National Mapping Program
Technical Instructions

Part 2
Specifications

Standards for Digital Elevation Models

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

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2. SPECIFICATIONS

2.1 DEFINITIONS: ERRORS AND BLUNDERS

DEM data contain errors of three types: blunders, which are removed prior to entry in the data base; systematic errors, which occur in a system-specific or a procedure-specific pattern; and random errors, which are of a purely random nature and are completely unpredictable. Although all three types may be reduced in magnitude by refinements in technique and precision, they cannot be completely eliminated.

2.1.1 Blunders

For DEM data, a blunder is a vertical error usually of major proportions often exceeding the maximum absolute error permitted (3 sigma) for each DEM level (see section 2.3) and as such is easily identifiable. Moreover, a blunder is an indication that the data collection process has deteriorated beyond the level of simple systematic or random errors. Blunders are mistakes caused by misreading contours, transposing numeric values, erroneous correlations, or careless observations. Wherever detected, errors caused by blunders must be removed.

2.1.2 Systematic Errors

Systematic errors are those errors that follow some fixed pattern or rule, are generally of constant magnitude or sign, are introduced by procedures or systems, and are typically predictable. These types of errors cause bias or artifacts in the final product. For DEM data, typical systematic errors include: vertical elevation shifts, either for the quadrangle as a whole or for individual local areas or profiles; fictitious features, such as phantom tops, ridges, benches, or striations; and improper interpretation of terrain surfaces due to the effects of trees, buildings, and shadows. Systematic errors can be eliminated or substantially reduced when the cause is known.

2.1.3 Random Errors

Random errors are those remaining after blunders and systematic errors have been removed. They result from accidental and unknown combinations of causes beyond the control of the observer. Random errors are classed as normally distributed and are characterized by: (1) variation in sign - positive and negative errors occurring with equal frequency, (2) small errors occurring more frequently than large errors, and (3) extremely large errors rarely occurring.

2.1.4 Root-Mean-Square Error

The vertical root-mean-square error (RMSE) statistic is used to describe the vertical accuracy of a DEM, encompassing both random and systematic errors introduced during production of the data. The RMSE is defined as:

$$RMSE = \sqrt{\frac{\sum (Z_i - Z_t)^2}{n}}$$

where Z_i = interpolated DEM elevation of a test point
Z_t = true elevation of a test point
n = number of test points

For Z_t, true elevation refers to the most probable elevation, because values are normally taken from production map sources. Field control or vertical aerotriangulation control points should be used if available. The RMSE derived from the above accuracy computation is encoded in element number 5 of record C of the DEM. Accuracy is computed by a comparison of linear interpolated elevations in the DEM with corresponding known elevations. Test points should be well distributed, representative of the terrain, and have true elevations with accuracies well within the DEM accuracy criteria. Acceptable test points include, in order of preference: field control, aerotriangulated test points, spot elevations, or points on contours from existing source maps with appropriate contour interval. Care should be exercised in selecting bench mark or supplemental bench mark control points from map sources because many of these are on structures above the ground (freeway right-of-ways, overpasses, railroad bridges, etc.). When in doubt, don't use these points. A minimum of 28[1] test points per DEM is required to compute the RMSE, which is composed of a single test using 20 interior points and 8 edge points. Edge points are those which are located along, at, or near the quadrangle neatlines and are deemed by the editor to be useful to evaluating the accuracy of the edge of the DEM. Collection of test point data and comparison of the DEM with the quadrangle hypsography are conducted by the quality control units within the USGS.

2.1.4.1 Edge Consistency

Edge testing is incorporated as part of the interior RMSE test. As indicated in section 2.1.4, a minimum of 28 test points per DEM is required. Exceptions are allowed for sheets consisting primarily of water or other void areas such as along international borders. In such cases a minimum of 20 points is required to compute the RMSE even though the points are in close proximity on the available land masses. In the case of arc second DEM's where common points along edges exist between two DEM's, the production centers are responsible for determining the currency and relative accuracy of the affected DEM's before making a determination whether to hold the elevations of one DEM's common edge in preference to the adjoining DEM's edge or whether to mean or feather both edges together with common weights.

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[1] Principals of Error Theory and Cartographic Applications, Aeronautical Chart and Information Center Technical Report No. 96, Feb. 1962, C. R. Greenwalt and M. E. Shultz, St. Louis, Missouri.

2.2 ACCURACY

A number of factors affect gridding processes and the accuracy of the final DEM product.

- o All DEM's where the companion map (of the same geographic extent) contour interval is 10 foot or less are gridded in vertical units of feet.

- o A dependency exists between the scale of the source materials and the level of detail or grid refinement that is possible from a given source.

- o During the process of changing scale, from large to small, some source data may be generalized or dropped out and, therefore, some features would not be available for formation of, or incorporation into, a grid at that scale.

- o The process of forming a grid with regular spacing requires the transfer of precise point or vector data to generalized grid square corners using a process similar to taking a simple weighted average. This process may alter the apparent position upon display of point or vector source data, reducing the ability to recover positions of specific features whose dimensions are less than the internal grid cell spacing.

- o The DEM collection process normally consists of successive stages of production through which errors may be cumulative: a highly accurate aerotriangulation solution, compilation of source data sets, and the final gridding process. In the case of derivation of DEM's from digital line graphs (DLG), the first two stages of production have their origins in the original compilation of the source map. If each stage of production satisfies accuracy criteria customarily applied to each intermediate product, then the maximum error that can be expected from all processes may be accumulated as a integral sum of all errors, such that the total error squared is the sum of the squares of the individual errors. So that each product in this production process may qualify to be used in the next step of the process, production personnel must make a strict accounting of accuracy for each production step leading to the final DEM.

- For cartographic-source DEM data, accuracy is highly dependent on original materials. Existing quadrangles that are used as source for hypsography and hydrography must conform to National Map Accuracy Standards (NMAS). Further, USGS map digitizing accuracy must conform to Standards for Digital Line Graphs, when DLG data are used as input to USGS gridding algorithms that produce DEM's .

