National Mapping Program
Technical Instructions

Part 2
Specifications

Standards for
Digital Orthophotos

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

CONTENTS

Page

2. Specifications 2-1
2.1 Definitions 2-1
2.2 Format 2-3
2.3 Collection 2-3
2.4 Processing 2-4
2.5 Datums and Coordinates 2-4
2.6 Accuracy 2-5
2.7 Ground Resolution 2-5
2.8 Image Radiometry 2-6
2.9 Image Mosaicking 2-6
2.10 Archive and Distribution Format 2-6
2.11 Quality Control 2-7
2.11.1 Radiometric Verification 2-7
2.11.2 Accuracy Verification 2-8
2.12 Header Data Format 2-8
2.12.1 Record 1 2-9
2.12.2 Record 2 2-12
2.12.3 Record 3 2-13
2.12.4 Record 4 2-15
2.13 Image Data Format Record 5 – Record N 2-20
References 2-37

FIGURES

2-1 Datum Corner Points 2-5
2-2 Leaf Off Periods 2-19
2-3 Monochrome Image File 2-33
2-4 Band Interleaved by Line 2-34
2-5 Band Interleaved by Band 2-35
2-6 Band Interleaved by Pixel 2-36

APPENDIXES

2-A Digital Orthophoto Header Record 2-21
2-B Universal Transverse Mercator Zones 2-30
2-C Example of Band Storage 2-31

LIST OF PAGES

A complete and current copy of part 2 of "Standards for Digital Orthophoto" consists of the pages (and most recent creation or revision dates) listed below.

Page	Date
2-i	07/92
2-ii	07/92
2-iii	07/93
2-1	07/92
2-2	07/92
2-3 thru 2-6a	07/93
2-7	07/92
2-8	07/92
2-9 thru 2-9a	07/93
2-10 thru 2-12	07/92
2-13 thru 2-16a	07/93
2-17	07/92
2-18	07/93
2-19	07/92
2-20 thru 2-20a	07/93
2-21 thru 2-25	07/92
2-26 thru 2-29a	07/93
2-30 thru 2-37	07/92

2. SPECIFICATIONS

2.1 DEFINITIONS:

Band - a continuous sequence of homogenous data.

Band Interleaved - the ordered mixing of lines or pixels of one or more bands with corresponding lines or pixels of other bands, for the purpose of forming a single image file.

Band Sequential - a sequence of one image band followed by another image band. A band sequential file may be formed by appending of bands in sequence within a single file.

Bilinear - the mathematical computation for an unknown value based on the linear interpolation along two axes. The axis are defined by use of a coordinate transformation algorithm to locate the quadrilateral of the four nearest profile points surrounding the unknown point. The interpolation computes the unknown value based on the average, by use of weights and distances, of the four nearest known values.

Brightness value (dn) - A number representing a discrete gray level in an image. The brightness value, also referred to as an image density, is related to the amount of radiant energy in watts per square unit striking the collection media of the sensor.

Contrast stretch - An image transformation technique that increases the local contrast of imagery. Input digital values are assigned new output brightness values by a transformation function that changes their digital range, mean, and standard deviation values.

Cubic Convolution - a mathematical computation for the interpolation of an unknown value based on a third degree polynomial equation passed through the known values.

Dodging - manipulation of the intensity of a portion of a photograph by selectively shading or masking.

Histogram – a graphic representation of frequency distribution. For image data, the histograms indicate pixel brightness values, typically along the x-axis, and the corresponding number of pixels occurring at each brightness value, typically along the y-axis.

Nearest Neighbor – the mathematical computation for an unknown value based solely on (set equal to) the value of the nearest known value.

Read Device – any of a number of computer devices (disks, tapes, memory) which may be read from; usually assigned a node and a logical address within a computer system by which other devices within that system may access (read from) stored data.

2.2 FORMAT

The standard format or area of coverage of a digital orthophoto shall be either quarter-quadrangle (3.75-minutes of latitude x 3.75-minutes of longitude plus overedge) or quadrangle (7.5-minutes of latitude x 7.5-minutes of longitude plus overedge). The geometric coverage shall extend from a minimum of 50 meters beyond the primary and secondary horizontal datum corner point extremes to a maximum of 300 meters beyond the primary and secondary datum corner point extremes (see figure 1-1). The implementation of an overedge range accomodates DOQs distributed by the National Digital Cartographic Data Base (NDCDB) which have been produced by cooperators not participating in Survey, Investigations, and Reseach funding. The USGS and other Federal agencies cooperating in the production of DOQs will produce DOQs which contain the 300 meter overedge. The normal orientation of data is by lines (rows) and samples (columns). Each line contains a series of pixels ordered from west to east. The order of the lines is from north to south. Digital orthophotos are produced so that when displayed on a computer graphics terminal, projection grid north is at the top.

2.3 COLLECTION

NAPP or NAPP-like photography is the primary image source used for production of digital orthophotos by NMD. This does not preclude other aerial photographic or digital image sources from being used. Digital orthophotos scanned from hardcopy NAPP- or NAPP-like imagery (diapositives) shall employ a scanning resolution no greater than 32 microns for 3.75' DOQs and no greater than 60 microns for 7.5' DOQs. The resultant ground resolution of each pixel will be 1 meter for 3.75' DOQs and 2 meters for 7.5' DOQs. All quarter-quadrangle orthophotos with ground resolutions which are less than 1 meter or greater than 1 meter but less than 1.28 meters shall be resampled to 1 meter. Interpolation from a 3.75' DOQ with a resolution coarser than 1.28 to a quarter-quadrangle is <u>not</u> allowed.

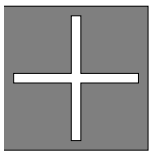
2.4 PROCESSING

Digital orthophotos require several types of inputs to produce an orthogonally rectified image from the original perspective image captured by the sensor. Chief among these are: 1) – the unrectified raster image file acquired from the scanning of the diapositive image or directly from the sensor, 2) – a digital elevation model with the same area of coverage as the digital orthophoto, 3) – the photoidentifiable image and ground coordinates of ground control positions (a minimum of four) acquired from ground surveys or aerotriangulation, and 4) – calibration information about the sensor collector device. These four inputs are used collectively to register the raw image file mathematically to the scanner or to the sensor platform, to determine the orientation and location of the sensor platform with respect to the ground, and to remove the relief displacement from the image file.

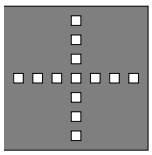
2.5 DATUMS AND COORDINATES

Digital orthophoto quarter-quadrangles shall be cast on the North American Datum of 1983 (NAD 83), Universal Transverse Mercator (UTM) projection, with coordinates in meters. Digital orthophoto quadrangles shall be cast on either North American Datum of 1927 (NAD 27) or NAD 83, UTM projection, with coordinates in meters. The principal horizontal primary datum for the quarter-quadrangle digital orthophoto shall be NAD 83. The principal secondary horizontal datum for quarter-quadrangle digital orthophotos shall be the NAD 27, the Puerto Rico Datum, the Old Hawaiian Datum, or other approved datums. The primary and secondary datums for digital orthophoto quadrangles shall adhere to the specifications of National Mapping Division Supplemental Topographic Instruction 92-1-C, dated 1/22/92. The datum shift values between the primary and secondary datums will be equivalent to those published in USGS Bulletin 1875.

The four primary datum corners shall be imprinted into the image as four solid white crosses (dn = 255) and the four secondary datum corners as four dashed white crosses (dn = 255) (see figure 2-1).



