

Standards for Digital Orthophotos

Standards for Digital Orthophotos

PREFACE

This document establishes the technical criteria to be used in production of digital orthophotos (DOQs) for USGS partners in the National Digital Orthophoto Program (NDOP) and other USGS cooperative agreements. Information in this document is integrated with other National Mapping Program Technical Instructions and specifications for data specific metadata by the Federal Geographic Data Committee (FGDC). Also defined are requirements for the collection, processing, and quality control of digital orthophoto data entered into the National Digital Cartographic Data Base (NDCDB).

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SUMMARY OF CHANGES

Complete revision 12/96

A complete revision of the Standards for Digital Orthophotos was undertaken to change both format and content of the digital orthophoto quadrangle (DOQ) header, revise technical standards for overedge imagery, and include color-infrared and true color DOQs as standard products. Changes from unlabeled data fields to keyword fields in the header make the information easier to understand while complying with mandatory file specific requirements of the Federal Geographic Data Committee's "Content Standards for Digital Geospatial Metadata." Editorial changes were also necessary to clarify the text. Previous changes have been incorporated in the revision.

Change 8/93 to Part 1 and Part 2

Allowable scanning resolution was increased to 32 μm . Overedge imagery beyond both the primary and secondary horizontal datum corner points can range from a 50 meter minimum to 300 meter maximum. These changes facilitated the participation of additional cooperators in the DOQ cost share program, yet ensured that DOQs continued to meet National Mapping Division's needs for digital line graph revision. Additional header metadata was required to describe compressed data.

First USGS National Mapping Program Standard for Digital Orthophotos was released in July, 1992.

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Part 1

General

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Part 1: General

1. GENERAL

1.1 DEFINITIONS

The terms "digital orthophoto" and "DOQ" are used throughout this document to refer to both the 1-meter ground resolution quarter-quadrangle digital orthophoto (3.75- x 3.75-minutes in extent) and the one or two-meter ground resolution quadrangle digital orthophoto (7.5- x 7.5-minutes in extent). Although the primary digital orthophoto of concern is the 1-meter quarter-quadrangle, "DOQ" will refer to both the quarter-quadrangle and quadrangle digital orthophotos unless otherwise noted. Ground resolution, for DOQs, is synonymous with ground sample distance (GSD). The terms one and two-meter ground resolution refer to the distance on the ground represented by each pixel in the x and y components. They do not infer the minimum distance that can be detected between two adjacent features, or the minimum size of a feature expressed in size of objects or distances on the ground. The term gray-scale refers to an 8-bit image having up to 256 gray levels. Black and white refers to gray-scale images from panchromatic film while monochrome refers to a gray-scale image containing light from one wavelength band (red, green, blue, or infrared).

Digital orthophoto - A digital image that has the properties of an orthographic projection. It is derived from a digitized perspective aerial photograph or other remotely sensed image data by differential rectification so that image displacements caused by camera tilt and terrain relief are removed.

Orthophoto chips - A digital orthophoto may be made up of several images mosaicked together to form the final image. Each separate piece of the mosaic that contributes to the final image is called a "chip".

National Aerial Photography Program (NAPP)- A multiple agency program coordinated by the USGS that provides panchromatic and color infrared coverage of the United States at 1:40,000 photo scale.

National High Altitude Aerial Photography Program (NHAP) - A multiple agency program coordinated by the USGS that acquired 1:80,000 photo-scale panchromatic and 1:58,000 photo-scale color infrared photography of the 48 conterminous United States from the years 1980-1987.

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1.2 OBJECTIVES

The U.S. Geological Survey (USGS) is designated as a lead Federal agency for the collection and distribution of digital cartographic data. The standards specified in this document pertain to the collection, processing, archive, and quality control of digital orthophoto data. Data produced to this standard will be archived in the National Digital Cartographic Data Base (NDCDB).