2.2.1 Horizontal Accuracy

The horizontal positions of grid posts in USGS DEM's are located at precise mathematically defined positions in UTM meters or arc seconds. These grid posts are fixed in position and can be considered constants for the purpose of determining accuracy. The only measurable or perceivable errors in the DEM exist as vertical errors that may be partially attributable to horizontal error inherent in the source data or to errors in converting horizontal and vertical components of the source to gridded format. Therefore, to measure the horizontal error within the DEM with any degree of confidence, the vertical component of the feature to be measured must be clearly identified; that is, the shape of the feature to be measured must be recognizable and then the horizontal position of that feature may be verified.

2.2.2 Vertical Accuracy

All USGS DEM's are tested and assigned a vertical RMSE. By so doing, the USGS is able to determine that its general procedures for collecting DEM's ensure a high level of data accuracy. Vertical accuracy specifications for DEM data depend on the production methodology, e.g. cartographic source, photogrammetric source, and degree of editing. RMSE calculation is specified in section 2.1.4, classification levels are specified in section 2.3, and production systems are referenced in table 1-2.

Because of practical limitations inherent in all collection systems there will always be some artifacts such as benches, striations, patches, or some other anomaly that imparts some signature of the collection system in the data set. Some of these artifacts, although falling within normal DEM vertical error tolerances, can coalesce with valid surface features. This coalescence should not be tolerated to the point where valid surfaces become unintelligible to the users of the data. For example:

- Isolated tops must be depicted with their approximate size and shape.
- Flat trending surfaces must be depicted as generally flat trending without confusing patterns or striations.
- Water bodies must be flat, be lower than the surrounding terrain, and have shorelines clearly delineated.

Corrective actions must be taken to minimize these artifacts; all DEM's must be viewed and edited before being submitted to the NDCDB.

For all DEM's, the grid spacing and spatial resolution results in data intervals that span terrain discontinuities, such as benches, tops, and drainage. Some features can be appropriately captured at a given grid spacing while other, smaller features are subdued or filtered out altogether.

2.2.3 Edge Matching

Edge matching is a process of matching elevation values along common quadrangle edges.

Prior to edge matching, the majority of in-process DEMs may have noticeable edge breaks of approximately 1 to 3 vertical units of resolution (feet or meters). Under these conditions, enforcement of a simple edge matching filter extending approximately 5 rows or columns to both sides of the edge should produce adequate topographic definition. Instances of breaks in excess of 3 vertical units of resolution require more extensive editing. Edge matching along these edges may include conventional editing procedures such as recontouring of local areas or use of area smoothing or filtering to extend to a maximum of 30 rows or columns to both sides of the edge.

2.2.4 Quality Control Flags

Information in the header of the DEM indicates the status of the file with respect to the edge matching as described above. The four status flags contain the status of the West, North, East, and South edges of a DEM as compared to the edges of the four adjoining DEM files.

The possible status values for a DEM entered into the NDCDB are:

1 = edge match checked and joined

Satisfies the intent of section <u>2.2.3 Edge Matching</u>.

2 = incompatible source.

This status value indicates that the adjoining DEM is on a different horizontal or vertical datum, and therefore should not be matched. The datums of the DEM are as indicated in the type A record, Appendix 2-A, elements 26 and 27.

3 = edge external to project, no match required

This standard does not require external project edges to be matched.

4 = vertical units not compatible, edge not joined

Normally no attempt is made to join DEMs which are generated in different vertical units, such as feet versus meters.

2.3 CLASSIFICATION LEVELS

DEM's are classified 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 DEM record A. Data failing to meet the elements required for that classification level (see part 3, Quality Control) are not entered into the NDCDB and are either returned for further editing or rejected.

2.3.1 Level 1

Level 1 DEM's are elevation data sets in a standardized format. This level includes 7.5-minute DEM's or an equivalent that is derived from stereo profiling or image correlation of National High Altitude Photography Program, National Aerial Photography Program, or equivalent photographs.

A vertical RMSE of 7 meters or less is the desired accuracy standard. A RMSE of 15 meters is the maximum permitted. A 7.5-minute DEM at this level has a absolute elevation error tolerance of 50 meters (approximately three times the 15-meter RMSE) for blunders for any grid node when compared to the true elevation. Any array of points in the DEM can not encompass more than 49 contiguous elevations in error by more than 21 meters (three times the 7-meter RMSE). Systematic errors within the stated accuracy standards are tolerated in level 1 DEM's.

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 retained within the NDCDB and will eventually be replaced by higher accuracy DEM's. The DEM record C (appendix 2-C) contains the RMSE accuracy statistics acquired during quality control.

A 30-minute DEM may be produced from level 1 or level 2 source 7.5-minute DEM data. These DEM's are level 1 and carry a computed RMSE in record C. No maximum value is set for this RMSE because minimum accuracy requirements are assumed to have been satisfied in conjunction with the source DEM original production. These DEM's may be replaced by level 2 DEM's acquired from 1:100,000-scale hypsography or hydrography source materials.

2.3.2 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, with no errors greater than one contour interval. The DEM record C contains the accuracy statistics acquired during quality control.

2.3.3 Level 3

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

2.4 FORMAT

The logical format for DEM data sets is listed in appendixes 2-A, 2-B, and 2-C for logical record types A, B, and C. The following physical structure is required for all DEM data files for entry into the NDCDB:

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

- o 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. Pad logical record with blanks if necessary to fill to the end of the logical record. Pad bytes 1,021-1,024 of each logical record with blanks.

- o A default physical record size of 4,096 bytes; that is, 4 logical records per physical record is used to facilitate efficient data storage.