Corner Cross NAD 83
(13 pixels by 13 pixels solid)



Corner Cross Secondary Datum
(13 pixels by 13 pixels dashed)

Figure 2-1
Datum Corner Points

2.6 ACCURACY

Digital orthophoto quadrangles and quarter-quadrangles must meet horizontal National Map Accuracy Standards (NMAS) accuracy requirements at 1:24,000 and 1:12,000 scale, respectively. The NMAS specify that 90 percent of the well-defined points tested must fall within 40 feet (1/50 inch) at 1:24,000 scale and 33.3 feet (1/30 inch) at 1:12,000 scale. The vertical accuracy of the source DEM must be equivalent to or better than a level 1 DEM, with a root-mean-square-error (RMSE) of no greater than 7.0 meters. A planar-DEM (sloped-plane substitute grid) may be used for areas where the relief difference (high to low elevation) does not exceed 150 feet. All remaining inputs and processes (i.e. aerotriangulation control and methodology, scanner calibration, and sensor calibration) used in digital orthophoto production must be sufficiently accurate to ensure that the final product meets NMAS.

2.7 GROUND RESOLUTION

The horizontal ground resolution (the area of the ground represented in each pixel in x and y components) of NDCDB digital orthophoto quarter-quadrangles shall be 1 meter. This includes 3.75’ DOQs produced by USGS and other Federal agencies participating in produced by USGS and other Federal agencies participating in orthophoto production under joint funding agreements and producers of 3.75-minute DOQs participating under cooperative agreements with the USGS. The horizontal ground resolution for 7.5-minute digital orthophoto quadrangles shall be 2 meters. Digital orthophotos that will not be archived in the NDCDB may be produced to other

resolutions. NAPP-derived digital orthophotos produced with resolutions finer than 1 meter or greater than 1 meter but less than 1.28 meters (the ground resolution result of NAPP photography scanned at 32 microns) shall be processed through a bilinear resampling to the 1 meter archival horizontal ground resolution. 3.75-minute DOQs produced with a horizontal ground resolution greater than 1.28 meters shall not be resampled to a finer ground resolution.

2.8 IMAGE RADIOMETRY

Image brightness values shall be represented by 256 gray levels and represented by a number in a range of 0-255. A value of 0 shall represent the color black and a value of 255 the color white; all intermediate values are shades of gray varying uniformly from black to white. Areas where the rectification process is incomplete due to incomplete data (i.e., lack of elevation data, gaps), shall be represented with a numeric value of 0.

2.9 IMAGE MOSAICKING

When two or more digital orthophoto chips are mosaicked, the chip judged by visual inspection to have the best contrast shall be used as the reference image. The brightness values of the other chips shall be adjusted to match that of the reference chip. The join lines between the overlapping chips shall be chosen so as to minimize tonal variations. Localized adjustment of the brightness values shall be performed to minimize tonal differences between join areas.

2.10 ARCHIVE AND DISTRIBUTION FORMAT

The header information and image data shall conform to the specifications in sections 2.12 and 2.13. The physical and logical record lengths for an individual file are fixed, but may vary

between files. For file input processing, the record length shall be treated as undefined or unknown by the read device. The logical record length, physical record length, and number of records in the data set are recorded in record 1, element 32 (the number of records or lines and pixels per band) and element 33 (number of bands and order and method of storage). The header records are written in ASCII nomenclature, are 400 bytes each, and are recorded in the digital orthophoto as records one through four. Each header record is padded with blank fill from bytes 401 to M, where M equals the logical record length of a single line of image data. Therefore, the header records and image data records are recorded with the same byte length per record on the physical output medium. Appendix 2-A defines the file format specifications.

2.11 QUALITY CONTROL

2.11.1 Radiometric Verification

During photographic reproduction of the image a limited amount of analog dodging is customarily performed to improve the image quality. The image brightness values are collected as represented on the source imagery with minimal image quality manipulation. Image brightness values may deviate from the brightness values of the original imagery due to image value interpolation during the scanning and rectification processes. Radiometric accuracy shall be verified by visual inspection of the digital orthophoto with the original unrectified image to determine if the digital orthophoto has the same or better image quality as the original unrectified input image(s).

When unrectified image scan lines are not parallel to the DEM elevation profiles, a systematic occurrence of artifacts (a moire pattern) may be introduced into the processed orthophoto image. The occurrence of artifacts is particularly evident when nearest-neighbor processing is used, producing a geometric pattern of wavy lines in the digital orthophoto. This pattern is related to the manner in which the image lines are alternately reinforced or diminished when the DEM profiles cross or align with the image lines. If the area of interest is more extensive than nearest-neighbor processing can resolve (generally more than 3 pixels wide),

the neighboring pixel values can be averaged using either bilinear or cubic convolution image processing (bilinear is normally the default algorithm used for digital orthophoto production). The advantage of nearest-neighbor processing is that the original scanned brightness values for each pixel are preserved exactly, while with bilinear or cubic convolution processing, each pixel is a weighted average composed of neighboring pixel brightness values. To minimize artifacts when the nearest neighbor algorithm is used, the scan diapositive shall be rotated, when mounted on the scanner, parallel to the orthophoto DEM profiles.

2.11.2 Accuracy Verification

Visual verification shall be performed for image completeness, to ensure that no gaps exist in either the image area or the overedge coverage. The accuracy of the file shall be verified by comparing image line and sample geometric coordinates to coordinates derived from higher order accuracies for the same points.

2.12 HEADER DATA FORMAT

The digital orthophoto header format shall adhere to that specified in sections 2.12.1 – 2.12.4. The header and image structure, record formats, and codes are defined in Appendix 2-A. All header fields identified as reserved shall be filled with blanks. Optional specifications exist in the header format to allow expansion of the header records to include additional information concerning future programs or processes related to digital orthophoto production. The standard defaults used in the digital orthophoto program are

specified below.

The header records are structured as a series of four logical records, each allocated as 400 bytes of ASCII text. These records are padded further, as necessary, with ASCII blanks to equal the length of the image data records. The minimum record length of 400 bytes is arbitrary but corresponds to the minimum practical length of image data records anticipated for any orthophoto file. The four header records contain a wide range of descriptive information about the image data, including: file identification; the coordinate systems and datums upon which the digital orthophoto is cast; and

lineage information relating to the source DEM, source photography, and ground control.

2.12.1 Record 1

Record 1 identifies the area of geographic coverage of the image, including the quadrangle name and 3.75-minute quadrant (assuming a digital orthophoto quarter-quadrangle rather than a digital orthophoto quadrangle) within the 7.5-minute quadrangle. Separate Federal Information Processing Standard (FIPS) state/county fields are provided for up to four states and up to five counties per state. Other information in record 1 includes the producing organization for the data; the types and order of band storage; the types of elevation storage (DEMs are not included at the present time); specification of horizontal and vertical datums and related zone; and specification of the parameters of the cartesian coordinate system including origin, rotation, and units of measure. This record also contains the ground coordinates of quadrangle corners in the primary horizontal datum.

Elements 1-2 - Quadrangle name, quadrant.

The digital orthophoto name, element 1, for the 3.75-minute quarter-quadrangle is the 7.5-minute map name followed by the 3.75-minute quadrant designation, element 2, specified as NE, NW, SW, or SE. Element 2 is not applicable to 7.5-minute digital orthophotos.