The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), the Farm Services Agency (FSA), the U.S. Forest Service (USFS), and the U.S. Geological Survey, National Mapping Division (NMD) are partners in the National Digital Orthophoto Program (NDOP). The program was created to ensure that each agency's digital orthophoto requirements are met, and to serve the needs of the broader user community for digital imagery data. The NRCS uses digital orthophotos as a common base map to facilitate the collecting, organizing and sharing of natural resource data at county field offices. The FSA uses digital orthophotos to assist in tracking producer records at county field offices. The Forest Service employs digital orthophotos as a means to more accurately inventory the national forests. NMD extracts digital base category data directly from digital orthophotos. The Standards for Digital Orthophotos supports these orthophoto requirements. Given that the requirements and technologies involved in producing digital orthophotos will remain dynamic for some time, the Standards for Digital Orthophotos outlines many key dependencies involved in producing digital orthophotos and, in some cases, alternative methods of production.

This document also provides USGS components with guidelines for performing quality control and acceptance of digital orthophoto data into the NDCDB. Data generated by NRCS, FS, NMD and other Federal agencies, or procured from the private sector, must conform to this standard, to be accepted for entry in the NDCDB.

1.3 PRODUCT DESCRIPTION

A digital orthophoto is a geo-referenced image prepared from a perspective photograph, or other remotely-sensed data in which the displacement within the image due to sensor orientation and terrain relief has been removed. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. They serve a variety of purposes, from interim maps to field

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references for earth science investigations and analysis. The digital orthophoto is useful as a layer of a geographic information system and as a tool for revising digital line graphs. Image processing algorithms can be applied to the image data to support planimetric image classification, three-dimensional modeling, and many other spatial applications. A digital orthophoto, as described in these standards, can be produced from any scale of photography. However, the program is oriented primarily toward the production of 1-meter gray-scale and color-infrared digital orthophoto quarter-quadrangles from 1:40,000-scale National Aerial Photography Program (NAPP) or NAPP-like photography. Production of one or two-meter digital orthophoto quadrangles will be primarily supported by mosaicking digital orthophoto quarter-quadrangles. Presently, hard-copy outputs from the digital orthophotos include 1:12,000-scale orthophoto quarter-quadrangles and 1:24,000-scale orthophoto quadrangles.

The digital orthophoto is created by scanning an aerial photograph transparency (diapositive) with a precision image scanner. The scanned data file is then digitally rectified to an orthographic projection by processing each image pixel through photogrammetric space resection equations. This process requires, as input, ground control points acquired from ground surveys or developed in aerotriangulation, conjugate photo-coordinates of ground control, camera orientation parameters, and a digital elevation model (DEM). The rectified digital image is then archived on suitable digital storage media with a keyword-based informational (metadata) header affixed to the beginning of the digital image.

1.4 SOURCES

The procedures and instrumentation used for production of digital orthophotos vary, depending on the systems available. Currently, NAPP or NAPP-like photography is the primary source used for the production of digital orthophotos by the USGS. NAPP photographs are quarter-quadrangle centered (3.75 minutes of longitude and latitude in geographic extent) and are exposed at a nominal flying height of 20,000 feet above mean terrain with a 6-inch (152.4 mm) focal-length camera (photo scale = 1:40,000). A quadrangle (7.5-minute) digital orthophoto is produced either by mosaicking 3.75-minute digital orthophotos or digital orthophoto chips or by generating the digital orthophoto from 1:80,000 photo-scale black and white photography from the National High Altitude Aerial Photography Program (NHAP). Color-infrared and natural color photographs may be used as a source

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for digital orthophotos. Black and white DOQs may be generated from CIR and natural color source. Other aerial photographic or digital sources may be used in the future.

The photography is scanned with an aperture that can be adjusted between 7.5 and 30 micrometers (μm), depending upon the image scanner and desired output ground/pixel resolution. For example, an aperture between 25 and 30 μm yields a reasonable compromise between file size and adequate image resolution to support the present digital orthophoto program requirements. A 9 by 9 inch (240 mm square) black and white aerial photograph scanned with an aperture of 25 μm yields approximately 88 megabytes (MB) of raw data. Using 1:40,000-scale photographs, a 25 μm scan equates to a ground sample distance of 1 meter. A black and white quarter-quadrangle digital orthophoto generated and cropped from a 240- by 240-millimeter photograph, scanned at 25 μm , with the requisite overedge and header produces a rectified file between 45-50 megabytes.