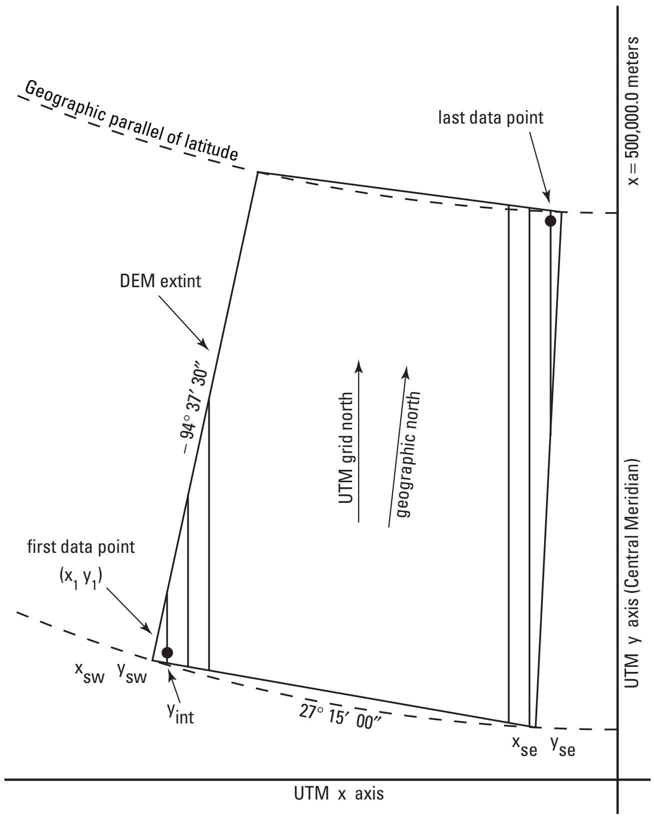
- o Data written as ANSI standard ASCII characters.

2.5 GEOMETRY

Profiles are the basic building blocks of DEM's and are defined as one-dimensional arrays, that is, arrays of dimension m rows by 1 column, where m is the length of the profile.

Figure 2-1 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 2-2 provides a similar example for a quadrangle east of the central meridian.

Figure 2-3, 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 $\triangle y$ and the spacing between profiles is $\triangle x$. Figure 2-3, 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, if any, measured from the coordinate projection system. The rotation angle of 7.5-minute DEM's is zero if profiles are ordered by columns (parallel to the UTM central meridian) or is set to 90^o if profiles are ordered by rows (i.e. this would be the case if row ordering has been superseded by column ordering, see record A, element 16 in appendix 2-A). The rotation angle for all arc second DEM's is always set to zero (see record A, element 13, in appendix 2-A). In contrast to the 7.5-minute UTM DEM, each arc second DEM profile is composed of the same number of elevations per profile and the DEM array is a geographic square or rectangle. Therefore, the equations of figure 2-3 are greatly simplified.



Example computation of UTM coordinates (x_1y_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 30m east of the southwest corner.

$$\frac{x_{sw}}{30\text{ m}} = \frac{339117.761\text{m}}{30\text{ m}}$$
$$= 11303.9 \text{ (round up)}$$
$$= 11304$$
$$x_1 = (11304)(30\text{ m})$$
$$= 339120\text{ m}$$

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}

$$m = (y_{se} - y_{sw}) / (x_{se} - x_{sw})$$
$$= -154.589 / 12377.280$$
$$= -.0124897$$

$$b = y_{sw} - mx_{sw}$$
$$= 3015001.964 - [(-.0124897)(339117.761)]$$
$$= 3019237.443\text{ m}$$

$$y_{int} = b + mx_1$$
$$= [(-.0124897)(339120)] + 3019237.443$$
$$= 3015001.936\text{ m}$$

b) Compute y_1

$$\frac{y_{int}}{30\text{ m}} = \frac{3015001.936\text{ m}}{30\text{ m}}$$
$$= 100500.06 \text{ (round up)}$$
$$= 100501$$
$$y_1 = (100501)(30\text{ m})$$
$$= 3015030\text{ m}$$

Figure 2-1
Computation of first data point in a 7.5-minute digital elevation model west of the central meridian.

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

The southwest corner of the 7.5-minute DEM in this example is at latitude 27° 07′ 30″, longitude –92° 30′ 00″ (x_{sw} = 549553.918, y_{sw} = 3000211.052). The northwest corner is at latitude 27° 15′ 00″, longitude – 92° 35′ 00″ (x_{nw} = 549498.713, y_{nw} = 3014056.068).

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

$$\frac{x_{nw}}{30\text{ m}} = \frac{549498.713\text{ m}}{30\text{ m}}$$
$$= 18316.6 \text{ (round up)}$$
$$= 18317$$
$$x_1 = (18317)(30\text{ m})$$
$$= 549510\text{ m}$$

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 western longitude line of the 7.5-minute quadrangle.

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

$$m = (y_{nw} - y_{sw}) / (x_{nw} - x_{sw})$$
$$= 13845.016 / -55.205$$
$$= -250.793$$

$$b = y_{sw} - mx_{sw}$$
$$= 3000211.052 - [(-250.793)(549553.918)]$$
$$= 140824486.809\text{ m}$$

$$y_{int} = b + mx_1$$
$$= 140824486.809 + [(-250.793)(549510)]$$
$$= 3011225.379\text{ m}$$

b) Compute y_1

$$\frac{y_{int}}{30\text{ m}} = \frac{3011225.379\text{ m}}{30\text{ m}}$$
$$= 100374.179 \text{ (round up)}$$
$$= 100375$$
$$y_1 = (100375)(30\text{ m})$$
$$= 3011250\text{ m}$$