Elements 3-27 - Nation/State/County of Coverage
Contains the Nation, State, and county of coverage for digital orthophotos, using code specifications contained in the Federal Information Processing Standard (FIPS) 6-4. The order of the States and counties in the header shall be based on the square mileage contained in the image (from high to low). Each State shall be coded as a 2-digit alpha code, each county shall be a 3-digit numeric code (Reference FIPS PUB 6-4). For example, the Teec Nos Pos, AZ-NM-UT-CO, NE quarter quadrangle encodes all four alpha state FIPS codes sequentially as follows: AZ, NM, UT, CO. The respective county numeric FIPS codes for Apache County, Arizona, San Juan County, New Mexico, San Juan County, Utah, and Montezuma County, Colorado are 001, 045, 037, 083.

Element 30 - Producer code
Identifies the production mapping center responsible for creating the digital orthophoto. Contractors shall use the code of the oversight mapping center.

Element 31 - Data Ordering
The data shall be organized by line, each line containing a series of pixels from west to east. The order of lines shall be from north to south (code=2).

Element 32 - Lines and Samples or Rows and Columns
The number of lines by the number of samples of a single band of the data set, ordered as specified in record 1, element 31.

Elements 33 - Band Types and Order of Storage
The default band storage is black and white. Provision also is made in this field for various other possible band types: red, green, and blue, with or without elevations; or combinations of these elements. The order of colors for band storage is always red, green, blue, black-and-white, followed by elevation (or some subset of those). (See appendix 2-C for examples).

Element 34 - Elevation Storage
The standard digital orthophoto does not contain elevation data (code=0). If the option to store elevation data is exercised in the

future, the data shall be stored as two-byte values. Elevation data can be formatted as profiles or pixels. When stored as profiles, pixel elevations may be determined by bilinear interpolation using the four adjacent profile elevations.

Element 35 - Band and Elevation Storage

Defines the storage patterns for both image and elevation data. Under the current digital orthophoto program the only option available is to store the image file and DEM as separate files (code=0). Provision has been made for both vertical storage (separate files for each band, or bands interleaved by line, record, or band), or horizontal storage (appending all bands for a given line or record into one line or record or interleaving bands by pixel for a given record). See appendix 2-C for samples and clarification of these types of order.

Elements 36-38 - Primary and Secondary Datums

The vertical datum field shall be left as ASCII blanks since elevation data are not stored with the digital orthophoto. The principal primary horizontal datum for digital orthophoto quarter-quadrangles shall be NAD 83 (code=4) and the principal secondary horizontal datum shall be the past principal horizontal datum for the geographic area (i.e., NAD 27, Old Hawaiian, Puerto Rico). The principal primary and secondary horizontal datum for digital orthophoto quadrangles shall be NAD 83, NAD 27, or other approved datums.

Element 39 - Angle of Rotation

Provides the angle of rotation between the image lines and the UTM x-axis, measured in radians. The default angle shall be zero.

Elements 40-42 - Primary Ground X-Y Reference System, Code and Units

Provides the ground X-Y reference system, the appropriate UTM zone number as referenced in appendix 2-B, and default units of the orthophoto, designated as meters (code=2).

Elements 43-46 - Ground Coordinates of Quadrangle Corners on the Primary Horizontal Datum

Contains the ground X and Y coordinates of the four theoretical

quadrangle neatline corners (even 3.75-minute or 7.5-minute format) of the quarter-quadrangle or quadrangle digital orthophoto in a SW, NW, NE, and SE order, using the projection, primary horizontal datum, zone, and units specified record 1, elements 37 and 40-42.

2.12.2 Record 2

Record 2 contains transformation parameters and coordinates to allow conversion from the internal line and sample coordinate system to the primary datum coordinate system. This record also contains the ground coordinates of quadrangle corners in the secondary horizontal datum.

Element 1 – Transformation Constants, for Projection and Primary Horizontal Datum

Provides the transformation constants to derive ground X-Y values from digital orthophoto internal (line and sample) coordinates for any ground X-Y coordinates, using the projection, primary horizontal datum, zone and units of record 1, elements 37 and 40-42.

where:

e = Xcentroid f = Ycentroid

xc = line centroid yc = sample centroid

and:

$$X = a(line-xc) + b(sample-yc)+e$$

$$Y = c(line-xc) + d(sample-yc)+f$$

or

where:

$$g = (b/a)+(a/b) \quad h = (d/c)+(c/d)$$

and:

$$line = ((X-e)/b-(Y-f)/a)/g + xc$$

$$sample = ((Y-f)/c-(X-e)/d)/h + yc$$

Elements 2-5 – Ground Coordinates of Quadrangle Corners in the Secondary Horizontal Datum

Contains the ground X and Y coordinates of the four theoretical quadrangle neatline corners (even 3.75-minute or 7.5-minute format) of the quarter-quadrangle or quadrangle digital orthophoto in a SW, NW, NE, and SE order, using the projection and secondary horizontal datum, zone, and units of record 1, elements 38 and 40-42.

2.12.3 Record 3 - 400 bytes

Record 3 contains transformation parameters and coordinates to allow conversion from the internal line and sample coordinate system to the secondary horizontal datum coordinate system. This record also contains line and sample coordinates of the four theoretical quadrangle neatline corners in the primary and secondary horizontal datum and projection, as well as the horizontal coordinates in the primary and secondary horizontal datums of the first pixel (1,1) of the image file.

Element 1 – Transformation Constants, of Projection and Secondary Horizontal Datum

Contains transformation constants to derive ground X-Y values from digital orthophoto internal (line and sample) coordinates, or any internal orthophoto coordinates (line and sample), for any ground X-Y coordinates in the projection, secondary horizontal datum, zone and units of record 1, elements 38 and 40-42. (See record 2, element 1 for a description of equations to use when employing these constants.)

Elements 2-5 - Primary Horizontal Datum Internal Coordinates of Quadrangle Corners

Contains line and sample coordinates of the four theoretical quadrangle neatline corners (even 3.75-minute or 7.5-minute format) of the quarter-quadrangle or quadrangle digital orthophoto in a SW, NW, NE, SE order in the primary horizontal datum and projection, zone and units of record 1, elements 37 and 40-42.

Elements 6-9 - Secondary Horizontal Datum Internal Coordinates of Quadrangle Corners

Contains line and sample coordinates of the four theoretical quadrangle neatline corners (even 3.75-minute or 7.5-minute format) of the quarter-quadrangle or quadrangle digital orthophoto in a SW, NW, NE, SE order in the secondary horizontal datum and projection, zone and units of record 1, elements 38 and 40-42.

Elements 10–11 – Ground Coordinates of First Line, First Pixel on the Primary and Secondary datum

Contains ground coordinates of the first pixel in the first line of data (internal coordinates 1,1) in the primary and secondary horizontal datum (internal coordinates are recorded in record 3, elements 2–9), using the projection and horizontal datums of record 1, elements 37, 38, and 40–42.

2.12.4 Record 4

Record 4 contains information related to the source DEM and lineage information related to the digital orthophoto acquisition systems, including the camera, scanner, processing software, the related resolutions of those systems, and information relating to image compression. Note: Since DEMs are not currently stored with the digital orthophoto file (as indicated in record 1, element 34, code=0), elements 2 to 6, and 10 to 14 of record 4 are also set to zero by default.

Element 1 – Elevation units

Provides the elevation unit. The default elevation unit is meters (code=2).

Elements 2–3 – DEM Minimum and Maximum Elevations

Provides the minimum and maximum elevations of the DEM used to rectify the digital orthophoto in the units specified in record 4, element 1.

