zero, this will indicate a sphere. If the field is 1, this field will be interpreted as containing the semiminor axis of the ellipsoid.
3	***	***	***	Latitude of 1st standard parallel
4	***	***	***	Latitude of 2d standard parallel
5	***	***	***	Longitude of central meridian
6	***	***	***	Latitude of projection's origin
7	***	***	***	False easting in the same units of measure as the semimajor axis of ellipsoid
8	***	***	***	False northing in the same units of measure as the semimajor axis of ellipsoid
9-15 (not used for projections on this page)				

* Projection code number.

** For the Northern Hemisphere, supplying UTM zone will result in ignoring any given projection parameters.

*** Parameter is not applicable to projection.

Note: All angles (latitudes, longitudes, or azimuth) are required in degrees, minutes, and arc-seconds in the packed real number format +DDDMMSS.SSSSS.

Parameter	(05) Mercator	(06) Polar Stereographic	(07) Polyconic	(08) Equidistant Conic Type A	Type B
1	Semimajor axis of ellipsoid. If this field is left blank (=0), the value for Clarke's 1866 spheroid in meters will be assumed.				
2	Eccentricity squared of ellipsoid (e). If field this is left blank (=0), this will indicate a sphere. If the field is 1, this field will be interpreted as containing the semiminor axis of the ellipsoid.				
3	***	***	***	Latitude of standard parallel	Latitude of 1st standard parallel
4	***	***	***	***	Latitude of 2d standard parallel
5 Longitude of Central Meridian	Longitude directed straight down below pole of map	. . . . . . Longitude of central meridian			
6	***	Latitude of true scale	. . . . . . Latitude of projection's origin		
7	. . . . . False easting in the same units of measure as the semimajor axis of ellipsoid				
8	. . . . . False northing in the same units of measure as the semimajor axis of ellipsoid				
9	***	***	***	Zero	Any non-zero number
10-15 (not used for projections on this page)					

Parameter	(09) Transverse Mercator	(10) Stereographic	(11) Lambert Azimuthal Equal-Area	(12) Azimuthal Equidistant	(13) Gnomonic	(14) Orthographic
1	Same as projections 03 thru 08	. . . . .Radius of the sphere of reference . . . . If this field is left blank, the value 6370997.0 meters will be assumed				
2	Same as projections 03 thru 08	***	***	***	***	***
3	Scale factor at central meridian	***	***	***	***	***
4	***	***	***	***	***	***
5	Longitude of central meridian	. . . . .Longitude of center of projection				
6	Latitude of origin	. . . . Latitude of center of projection				
7	False easting in the same units of measure as the semimajor axis or radius of the sphere					
8	False northing in the same units of measure as the semimajor axis or radius of the sphere					
9-15 (not used for projections on this page)						

Parameter	(15) General Vertical Near-Side Perspective	(16) Sinusoidal (Plate Caree)	(17) Equirectangular	(18) Miller Cylindrical	(19) Van Der Grinten I
1	. . . . Radius of the sphere of reference . . . . If this field is left blank, the value 6370997.0 meters will be assumed.				
2	***	***	***	***	***
3	Height of perspective point above sphere	***	***	***	***
4	***	***	***	***	***
5	Longitude of center of projection	. . . . Longitude of central meridian			
6	Latitude of center of projection	***	***	***	***
7	. . . . False easting in the same units of measure as radius of the sphere				
8	. . . . False northing in the same units of measure as radius of the sphere				
9-15 (not used for projections on this page)					

Parameter	(20) Oblique Mercator (Definition Format A)	(Definition Format B)	Parameter	(20) Oblique Mercator (Definition Format A)	(Definition Format B)
1	Same as for projections 03 thru 09		9	Longitude of first point defining central geodetic line of projection	***
2	Same as for projections 03 thru 09		10	Latitude of first point defining central geodetic line of projection	***
3	Scale factor at the center of projection		11	Longitude of second point defining central geodetic line of projection	***
4	***	Angle of azimuth east of north for central line of projection	12	Latitude of second point defining central geodetic line of projection	***
5	***	Longitude of point along central line of projection at which angle of azimuth is measured	13	Zero	Any non-zero number
6	Latitude of origin of projection		14 and 15 (not used for this projection)		
7	Same as for projections 03 thru 19				
8	Same as for projections 03 thru 19				

APPENDIX H.--National and International Datums Used for Digital Elevation Data

Two types of horizontal datums are presently in use for DEM data distributed by the USGS, the civilian North American Datum (NAD) and military World Geodetic System (WGS). The NAD 27 datum is currently used to define positions on USGS topographic maps and 7.5-minute DEM's. Plans are to convert to the new NAD 83 for these applications. The WGS 72 is currently used to define positions for 1-degree NIMA DEM's and DTED's. NIMA is converting these data to the new WGS 84. The NAD 83 and WGS 84 datums are being phased into the mapping community at different rates or where resources are available. For the conterminous United States these new datums are considered to be functionally the same; however, the two have been defined separately since they were designed to serve different segments of the mapping community, primarily civilian and military. The following information will help clarify the relationship between these datums.

The Role of the Ellipsoid in Defining Datums

Unlike local surveys, which treat the Earth as a plane, the precise determination of the latitude and longitude of points over a broad area must take into account the actual shape of the Earth. To achieve the precision necessary for very accurate location, the Earth cannot simply be assumed to be a sphere. Rather, the Earth's shape more closely approximates an ellipsoid (oblate spheroid): flattened at the poles and bulging at the Equator. Thus the Earth's shape, when cut through its polar axis, approximates an ellipse.