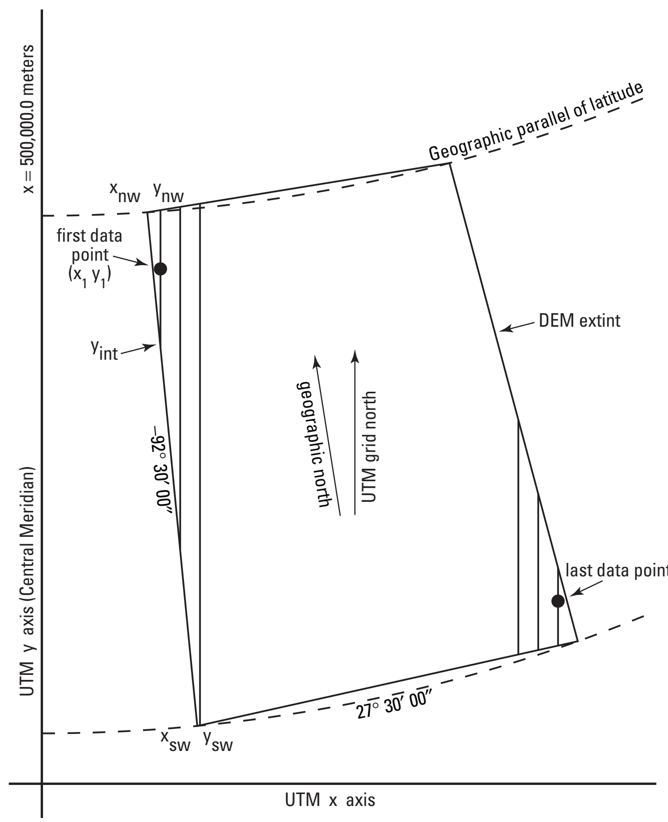


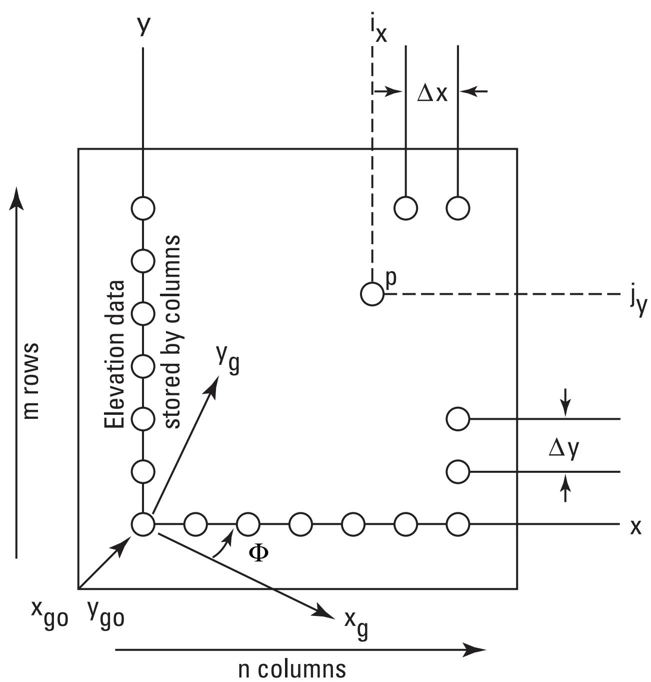
Figure 2-2

Computation of first data point in a 7.5-minute digital Elevation model east of the central meridian.

(1)

$$x_p = (i_x - 1)(\Delta x)$$

$$y_p = (j_y - 1)(\Delta x)$$



(2)

$$x_{gp} = x_{go} + x_p \cos\Phi - y_p \sin\Phi$$

$$y_{gp} = y_{go} + x_p \sin\Phi - y_p \cos\Phi$$

Figure 2-3
Geometry and nomenclature of the
digital elevation model file.

2.6 AREAS OF CONSTANT ELEVATION

When a DEM is generated, it may contain areas of constant elevation derived from corresponding areas within the graphic or digital source containing estimated or false elevations. Three types of these areas may occur: void areas, suspect areas, and water bodies.

2.6.1 Void Areas

Void areas occur in the DEM as a result of interruptions to the contours of the source graphic or DLG (eg. photoimages overprinted onto a topographic map). Void areas are identified in DLG hypsographic data by using the void area code: 020 0100. (Refer to the Standards for Digital Line Graphs, part 3, section 3.4.3.) Each DEM elevation post located within a void area is assigned a false negative value of -32,767[2]. The void and suspect area indicator flag is set in record A, element 25, whenever a void area occurs, with a percentage calculated and stored of the total number of grid posts in the DEM assigned the false negative value, written to record A, element 29. (Refer to section 2.6.4 below.)

2.6.2 Suspect Areas

Suspect areas in the DEM result from corresponding areas on the graphic source that are shown as "disturbed surfaces." They are symbolized by contours that have been overprinted with photorevised or other surface patterns. Examples of disturbed surfaces are: lava flows, land slides, open pit mining, construction cut and fill, and land fill operations.

An estimated elevation is supplied for suspect areas based on the presumed elevation at the time the DEM grid is generated; however,

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[2] A value of -32,767 represents the smallest negative decimal number that may be stored in a 16-bit binary computer word.

the true elevation is subject to change without notice. When an elevation cannot be estimated for a suspect area, the area is downgraded to a void area and assigned a false negative value of -32,767. (See footnote 2, preceding page.) The presence of a suspect area is noted in record A by setting the void and suspect area indicator flag. Grid posts falling in suspect areas are added to the DEM grid as though they were valid elevations; they are distinguishable from normal DEM grid posts only by an independent inspection of the graphic source. For this reason, no percentage value is given in record A for the total number of grid posts in the DEM that are assigned an estimated value.

Note: Suspect areas relate only to graphic sources. Furthermore, no commensurate code exists for suspect areas in the DLG hypsography category.

2.6.3 Water Body Areas

Water body areas are naturally occurring areas of constant elevation. Oceans or estuaries at mean sea level are assigned an elevation value of zero. All other water bodies are assigned their known or an estimated elevation.

Refer to section 3.1.2 for additional criteria regarding water body areas, including the assignment of estimated elevations.

2.6.4 Void and Suspect Area Flag

The void and suspect area flag in record A provides a means to alert the user to the occurrence of grid posts in the DEM array derived from void or suspect areas in the data source. This flag is set when void areas occur in the graphic or digital source and when suspect areas occur in the graphic source (suspect areas are not encoded in DLG's). In cases where the flag is set to suspect, an attempt is made to populate the DEM grid with a reliable elevation estimate, rather than using the false negative value described in section 2.6.1.

2.6.5 Population of Full DEM Grid Array

In all cases where void areas, suspect areas, or water body areas occur in the DEM, the full DEM array is always populated regardless of areal extent. This requirement includes DEM's containing large expanses of oceans or lakes.

2.7 DIGITAL ELEVATION MODEL CAVEATS

Some changes to the 1983 record type A format were mandated in 1987 and additional changes have been made in conjunction with publication of this revised document. Compatibility of the changes with old and new DEM software is achieved by honoring the old byte positions and data types and entering new data into positions previously reserved as filler or voids. Byte positions affected by these changes are bytes 1-144 and bytes 865-896. Bytes 897-1,024 remain as blank fill to the end of the type A physical record.