Elements 4–6 – DEM Spatial X–Y–Z Resolution

Elements 4–5 provide the DEM spatial ground (X and Y) resolution, given in the units specified in record 1, element 41. Element 6 contains the elevation (Z) resolution, given in the units specified in record 4, element 1. Elements 4–6 are set to zero when record 1, element 34 equals zero.

Elements 7-9 - Digital Orthophoto Spatial X-Y-Z Resolution
Elements 7-8 provide the ground spatial resolution (X and Y) of each pixel, given in the units specified in record 1, element 42. If the image has been resampled from another DOQ, the original ground spatial resolution will be retained in elements 7-8. The new (resampled) ground spatial resolution will be contained in record 4, element 32. Element 9 contains the elevation (Z) resolution, given in the units specified in record 4, element 1 or shall be zero if record 1, element 34 equals zero.

Elements 10-13 - Orthophoto Source DEM Derived from Contour and Hypsography Digital Line Graph (DLG) and Contour Elevation Units
Elements 10-11 provide the largest primary contour interval and units of the corresponding topographic quadrangle for this geographic area. Complete this element when the DEM was derived from a hypsography DLG and the DLG contained two or more primary contour intervals. Set values equal to zero if the DEM was not derived from a hypsography DLG. Elements 12-13 specify the smallest or only primary contour interval and the units of the smallest or only primary contour interval of the corresponding topographic quadrangle for this geographic area. These elements are present when the DEM is derived from a hypsography DLG and the DLG contains one or more primary contour intervals. Values shall equal zero if not present.

Element 14 - Suspect and Void Areas
This element is a flag which indicates the presence of suspect or void areas in the DEM used in producing the digital orthophoto. Those portions of the digital orthophoto produced from a source DEM with void or suspect elevations, or portions of the digital orthophoto for which no corresponding source image data existing shall be represented in the image file as black with an image density of zero. Suspect or void areas are defined in the U.S. Geological Survey Standards for Digital Elevation Models.

Elements 15-17 - Horizontal Accuracy, DEM RMSE, and DOQ Number of Test Points

Contains the horizontal accuracy of the digital orthophoto and digital elevation model, as determined by comparison with data of higher-order accuracy, expressed as an RMSE in the units specified in record 1, element 42. The digital orthophoto minimum number of test points is four but will normally be at least nine.

Element 18 - Pixel Processing Algorithm

Specifies the pixel processing algorithm used to generate the digital orthophoto, which will vary depending on the image processing requirements. The default value is bilinear.

Elements 19-21 - Production System, Date and Film Type

Contains a description of the hardware and software components (i.e. software version number) used to make the orthophoto, the production date and film type. The film type is left blank if the image was acquired directly in digital form.

Element 22 - Imagery Source Identification

Contains the manufacturer's film identification number, agency identification, roll, and exposure number. Left blank if the image was acquired directly in digital form.

Element 23 - Image Mosaicking

Indicates the number of images used in a mosaicked digital orthophoto. A value of zero for this element indicates no mosaicking. The origins of the imagery are specified in record 4, elements 21 and 22.

Element 24-25 - Leaf Off Flag, Imagery Source Date

Element 24 contains the leaf off status ("Lb"=leaf off, "bb" = no leaf off, (b = blanks)). "Leaf off" qualifiers may be determined by

comparing the date of photography with the geographic regions depicted in figure 2-2. Figure 2-2 documents the approximate start and end dates of foliage coverage for geographic regions of the United States. These dates define a narrow window of opportunity for acquiring aerial photography, occurring in late winter and early spring when most deciduous, broad-leaf trees are devoid of leaves. Photography taken during these periods is flagged with an "L" in record 4, element 24. For the western U.S., leaf off does not apply because the predominant forest type is evergreen conifers, which have foliage all year. Similarly, Alaska, Hawaii, and Puerto Rico are do not have a leaf-off period because the vegetation is either evergreen, tundra, or tropical, and therefore is not of the deciduous, broad-leaf type. Photography taken in other than the leaf off period, or where a leaf off period does not apply, is flagged with a blank in record 4, element 24.

Element 25 contains the date of the imagery (expressed as YYYYMMDD). When the digital orthophoto is comprised of multiple image chips (record 4, element 22 > 0), the imagery source date shall be the date of the oldest source.

Elements 26-27 - Sensor Focal Length and Nominal Flying Height
Contains the calibrated focal length of the sensor used to acquire the imagery, expressed in millimeters and fractions of millimeters. The nominal flying height (average height above terrain), as computed, shall be entered in the units specified in record 4, element 1.

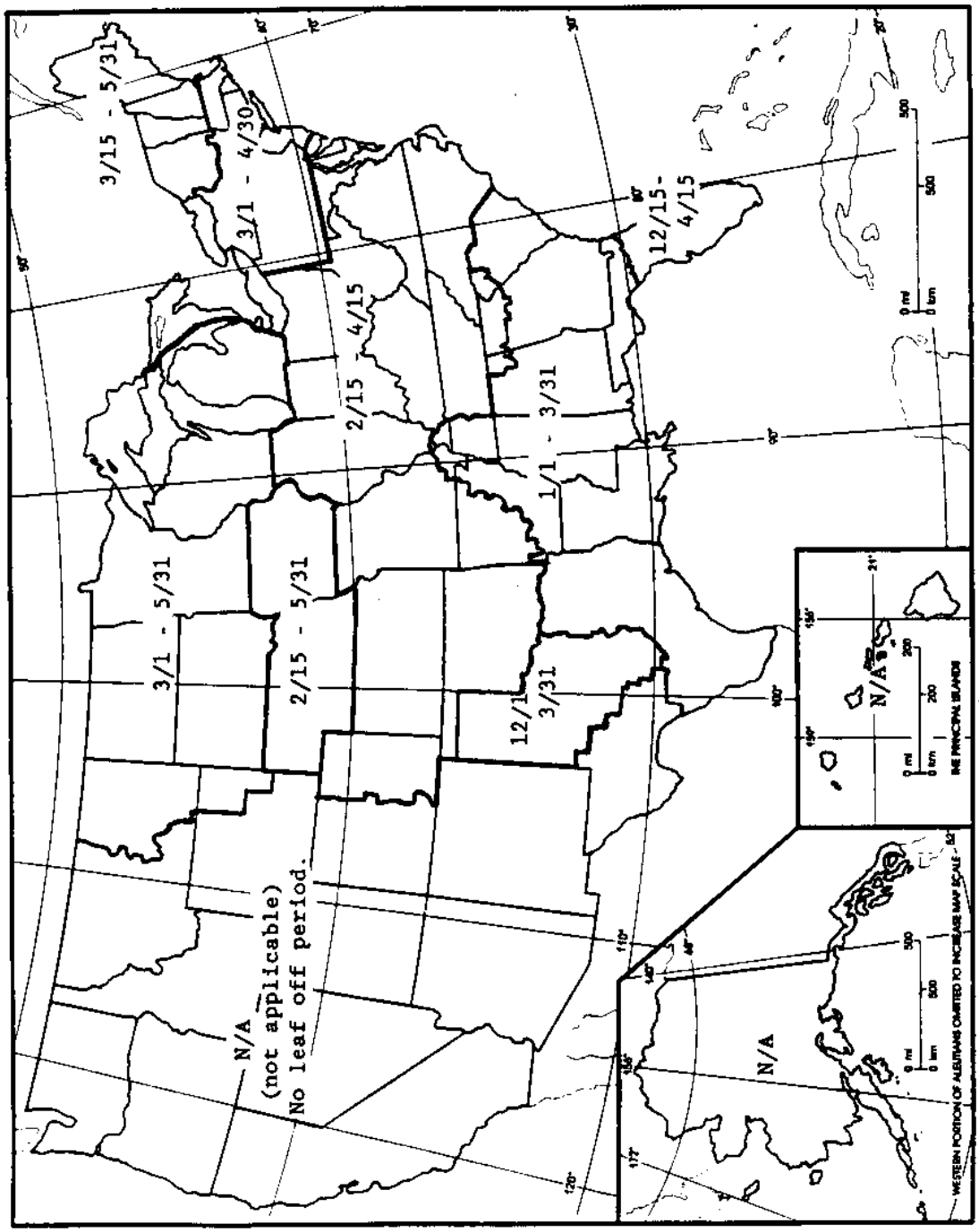


Figure 2-2 LEAF OFF PERIODS

Note: This figure is intended to convey periods of "Leaf Off" and is not to be used for planning acquisition of aerial photography.
(SOURCE: Leaf Off dates from U. S. Department of Agriculture, Soil Conservation Service, 1976)

Element 29 - Scanning Aperture Size
The scanning aperture size in both x and y directions expressed in microns. Enter zero if the imagery was acquired directly in digital form.