Geodetic surveying, which takes into account variations in the shape of the Earth, is based on a reference ellipsoid to the geoid, the actual shape of the Earth, that is selected as a best fit over a limited area. The ellipsoid used to define a datum is a mathematical surface upon which computation of position can be based, as opposed to the actual surface of the Earth on which surveys are conducted. The geoid, which approximates the sea level surface, is an equipotential surface of the Earth's gravity field. It can be thought of as a continuous sea-level surface extended beneath the continents. It is the "level" surface of reference for astronomic observations and geodetic leveling, but because of undulations that respond to the Earth's mass distributions, it is not a useful computational surface for horizontal surveys.

Horizontal Surveys -- Conversions

NAD 27

The NAD 27 is defined with an initial point at Meades Ranch, Kansas, and by the parameters of the Clarke 1866 ellipsoid. The location of features on USGS topographic maps, including the definition of 7.5-minute quadrangle corners, are referenced to the NAD 27.

NAD 83

Using recent measurements with modern geodetic, gravimetric, astrodynamic, and astronomic instruments, the Geodetic Reference System 1980 (GRS 80) ellipsoid has been defined as a best fit to the worldwide geoid. Unlike NAD 27, which is based on an initial point (Meades Ranch, Kansas), NAD 83 is an Earth-centered datum and uses the GRS 80 ellipsoid. Because the NAD 83 surface deviates from the NAD 27 surface, the position of a point based on the two reference datums will be different.

WGS 72

The definition of NIMA DEM's, as presently stored in the USGS data base, references the WGS 72 datum. Like NAD 83, WGS 72 is an Earth-centered datum. The WGS 72 datum was the result of an extensive effort extending over approximately three years to collect selected satellite, surface gravity, and astrogeodetic data available through 1972. The combination of the data was performed using a unified WGS solution (a large-scale least squares adjustment). Such an adjustment was made possible in part because of the availability of adequate computers and software.

WGS 84

The WGS 84 datum was developed as a replacement for WGS 72 by the military mapping community as a result of newer, more accurate instrumentation and more comprehensive control networks. It is an improvement over WGS 72 in several respects. New and more extensive data sets and improved software were used in the development. A more extensive file of Doppler-derived station coordinates was available and for many more local geodetic systems; improved sets of ground-based Doppler and laser satellite-tracking data and surface gravity were available; and geoid heights were deduced from satellite radar altimetry (a new data type) for oceanic regions between 70° north and south latitude (approximately). This system is described in "World Geodetic System 1984," Department of Defense NIMA TR 8350.2, September 1987.

NIMA has recomputed the 1-degree DTED's for the contiguous United States and has made a copy of the data set available to the USGS.

NAD 27 - NAD 83

The methods available for transformation from NAD 27 to NAD 83 can result in inconsistencies. Therefore, a single method of conversion has been adopted by the USGS. The method involves the use of 7.5-minute grid intersection tables developed by the National Ocean Service and the software program NADCON, which is available as an interactive PC-based program or adapted to batch processing on PC or mainframe computers. Bilinear interpolation of the shifts derived for the four quadrangle corners results in a uniform horizontal translation of values which are applied to all points interior to and including the edges of the quadrangle.

WGS 72 - WGS 84

Table H-1 contains information on converting WGS 72 coordinates to WGS 84. There are no NIMA plans to develop WGS 72 coordinates of improved accuracy. However, if WGS 84 coordinates have been determined, the WGS 72-to-WGS 84 formulation in table H-1 can be reversed and used with the WGS 84 coordinates to obtain improved WGS 72 coordinates.

DEM Datum Identification

The datum applicable to a given DEM data set can generally be determined by the following criteria:

All USGS DEM's lacking the new record A, elements 16-29, are NAD 27.
All NIMA DEM's and DTED's lacking datum descriptors are WGS 72.
All DEM's having the new record A elements have datums as indicated in record A, element 28.

Table H1.--Difference Between WGS 84 and WGS 72 Geodetic Coordinates*

	Difference (Meters)		
Degrees	Latitude	Longitude	Height
90 N	0.0	0.0	4.1
85	0.4	1.5	4.1
80	0.8	3.0	4.0
75	1.3	4.4	3.9
70	1.7	5.9	3.8
65	2.1	7.2	3.6
60	2.4	8.6	3.4
55	2.8	9.8	3.2
50	3.1	11.0	3.0
45	3.4	12.1	2.7
40	3.6	13.1	2.4
35	3.9	14.0	2.0
30	4.1	14.8	1.7
25	4.2	15.5	1.3
20	4.4	16.1	1.0
15	4.4	16.5	0.6
10	4.5	16.5	0.2
5 N	4.5	17.1	-0.2
0	4.5	17.1	-0.6
5 S	4.4	17.1	-1.0
10	4.4	16.9	-1.4
15	4.2	16.5	-1.8
20	4.1	16.1	-2.1
25	3.9	15.5	-2.5
30	3.7	14.8	-2.8
35	3.5	14.0	-3.1
40	3.3	13.1	-3.4
45	3.0	12.1	-3.7
50	2.7	11.0	-3.9
55	2.4	9.8	-4.2
60	2.1	8.6	-4.3
65	1.7	7.2	-4.5
70	1.4	5.9	-4.7
75	1.1	4.4	-4.8
80	0.7	3.0	-4.8
85	0.4	1.5	-4.9
90 S	0.0	0.0	-4.9

*Applies only when proceeding directly from WGS 72 coordinates to WGS 84 coordinates; does not contain the effect of the WGS 84 Earth gravitational model and geoid, nor the effect of local geodetic system-to-WGS 84 datum shifts being better than local geodetic system-to-WGS 72 datum shifts.