2.8 DATA RECORDS

Record type A, element 1 has been changed to require certain information in specified byte locations. A new element, element 2, record type A, has been defined to record the NMD organization from which the DEM was authorized. The element counts of old record type A, elements 2-15, have been incremented by one to elements 3-16 (see appendix 2-A). An attempt has been made to keep the old and new DEM formats compatible; therefore, although the element counts have changed, the byte positions and information content of these fields (old elements 2-15, new elements 3-16) remain the same. This change should be transparent to old DEM applications programs. The new element 2, the mapping center of DEM origin is named in record A, bytes 141-144. Valid codes are MAC (Mapping Application Center), GPM2 (specific to MAC Gestalt Photo Mapper II auto correlator), MCMC (Mid Continent Mapping Center), RMMC (Rocky Mountain Mapping Center), WMC (Western Mapping Center) and FS (U.S. Forest Service). Codes indicating other sources of DEM's (other government agencies and private contractors) will be defined when required. Also, new data elements 17-29 have been appended to the end of the type A record (see appendix 2-A). These elements are contained in the end of the previously blank filled portion of the 1,024 byte record. This change is also transparent to existing DEM programs. Standard ASCII alphanumeric values are required for all element fields. Table 2-1 lists standard default record A, data element values where applicable.

Appendix 2-H provides an explanation of datums as indicated in type A record, elements 26 and 27. Appendixes 2E-2G 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 bands called profiles. Therefore, the number of complete profiles covering the DEM area is the same as the number of type B records in the DEM. In a UTM structured DEM, an occasional profile exists within the bounds of the DEM quadrilateral but is void of elevation grid points and 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 at the respective DEM corner.) The type C record contains statistics on the accuracy of the data in the file.

The following special conventions shall be observed for the population of data fields in the A, B, and C record elements:

All character fields must be in upper case. Character field of no data value must be blank, ASCII space (binary 0010 0000)

All integer or character flagged fields of no data value but which default to zero must be ASCII zero (binary 0011 0000).

All real (non-integer) numeric fields shall be populated. Default zero fill shall follow the following convention:

```
 123456789012345678901234 (byte position, left justified)
“     .000000000000000D+00" | Standard format specified is
“    0.0"                   | D24.15.  Zero values listed are
“    0.000000000000000D+00  | common machine dependant numeric
“     .000000000000000"     | defaults for real zeros.
```

Table 2-1

Digital elevation model standard record A, data element defaults

Type A Record Data Element	Explanation - All values shown are standard defaults as they apply to all series DEM's. Data elements not listed (ex. elements 1-3) are not subject to defaults.
4	Pattern code = 1, indicating a regular elevation pattern.
7	Map projection fields, all 15 fields normally set to zeroes.
10	Number (n = 4) of sides in the polygon that defines the DEM file.
13	Counterclockwise angle (in radians) = 0.0, from the primary axis of ground planimetric reference system to the primary axis of the DEM local reference system.
14	Accuracy code =1, indicates that a record of accuracy, record C, exists
16	Two element array (m x n) indicating number of rows and columns of profiles. The row value is set as a constant of m = 1 indicating each profile is a one-dimensional array. The column value n indicates the total number of data profiles in the file.
if 17 then 18	Largest contour interval. Field 17 is set to interval if more than one standard contour interval is assigned for the quadrangle. If a largest contour interval does not exist then elements 17 and 18 are set to zero (0). (Level 2 DEM's only)
19 and 20	Smallest contour interval. Commonly referenced as the standard contour interval, as assigned to the quadrangle map. In units of meters or feet. (Level 2 DEM's only)
21	Data source date. Synonymous with the original compilation source (photography) date. The date of photorevision is not used in most cases unless there are substantial changes which would affect the content of the DEM. In the event that a DEM is composed of separate cells with different dates, the date shall be set to that of the latest date.
22	Data inspection date. Edit system inspection date prior to data base archival.
23	Inspection and revision flag. Set to blank or inspected (I). Revision (code R) is not implemented (revision is a defacto inspection and replacement).
25	Suspect and void flag. Zero (0) indicates none. One (1) indicates possible existence of -32,767 values in DEM or suspect and void on map source.
28	Data edition. Always set to one (1) indicating first edition.

APPENDIX 2-A
DIGITAL ELEVATION MODEL DATA ELEMENTS
LOGICAL RECORD TYPE A

Digital Elevation Model Data Elements Logical Record Type A

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
1	File name	ALPHA	A40	1	40	The authorized digital cell name followed by a comma, space, and the two-character State designator(s) separated by hyphens. Abbreviations for other countries, such as Canada and Mexico, shall not be represented in the DEM header.
	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	109	Blank fill.
	SE geographic corner	INTEGER*2, REAL*8	2(I4,I2,F7.4)	110	135	SE geographic quadrangle corner ordered as: x = Longitude = SDDDMMSS.SSSS y = Latitude = SDDDMMSS.SSSS (neg sign (S) right justified, no leading zeroes, plus sign (S) implied)

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element	Type (FORTRAN Notation)	Physical Record Format: ASCII Format	Starting byte	Ending byte	Comment
Process Code	ALPHA	A1	136	136	1=Autocorrelation RESAMPLE Simple bilinear 2=Manual profile GRIDEM Simple bilinear 3=DLG/hypsography CTOG 8-direction linear 4=Interpolation from photogrammetric system contours DCASS 4-direction linear 5=DLG/hypsography LINETRACE, LT4X Complex linear 6=DLG/hypsography CPS-3, ANUDEM, GRASS Complex polynomial 7=Electronic imaging (non-photogrametric), active or passive, sensor systems.

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
1	Filler	---	---	137	137	Blank fill.
	Sectional Indicator	ALPHA	A3	138	140	This code is specific to 30-minute DEM's. Identifies 1:100,000-scale sections. (See appendix 2-I)
2	Origin code	ALPHA	A4	141	144	Free format Mapping Origin Code. Example: MAC, WMC, MCMC, RMMC, FS, BLM, CONT (contractor), XX (state postal code).
3	DEM level code	INTEGER*2	I6	145	150	Code 1=DEM-1 2=DEM-2 3=DEM-3 4=DEM-4
4	Code defining elevation pattern (regular or random)	INTEGER*2	I6	151	156	Code 1=regular 2=random, reserved for future use.