Element 30 - Scanner Sampling Resolution
Contains the sampling resolutions in both x and y directions expressed in microns. This element shall equal zero if the imagery was acquired directly in digital form.

Element 31 - Radiometric Resolution of the Image
Set default of 8 bits per pixel (code=1).

Element 32 - Resampled Ground Resolution
When the orthophoto is not resampled, element 32 equals zero, otherwise enter the new ground spatial resolution in units of record 1, element 42. If resampled, the original ground spatial resolution of the resampled DOQ is found in record 4, elements 7-8.

Element 33 - Compression Flag
Element 33 contains a flag indicating compression status ("S" or blank = standard image, no compression, "C"=compressed image). Image compression is the reduction (compression) of the number of bits required to describe an image. DOQs may be distributed in a compressed format, while DOQs in the NDCDB archive remain in their original, uncompressed state. If flag is "S" or blank, then record 4, elements 34-37 are blank. A blank indicates a standard DOQ produced prior to implementation of NMD compression policy.

Element 34 - Compressed Image Size
Contains the the compressed image file size in bytes. This file is blank if element 33 equals a blank or "S".

Element 35 – Compression Algorithm

The name and version of the compression algorithm is identified in element 35. This field is blank if element 33 equals a blank or "S".

Element 36 – Compression type

Element 36 indicates whether the image compression was an irreversible or lossy ("I") process or if a reversible or lossless ("R") process was applied. An irreversible or lossy compression indicates a compression process which entails some loss of image data. A reversible or lossless compression process is one that preserves all the original detail. This field is blank if element 33 equals a blank or "S".

Element 37 – Compression Control Factor

This element contains a control factor specific to the compression algorithm. It regulates the amount of compression and may serve as an indicator of the amount of compression and, therefore the quality of the compressed image. For example, JPEG compression alogrithms refer to a control element called a "Q" or quality factor. This field is blank if element 33 equals a blank or "S".

2.13 Image Data Format Records 5 – N

Image data are records 5 – N, where N equals the number of lines of data. Appendix 2-C illustrates and describes examples of the structure of valid types of image data.

APPENDIX 2-A. Digital Orthophoto Header

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 1		
1	Quadrangle name	38	1-38	A38	Authorized quadrangle name
2	Quadrant	2	39-40	A2	Quadrangle quadrant (SW, NW, NE, SE).
3	Nation	4	41-44	2A2	FIPS nation code. Valid codes are US, CA, MX (bytes 43, 44 blank if only one nation)
4	State 1	2	45-46	A2	FIPS PUB 6-4 first state in file.
5	State 2	2	47-48	A2	second state
6	State 3	2	49-50	A2	third state
7	State 4	2	51-52	A2	fourth state
8	State 1, County 1	3	53-55	A3	FIPS PUB 6-4 first county in first state.
9	State 1, County 2	3	56-58	A3	second county
10	State 1, County 3	3	59-61	A3	third county
11	State 1, County 4	3	62-64	A3	fourth county
12	State 1, County 5	3	65-67	A3	fifth county
13	State 2, County 1	3	68-70	A3	FIPS PUB 6-4 first county in second state.
14	State 2, County 2	3	71-73	A3	second county
15	State 2, County 3	3	74-76	A3	third county

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 1-Cont'd		
16	State 2, County 4	3	77-79	A3	fourth county
17	State 2, County 5	3	80-82	A3	fifth county
18	State 3, County 1	3	83-85	A3	FIPS PUB 6-4 first county in third state.
19	State 3, County 2	3	86-88	A3	second county
20	State 3, County 3	3	89-91	A3	third county
21	State 3, County 4	3	92-94	A3	fourth county
22	State 3, County 5	3	95-97	A3	fifth county
23	State 4, County 1	3	98-100	A3	FIPS PUB 6-4 first county in fourth state.
24	State 4, County 2	3	101-103	A3	second county
25	State 4, County 3	3	104-106	A3	third county
26	State 4, County 4	3	107-109	A3	fourth county
27	State 4, County 5	3	110-112	A3	fifth county
28	Reserved	2	113-114		Reserved for future use.
29	Filler	23	115-137	A23	Alpha filler for additional descriptive text.
30	Producer code	4	138-141	A4	Mapping center origin code EMC,MCMC,WMC,RMMC,FS,BLM,SCS (contractors use code of oversight mapping center)

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 1-Cont'd		
31	Data ordering	3	142-144	I3	1=samples n-s, lines w-e 2=samples w-e, lines n-s
32	No. of lines and samples	12	145-156	2I6	Number of lines & samples in single band
33	Band types, order, number of bands present, and storage sequence	3	157-159	I3	Code 1=1 band black & white (B&W) 2=1 band red 3=1 band green 4=1 band blue 5=3 band color (RGB) 6=3 band RGB + 1 band B&W 7=1 band B&W + elevation data 8=3 band RGB + elevation data 9=3 band RGB & 1 band B&W + elevation data
34	Elevation storage	3	160-162	I3	Code 0=not stored 1=by profile 2=by pixel Elevations stored as 2-byte values
35	Band & elevation storage	3	163-165	I3	Code 0=separate file(s) 1=band sequential in one file 2=band interleaved by band in one file 3=band interleaved by band/record in one file 4=band interleaved by pixel/record in one file
36	Vertical datum	2	166-167	I2	Code 1=Local mean sea level 2=National Geodetic Vertical Datum 1929 3=North American Vertical Datum 1988 (Blank if DEM not stored record 1,element 34 = 0)

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 1-Cont'd		
37	Primary Horizontal Datum	2	168-169	I2	Code 1=North American Datum 1927 (NAD 27) 2=World Geodetic System 1972 3=World Geodetic System 1984 4=North American Datum 1983 (NAD 83) 5=Old Hawaii Datum 6=Puerto Rico Datum
38	Secondary Horizontal Datum	2	170 171	I2	Same as record 1, element 37
39	Angle of rotation	24	172-195	D24.15	Counterclockwise angle (in radians) from the primary axis of ground planimetric reference to the primary axis of the orthophoto local reference system. Normally set to 0.0
40	Ground X-Y reference system	3	196-198	I3	Code 0=Geographic 1=Universal Transverse Mercator (UTM) 2=State Plane Coordinate System (SPCS)
41	Code defining zones in ground planimetric reference system	6	199-204	I6	Projection zone code. Set to zero for geographic projection
42	Ground X-Y planimetric units	3	205-207	I3	Code 0=radians 1=feet 2=meters 3=arc seconds
43	SW ground coordinate	48	208-255	2D24.15	X-Y unit ground coordinates of the four quadrangle corners in the projection and primary datum of
44	NW ground coordinate	48	256-303	2D24.15	