Digital Elevation Model Data Elements Logical Record Type A--continued

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 2-G. 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 2-E and 2-F for 7.5-minute DEM's. Code is set to zero if element 5 is also set to zero, defining data as geographic.

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
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 through-out 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 DEMs.
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	Set to n=4.

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
11	A 4,2 array containing the ground coordinates of the quadrangle boundary for thehe 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 as 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 and are the algebraic result of the method outlined in data element 6, logical record B.
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 2-3. Set to zero to align with the coordinate system specified in element 5.
14	Accuracy code for elevations	INTEGER*2	I6	811	816	Code 0=unknown accuracy 1=accuracy information is given in logical record type C.

Digital elevation model data elements logical record type A

Data element		Type (FORTRAN notation)	Physical record format: ASCII format	Starting byte	Ending byte	Comment
15 **	A three-element array of DEM spatial resolution for x, y, z. Values are expressed in units of resolution. The units of measure are consistent with those indicated by data elements 8 and 9 in this record.	REAL*4	3E12.6	817	852	Only integer values are permitted for the x and y resolutions. For all USGS DEMs except the 1-degree DEM, z resolutions of 1 decimal place for feet and 2 decimal places for meters are permitted. Some typical arrays are: 30, 30, 1; and 10, 10, .1 for 7.5-minute DEM 2, 2, 1; and 2, 2, .1 for 30-minute DEM 3, 3, 1 for 1-degree DEM 2, 1, 1; and 2, 1, .1 for 7.5-minute Alaska DEM 3, 2, 1; and 3, 2, .1 for 15-minute Alaska DEM
16	A two-element array containing the number 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.
Note:	*Old format stops here*					
17	Largest primary contour interval	INTEGER*2	I5	865	869	Present only if two or more primary intervals exist (level 2 DEM's only).
18	Source contour interval units	INTEGER*1	I1	870	870	Corresponds to the units of the map largest primary contour interval 0=N.A., 1=feet, 2=meters (level 2 DEM's only)

** The phrase“units of measure” makes reference to a specific measurement system that is indicated by the codedefining unit. The term “resolution” indicates that one resolution unit is equal to either one unit, several units, or a decimal part of one unit of measure; i.e, resolutions can exist for values such as .01, .1, 1, 2, 3, and etc. It should be noted that although both expressions are related, they can be confused with each other.

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
19	Smallest primary contour interval	INTEGER*2	I5	871	875	Smallest or only primary contour interval (level 2 DEM's only).
20	Source contour interval units	INTEGER*1	I1	876	876	Corresponds to the units of the map smallest primary contour interval. 1=feet, 2=meters. (Level 2 DEM's only)
21	Data source date	INTEGER*2	I4	877	880	"YYYY" 4 character year, e.g. 1975, 1997, 2001, etc. Synonymous with the original compilation data and/or the date of the photography.
22	Data inspection and revision date	INTEGER*2	I4	881	884	"YYYY" 4 character year. Synonymous with the date of completion and/or the date of revision.
23	Inspection flag	ALPHA*1	A1	885	885	"I" Indicates all processes of part3, Quality Control have been performed.

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
24	Data validation flag	INTEGER*1	I1	886	886	0= No validation performed. 1=RMSE computed from test points (record C added), no quantitative test, no interactive DEM editing or review. 2=Batch process water body edit and RMSE computed from test points. 3=Review and edit, including water edit. No RMSE computed from test points. 4=Level 1 DEM's reviewed and edited. Includes water body editing. RMSE computed from test points. 5=Level 2 and 3 DEM's reviewed and edited. Includes water body editing and verification or vertical integration of planimetric categories (other than hypsography or hydrography if authorized). RMSE computed from test points.

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
25	Suspect and void area flag	INTEGER*1	I2	887	888	0=none 1=suspect areas 2=void areas 3=suspect and void areas
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) (note: see appendix 2-H for datum information)
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 (note: see appendix 2-H for datum information)
28	Data Edition	INTEGER*2	I4	893	896	01-99 Primarily a DMA specific field. (For USGS use, set to 01)

Digital Elevation Model Data Elements Logical Record Type A--continued

Data Element		Type (FORTRAN Notation)	Physical Record Format ASCII Format	Starting byte	Ending byte	Comment
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).
30	Edge Match Flag	INTEGER	4I2	901	908	Edge match status flag. Ordered West, North, East, and South. See section 2.2.4 for valid flags and explanation of codes.
31	Vertical Datum Shift	REAL*8	F7.2	909	915	Vertical datum shift - Value is in the form of SFFF.DD Value is the average shift value for the four quadrangle corners obtained from program VERTCON. Always add this value to convert to NAVD88.

APPENDIX 2-B
DIGITAL ELEVATION MODEL DATA ELEMENTS
LOGICAL RECORD TYPE B

Digital elevation model data elements logical record type B

Data element		Type (FORTRAN notation)	Physical record format: ASCII format	Physical record format: Starting byte	Physical record format: 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 2-3. The row and 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 2-3. The first element in the field corresponds to the number of rows 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_{gp},Y_{gp}) of the first elevation in the profile	REAL*8	2D24.15	25	72	See figure 2-3.
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.

Digital elevation model data elements logical record type B

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 units of measure given by data element 9 in logical record type A and are the algebraic result of the method outlined in data element 6 of this record.
6**	An m,n array of elevations for the profile. Elevations are expressed in units of resolution	INTEGER*4	mn(I6)	6x(146 or 170) 146 = max for first block. 170 = max for subsequent blocks		A maximum of six characters are allowed for each integer elevation value. See data element 15 in appendix 2-A. A value in this array would be multiplied by the“z “spatial resolution (data element 15, record type A)” and added to the “Elevation of local datum for the profile (data element 4, record type B)” to obtain the elevation for the point. The planimetric ground coordinates of point X_{gp}, Y_{gp}, are computed according to the formulas in figure 2-3.

** The phrase “units of measure” makes reference to a specific measurement system that is indicated by the code defining unit. The term “resolution” indicates that one resolution unit is equal to either one unit, several units, or a decimal part of one unit of measure; i.e, resolutions can exist for values such as .01, .1, 1, 2, 3, and etc. It should be noted that although both expressions are related, they can be confused with each other.

APPENDIX 2-C
DIGITAL ELEVATION MODEL DATA ELEMENTS
LOGICAL RECORD TYPE C

Digital elevation model data elements logical record type C

Data		Type (FORTRAN	Physical record format ASCII	Starting	Ending	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	RMSE integer values are in the same unit of measure given by data elements 8 and 9 of logical record type A.
3	Sample size on which statistics in data element 2 are based	INTEGER*2	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	RMSE integer values are in the same unit of measure given by data 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 2-D
SAMPLE QUADRALATERAL COORDINATES

Sample quadrilateral coordinates

Quad Corner no.	Geographic coordinates: Latitude	Geographic coordinates: Longitude	UTM coordinates: Easting	UTM coordinates: Northing
SW 1	35°30'	-107°37’30"	261897	3931463
NW 2	35°37’30"	-107°37’30"	262267	3945330
NE 3	35°37’30"	-107°30’	273590	3945036
SE 4	35°30’	-107°30’	273238	3931169

APPENDIX 2-E
JURISDICTIONS, STATE PLANE COORDINATE SYSTEMS, AND ZONE REPRESENTATIONS

Jurisdictions, State Plane Coordinate Systems,
and zone representations
[Proj. type codes: TM, Transverse Mercator; OM, Oblique Mercator;
PC, Polyconic;LB, Lambert.]

Jurisdiction, zone name, or number	Alpha code	Proj. type	NAD27 zone code	NAD83 zone code
Alabama	AL			
East		TM	0101	0101
West		TM	0102	0102
Alaska	AK			
01		OM (5001)	5001	5001
through		TM (02-09)	through	through
10		LB (5010	5010	5010
Arizona	AZ			
East		TM	0201	0201
Central		TM	0202	0202
West		TM	0203	0203
Arkansas	AR			
North		LB	0301	0301
South		LB	0302	0302
California	CA			
01		LB	0401	0401
through		LB	through	through
06 and 07		LB	0407	0406
Colorado	CO			
North		LB	0501	0501
Central		LB	0502	0502
South		LB	0503	0503
Connecticut	CT	LB	0600	0600
Delaware	DE	TM	0700	0700
Dist. of Columbia	DC	LB	1900	1900
Florida	FL			
East		TM	0901	0901
West		TM	0902	0902
North		LB	0903	0903

Jurisdictions, State Plane Coordinate Systems,
and zone representations

Jurisdiction, zone name, or number	Alpha code	Proj. type	NAD27 zone code	NAD83 zone code
Georgia	GA			
East		TM	1001	1001
West		TM	1002	1002
Hawaii	HI			
01		TM	5101	5101
through		TM	through	through
05		TM	5105	5105
Idaho	ID			
East		TM	1101	1101
Central		TM	1102	1102
West		TM	1103	1103
Illinois	IL			
East		TM	1201	1201
West		TM	1202	1202
Indiana	IN			
East		TM	1301	1301
West		TM	1302	1302
Iowa	IA			
North		LB	1401	1401
South		LB	1402	1402
Kansas	KS			
North		LB	1501	1501
South		LB	1502	1502
Kentucky	KY			
North		LB	1601	1601
South		LB	1602	1602
Louisiana	LA			
North		LB	1701	1701
South		LB	1702	1702
Offshore		LB	1703	1703
Maine	ME			
East		TM	1801	1801
West		TM	1802	1802

Jurisdictions, State Plane Coordinate Systems,
and zone representations

Jurisdiction, zone name, or number	Alpha code	Proj. type	NAD27 zone code	NAD83 zone code
Maryland	MD	LB	1900	1900
Massachusetts	MA			
Mainland		LB	2001	2001
Island		LB	2002	2002
Michigan	MI			
East	(obsolete)	TM	2101	----
Central	(obsolete)	TM	2102	----
West	(obsolete)	TM	2103	----
North		LB	2111	2111
Central		LB	2112	2112
South		LB	2113	2113
Minnesota	MN			
North		LB	2201	2201
Central		LB	2202	2202
South		LB	2203	2203
Mississippi	MS			
East		TM	2301	2301
West		TM	2302	2302
Missouri	MO			
East		TM	2401	2401
Central		TM	2402	2402
West		TM	2403	2403
Montana	MT		----	2500
North		LB	2501	----
Central		LB	2502	----
South		LB	2503	----
Nebraska	NE		----	2600
North		LB	2601	----
South		LB	2602	----

Jurisdictions, State Plane Coordinate Systems, and zone representations

Jurisdiction, zone name, or number	Alpha code	Proj. type	NAD27 zone code	NAD83 zone code
Nevada	NV			
East		TM	2701	2701
Central		TM	2702	2702
West		TM	2703	2703
New Hampshire	NH	TM	2800	2800
New Jersey	NJ	TM	2900	2900
New Mexico	NM			
East		TM	3001	3001
Central		TM	3002	3002
West		TM	3003	3003
New York	NY			
East		TM	3101	3101
Central		TM	3102	3102
West		TM	3103	3103
Long Island		LB	3104	3104
North Carolina	NC	LB	3200	3200
North Dakota	ND			
North		LB	3301	3301
South		LB	3302	3302
Ohio	OH			
North		LB	3401	3401
South		LB	3402	3402
Oklahoma	OK			
North		LB	3501	3501
South		LB	3502	3502
Oregon	OR			
North		LB	3601	3601
South		LB	3602	3602
Pennsylvania	PA			
North		LB	3701	3701
South		LB	3702	3702
Rhode Island	RI	TM	3800	3800