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 1-Cont'd		
45	NE ground coordinate	48	304-351	2D24.15	record 1, elements 37 and 40-42
46	SE ground coordinate	48	352-399	2D24.15	See record 1, element 43
47	Reserved	1	400		Reserved for future use
48	Blank Fill		401 - M		M = byte count of image
			RECORD 2		
1	a, b, c, d, e, f, xc & yc constants to convert internal line & sample coordinates to and from projection and primary datum, record 1, elements 37 & 40-42	192	1-192	8D24.15	Transform from internal (line & sample) coordinates to ground or from ground coordinates to internal coordinates: e = Xcentroid f = Ycentroid xc = line centroid yc = sample centroid X = a(line-xc) + b(sample-yc)+e Y = c(line-xc) + d(sample-yc)+f or g = (b/a)+(a/b) h = (d/c)+(c/d) line = ((X-e)/b-(Y-f)/a)/g + xc sample = ((Y-f)/c-(X-e)/d)/h + yc
2	SW ground coordinate	48	193-240	2D24.15	X-Y unit ground coordinates of the four quadrangle
3	NW ground coordinate	48	241-288	2D24.15	corners in the projection and secondary datum of
4	NE ground coordinate	48	289-336	2D24.15	record 1, elements 38 and 40-42
5	SE ground coordinate	48	337-384	2D24.15	See record 2, element 2
6	Reserved	16	385-400		Reserved for future use
7	Blank Fill		401 - M		M = byte count of image

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 3		
1	a, b, c, d, e, f, xc & yc constants to convert internal line & sample coordinates to and from projection & secondary datum of record 1, elements 38 & 40-42	192	1-192	8D24.15	Same as record 2, element 1
2	SW internal coordinate	12	193-204	2I6	Internal unit coordinates (line and sample) of the quadrangle corners in the NAD83 datum. Corners are imprinted in the image as 4 solid white crosses. (see section 2.5)
3	NW internal coordinate	12	205-216	2I6	
4	NE internal coordinate	12	217-228	2I6	
5	SE internal coordinate	12	229-240	2I6	
6	SW internal coordinate	12	241-252	2I6	Internal unit coordinates (line and sample) of the quadrangle corners in the secondary datum of record 1. Corners are imprinted in the image as 4 dashed white crosses. (see section 2.5)
7	NW internal coordinate	12	253-264	2I6	
8	NE internal coordinate	12	265-276	2I6	
9	SE internal coordinate	12	277-288	2I6	
10	First pixel X-Y coordinates (Primary datum)	48	289-336	2D24.15	Primary datum ground X-Y value of internal coordinate first line first pixel (1,1)
11	First pixel X-Y coordinates (Secondary datum)	48	337-384	2D24.15	Secondary datum ground X-Y value of internal coordinate first line first pixel (1,1)
12	Reserved	16	385-400		Reserved for future use
13	Blank Fill		401 - M		M = byte count of image

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 4		
1	Elevation units	3	1-3	I3	Code 1=feet 2=meters
2	Minimum orthophoto elevation	10	4-13	F10.3	Values are in units of record 4, element 1. ***
3	Maximum orthophoto elevation	10	14-23	F10.3	Value in units of record 4, element 1. ***
4	X ground resolution	12	24-35	E12.6	Ground X-Y-Z resolution of DEM, in X-Y units of record 1, element 42 and
5	Y ground resolution	12	36-47	E12.6	Z in units of record 4, element 1. ***
6	Z resolution	12	48-59	E12.6	See record 4, element 4 ***
7	X pixel resolution	12	60-71	E12.6	Ground/pixel resolution, of DOQ, in X-Y units of record 1, element 42 and Z in units
8	Y pixel resolution	12	72-83	E12.6	of record 4, element 1. Z set to 0.0 if record 1, element 34=0
9	Z resolution	12	84-95	E12.6	See record 4, element 7
10	Largest primary contour interval	5	96-100	I5	Interval if source DEM derived from graphic, & two or more primary intervals, otherwise zero ***
11	Largest primary contour interval units	1	101	I1	Corresponds to the units of the map largest primary contour interval 1=feet, 2=meters ***
12	Smallest primary contour interval	5	102-106	I5	Set to zero if no primary contour interval or source not a graphic ***
13	Smallest primary contour interval units	1	107	I1	Corresponds to the units of the map smallest primary contour interval 1=feet, 2=meters ***

*** If record 1, element 34, elevation storage code = 0 (elevations not stored), then these fields, which are DEM specific, are default to zeroes.

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 4 - continued		
14	Suspect and void areas in elevation data used to make orthophoto or missing image data	2	108-109	I2	Code 0=none 1=suspect 2=void 3=suspect & void Image imprinted with digital value of 0.
15	Horizontal DOQ accuracy	6	110-115	F6.1	RMSE of image control points for X-Y, expressed in units of record 1, element 42
16	Vertical DEM accuracy	6	116-121	F6.1	RMSE of primary DEM used to rectify image. Use largest RMSE if more than one primary DEM.
17	Number of DOQ horizontal test points	4	122-125	I4	Minimum of four, usually nine
18	Pixel processing algorithm	2	126-127	I2	Code 0=nearest neighbor 1=bilinear 2=cubic convolution
19	Production system	24	128-151	A24	Alphanumeric description of hardware & software used
20	Production date	10	152-161	I6,2I2	Four-digit year, two-digit month & day (bbYYYYMMDD)
21	Film type	24	162-185	A24	Manufacturer & ID of film type
22	Source photograph identification	24	186-209	24A1	Alphanumeric description of photograph, agency, roll number, exposure number, etc.
23	Mosaicked Image	3	210-212	I3	Code 0=not mosaicked n=number of chips composing image
24	Leaf off, flag	2	213-214	A2	Flag = "Lb" for leaf off, otherwise flag = "bb", (b=blank).

Element no.	Element	No. of bytes	Start and end bytes	FORTRAN format	Description
			RECORD 4 - continued		
25	Source photograph date	8	215-222	I4,2I2	Four digit year, two digit month & day (YYYYMMDD)
26	Camera focal length	8	223-230	F8.3	Calibrated camera focal length in millimeters
27	Source photograph flying height	10	231-240	I10	Nominal flying height of photograph in units of record 4, element 1
28	Scanner type	24	241-264	A24	Alphanumeric description stating manufacturer, model number, etc.
29	Scanning resolution	12	265-276	2F6.2	Aperture resolution in x and y directions in microns
30	Scanner sampling resolution	12	277-288	2F6.2	Sampling resolution in x and y directions in microns.
31	Radiometric resolution of image	3	289-291	I3	Code 1=8 bits 2=16 bits
32	Resampled gound resolution	6	292-297	F6.2	Code 0.0=not resampled, else resampled resolution in units of record 1, element 42
33	Compression flag	1	299	A1	S or blank=uncompressed image C=compressed image
34	Compressed image file size	9	301-309	I9	Compressed file size in bytes
35	Compression algorithm	20	311-330	A20	Name of the compression algorithm and version number
36	Compression type	1	332	A1	I=irreversible compression (lossy) R=reversible (lossless)
37	Compression control factor	4	334-337	I4	Compression control factor
38	Reserved	103	298-400		Reserved for future use

39	Blank Fill	401 - M		M = byte count of image

RECORDS 5 - N

5 - N	Data records	--	---	--	Image data are records 5 - N where N equals the number of lines of data. See appendix 2-C for examples of structure of valid types of image data.