Jurisdictions, State Plane Coordinate Systems, and zone representations

Jurisdiction, zone name, or number	Alpha code	Proj. type	NAD27 zone code	NAD83 zone code
South Carolina	SC	LB	----	3900
North		LB	3901	----
South		LB	3902	----
South Dakota	SD			
North		LB	4001	4001
South		LB	4002	4002
Tennessee	TN	LB	4100	4100
Texas	TX			
North		LB	4201	4201
North Central		LB	4202	4202
Central		LB	4203	4203
South Central		LB	4204	4204
South		LB	4205	4205
Utah	UT			
North		LB	4301	4301
Central		LB	4302	4302
South		LB	4303	4303
Vermont	VT	TM	4400	4400
Virginia	VA			
North		LB	4501	4501
South		LB	4502	4502
Washington	WA			
North		LB	4601	4601
South		LB	4602	4602
West Virginia	WV			
North		LB	4701	4701
South		LB	4702	4702
Wisconsin	WI			
North		LB	4801	4801
Central		LB	4802	4802
South		LB	4803	4803

Jurisdictions, State Plane Coordinate Systems, and zone representations

Jurisdiction, zone name, or number	Alpha code	Proj. type	NAD27 zone code	NAD83 zone code
Wyoming	WY			
East (01)		TM	4901	4901
East Central (02)		TM	4902	4902
West Central (03)		TM	4903	4903
West (04)		TM	4904	4904
Puerto Rico	PR	LB	5201	5200
Virgin Islands	VI	LB	5201	5200
& St. Croix		LB	5202	5200
American Samoa	AS	LB	5300	----
Guam	GU	PC	5400	----

APPENDIX 2-F
UNIVERSAL TRANSVERSE MERCATOR ZONE LOCATIONS AND CENTRAL MERIDIANS

APPENDIX 2-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	141E	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 2-G
PARAMETERS REQUIRED FOR DEFINITION OF MAP PROJECTIONS

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 is assumed.
2	***	Latitude of any point within the UTM zone	***	Eccentricity squared of ellipsoid (e^2). If field is zero, this indicates a sphere. If the field is 1, this field is 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 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
+DDDOMMOSS.SSSSS.

Parameters required for definition of map projections--continued

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 is assumed.				
2	Eccentricity squared of ellipsoid (e). If 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 nonzero number
10-15 (not used on this page)					

Parameters required for definition of map projections--continued

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 is 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 on this page)						

Parameters required for definition of map projections--continued

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 is 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 on this page)					

Parameters required for definition of map projections--continued

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

APPENDIX 2-H
NATIONAL AND INTERNATIONAL HORIZONTAL AND VERTICAL DATUMS USED FOR DIGITAL ELEVATION DATA

National and international horizontal and vertical 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. The 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 because 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 accurate location, the Earth cannot 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 is the 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 is different.

WGS 72

NIMA DEM's, as presently stored in the USGS data base, reference 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 DMA (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 NADSHIFT, which is normally available as an interactive PC-based program or adapted to batch processing on main frame computers. Bilinear interpolation of the shifts derived for the four quadrangle corners results in a uniform horizontal translation of values that are applied to all points interior to and including the edges of the quadrangle.

WGS 72 - WGS 84

Table 2-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 the first table 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 type A record, 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 type A record elements have datums as indicated in type A record, element 27.

Vertical Datums used for Digital Elevation Models

The present U.S. national vertical datum, the National Geodetic Vertical Datum of 1929 (NGVD 29), was established by the U.S. Coast and Geodetic Survey's 1929 General Adjustment. About 75,000 km of U.S. level-line data were combined with about 35,000 km of Canadian level-line data in this adjustment, and mean sea level was held fixed at 26 tide gauges that were spaced along the east and west coast of North America and along the Gulf of Mexico. It was known at the time of the adjustment that because of their variation of ocean currents, prevailing winds, barometric pressures, and other physical causes, the mean sea level determinations at the tide gauges would not define a single equipotential surface. However, it was believed that the variations in the different determinations of mean sea level were probably of the same magnitude as the errors in the leveling data. This datum was originally named "Mean Sea Level Datum of 1929" and was changed to NGVD 29 in 1973 to eliminate reference to "sea level" in the title. This was a change in name only; the definition of the datum established in 1929 was not changed.

Since the 1929 adjustment, new leveling has been established that now totals about 625,000 km and each new line has been adjusted to the network. Through the years, the agreement between the new leveling and the network bench mark elevations slowly grew worse. There are three reasons for this disagreement:

1. Many bench marks were affected by unknown vertical movement due to earthquake activity, postglacial rebound, and ground subsidence.

2. Numerous bench marks were disturbed or destroyed by highway maintenance, building, and other construction projects.

3. New leveling became more accurate because of better instruments and procedures and improved computations.

It was decided in 1977 that the high accuracy achieved by the new leveling was being lost when forced to fit the 1929 network, and plans were made to begin developing a new national vertical network, North American Vertical Datum of 1988. This new datum is being studied and policies are being formulated for it's implementation into data sets such as the DEM. No USGS DEM's are currently using this new datum.

Table 2-H-1 --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.

APPENDIX 2-I
SECTIONAL INDICATOR

Sectional indicator

The 30-minute DEM's are distributed in groups of files that make up a 30- by 30-minute area of coverage representing the DEM for the east or west half of a 1:100,000-scale source map. The normal distribution group is four 15-minute files per 30-minute area. The quadrangle name field in the header record contains the name of the 1:100,000-scale source map. However, the pieces or sections into which each is divided are identified within the header type A record to the size and placement of each. In byte 138-140 each section is identified by a 3 character code XNN where:

X is a single letter indicating size
F = 15-minute block
S = 7.5-minute block

NN is a two-digit number indicating the specific quad. Figure 2-I-1 and 2-I-2 illustrate this division with the sections labeled with the code that appears in bytes 138-140 of the header record.

F01	F02	F03	F04
F05	F06	F07	F08

Figure 2-I-1

A 1:100,000-scale quad divided into eight 15-minute quads, 4 per 30-minute area.

S01	S02	S03	S04	S05	S06	S07	S08
S09	S10	S11	S12	S13	S14	S15	S16
S17	S18	S19	S20	S21	S22	S23	S24
S25	S26	S27	S28	S29	S30	S31	S32

Figure 2-I-2

A 1:100,000-scale quad divided into 32 7.5-minute quads, 16 per 30-minute area.