Appendix 2-B
Universal Transverse Mercator Zone Locations
and Central Meridians (CM)

Zone	CM	Range	Zone	CM	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-C

Examples of Band Storage

The following examples are hypothetical digital orthophoto quadrangles as specified in appendix 2-A, record 1, elements 32-35. The example illustrated by figure 2-3 (band type code = 1, black and white, elevations not stored) is considered to be the only authorized option available at this time. All other examples are submitted for the purpose of illustrating future file options. The size of a given digital orthophoto may vary with the amount of overedge and the specific coordinates of the quadrangle. These examples shall illustrate a quarter-quadrangle digital orthophoto conforming to a 3.75-minute DEM with 30-meter grid spacing having 176 profiles and 226 elevations per profile is illustrated. A uniform overedge of 14 DEM grid posts (14 x 30 = 420 meters) on all sides is also included. The sample model is 176 +(14 x 2)=204 by 226 +(14 x 2)=254

The digital orthophoto is from 1:40,000-scale NAPP photography scanned with a 25-micron spotsize and therefore has a one meter pixel resolution at ground scale. The size of the digital orthophoto is (204 - 1) x 30 = 6090 scan lines by (254 - 1) x 30 = 7590 pixel samples per line. Each image pixel is represented with an 8-bit byte (gray scale of 0 to 255) and therefore the sample black and white image represents 6090 bytes by 7590 bytes.

Abbreviations:
r-red band g-green band b-blue band e-elevation m-monochrome band

The figures on the following pages illustrate the various configurations of data that are possible as specified in record 1, elements 32-35. A combination of bands together in a record is referred to as band interleaving.

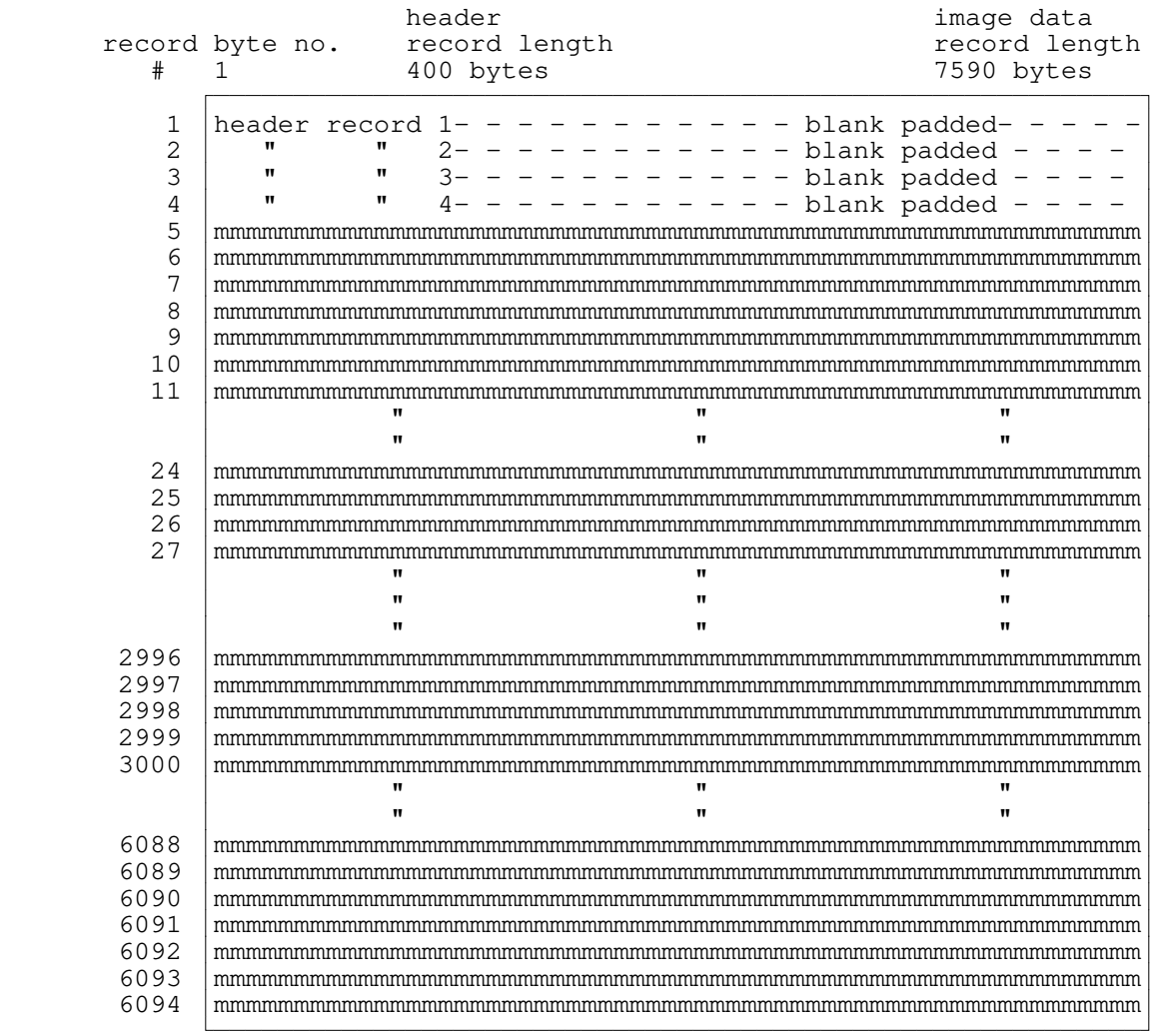
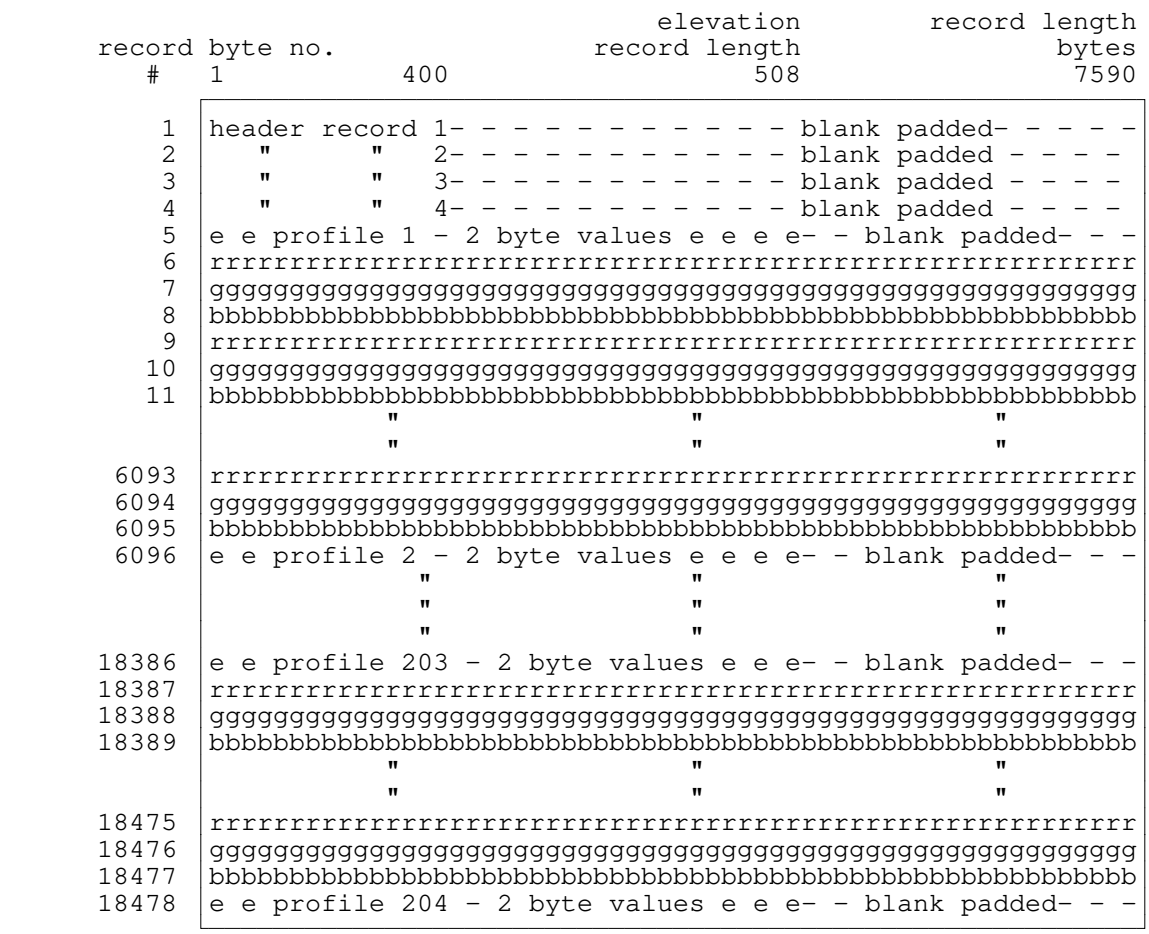


Fig. 2-3 Example of a standard digital orthophoto stored as a simple monochrome image file with none of the options exercised to store red, green, blue, or elevation data.



204 profiles of 254 elevations per profile - 18474 records (6090 x 3 + 204) of 7590 samples per record of image data. Represents a 25 micron scan of color infrared NAPP at 1:40,000 scale 1 meter ground pixel resolution.

Fig. 2-4 Example of an optional RGB Orthophoto stored as Band Interleaved by Line or Record Format with 30 records of image data between each 30 meter elevation profile

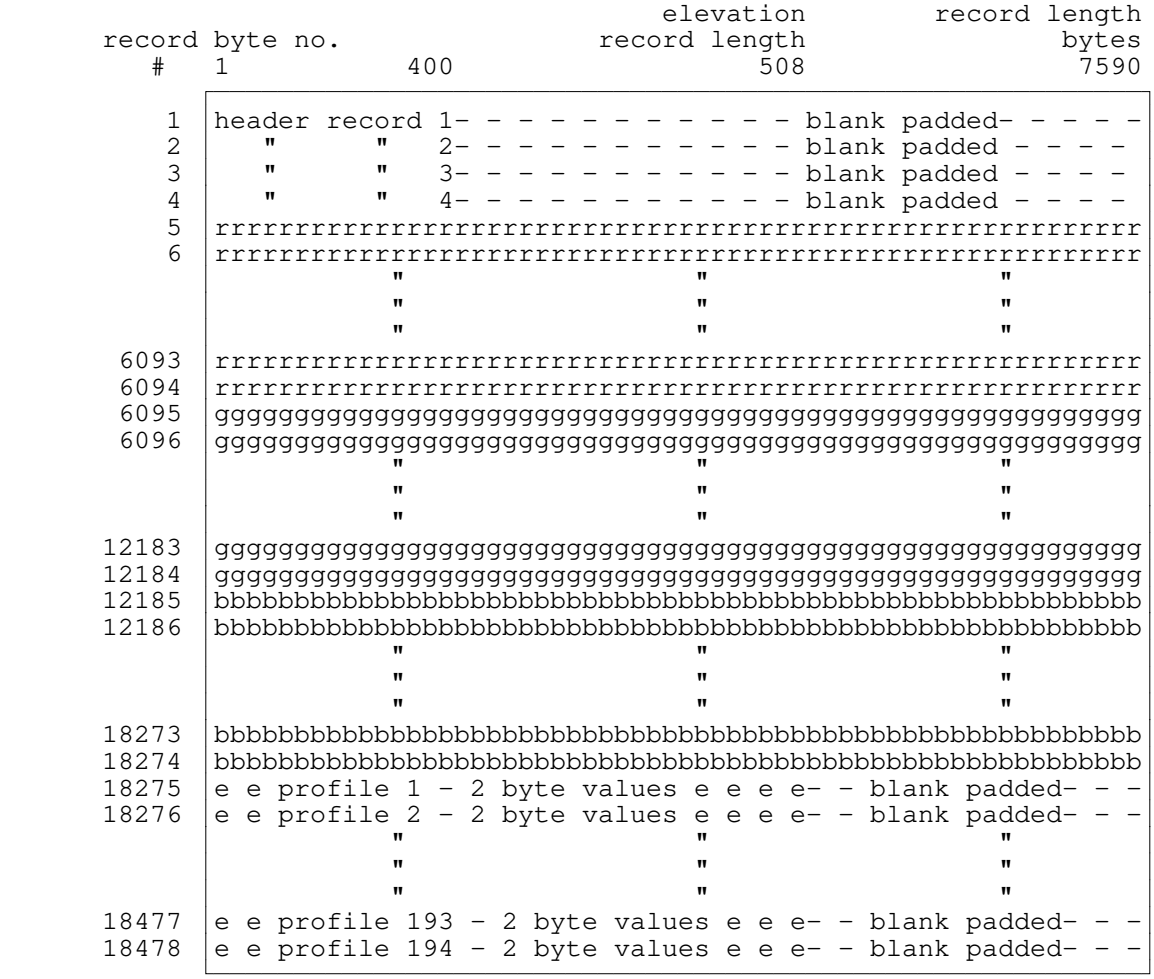


Fig. 2-5 Example of RGB Orthophoto stored as Band Interleaved by Band Format with 6090 records of each band appended to each other and 204 records of 254 elevations per profile blank padded to 7590 byte record lengths.

record #	byte no. 1 ... 400	length bytes
1	header record 1 - - - - blank padded- - - - - - - -	4040
	- -	8080
	- -	12120
	- -	16160
2	" " 2 - - - - blank padded- - - - - - - -	4040
	- -	8080
	- -	12120
	- -	16160
3	" " 3 - - - - blank padded- - - - - - - -	4040
	- -	8080
	- -	12120
	- -	16160
4	" " 4 - - - - blank padded- - - - - - - -	4040
	- -	8080
	- -	12120
	- -	16160
5	rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe r	4040
	gbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rg	8080
	be rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe	12120
	rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe	16160
6	rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe r	4040
	gbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rg	8080
	be rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe	12120
	rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe	16160
	" " "	
	" " "	
3612	rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe r	4040
	gbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rg	8080
	be rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe	12120
	rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe rgbe	16160

r - red band g - green band b - blue band e - elevation

3612 records of 16,160 bytes per record and a 2 byte elevation interpolated for each rgb pixel

Fig. 2-6 Example of RGB Orthophoto stored as Band Interleaved by Pixel per record with interpolated elevations for each pixel (this example is not related to previous examples)

References

U. S. Department of Commerce, National Institute of Standards and Technology, 1990, Counties and Equivalent Entities of the United States, its Possessions and Associated Areas, Federal Information Processing Standards Publication (FIPSPUB6-4).

U. S. Geological Survey, 1986, Standards for Digital Elevation Models: National Mapping Program Technical Instruction.