1.5 DIGITAL ORTHOPHOTO STRUCTURE AND FORMAT

The line length of DOQs varies from file to file. The standard, uncompressed grayscale DOQ format contains an ASCII header (metadata) followed by a series of 8-bit image data lines. The keyword-based, ASCII header may vary in the number of data entries. The header is affixed to the beginning of the image and is composed of strings of 79 characters each ended with a newline character. Each keyword string contains information for either identification, display, or registration of the image. Additional strings of blanks are added to the header so that the length of a header line equals the number of bytes in a line of image data. See Part 2: Specifications, 2.10 Archive and Distribution Format.

The orientation of image 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 archived and distributed so that when displayed on a computer graphics terminal, the projection grid north is at the top of the screen.

The standard DOQ format is either a 3.75-minute quarter-quadrangle or 7.5-minute quadrangle and is black and white, color-infrared (CIR), or natural color image. Both quarter-quadrangle and quadrangle DOQs contain overedge imagery. The 3.75-minute quarter-quadrangle DOQ has a ground pixel distance of 1 meter while the

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7.5-minute quadrangle has a one or two-meter ground pixel distance. The digital orthophoto is in the Universal Transverse Mercator (UTM) coordinate system on the North American Datum of 1983 (NAD 83) for 1-meter, 3.75-minute quarter-quadrangles. Either North American Datum of 1927 (NAD 27) or NAD 83 for one or two-meter, 7.5-minute quadrangles (See Section 2.5, Datums and Coordinates) can be used.

The standard, archived, quarter-quadrangle DOQ is uncompressed and is approximately 45-50 megabytes (MB) in size. DOQs are distributed in both compressed and uncompressed format. The compressed DOQ is approximately 4-6 MB in size and is accompanied by a separate header file.

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References

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

U.S. Geological Survey, 1991, Standards for 1:12,000-scale Orthophoto Quarter-Quadrangles: National Mapping Program Technical Instructions, 18 p.

U.S. Geological Survey, 1992, Standards for 1:24,000-scale Orthophoto Quadrangles: National Mapping Program Technical Instructions, 20 p.

Part 2

Specifications

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2. SPECIFICATIONS

2.1 DEFINITIONS

Band - a range of wavelengths of electromagnetic radiation. Also, image data gathered at this wavelength range.

Band Interleaved - the ordered mixing of lines (band interleaved by line, BIL) or pixels (band interleaved by pixels, BIP) of one or more bands with corresponding lines or pixels of other bands, to form a single image file. See Appendix 2-C.

Band Sequential (BSQ)- a sequence of image bands. A band sequential file may be formed by appending bands in sequence within a single file. See Appendix 2-C.

Bilinear interpolation - the mathematical computation of an unknown value based on linear interpolation along two axes. The interpolation computes the unknown value based on the weighted average of the four nearest known values. Bilinear interpolation may be used to compute pixel values in an image or elevation values from a grid elevation model.

Brightness value - a number (normally 0-255) representing a discrete intensity gray level of a pixel in an image.

Cubic Convolution - an image resampling method using cubic polynomials.

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

Metadata - description of the content, quality, condition, and other characteristics of data.

Micron (μm) / Micrometer - unit of length defined to be 10^{-6} meter.

Nearest Neighbor - an image resampling method that selects the value of the nearest neighboring pixel.

Panchromatic (photography) - a term applied to photographic materials possessing sensitivity to all visible spectral colors, including red.

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Resample - interpolation of pixel values based upon neighboring pixel values.

Resection, photogrammetric - three-dimensional determination of the location, attitude, or height of a camera, or of the photograph taken by that camera.

2.2 GEOGRAPHIC EXTENT

The area of coverage for a standard USGS digital orthophoto is either a quarter-quadrangle (3.75-minutes of latitude by 3.75-minutes of longitude plus overedge) or a quadrangle (7.5-minutes of latitude by 7.5-minutes of longitude plus overedge).

USGS requires overlap between adjoining DOQs to facilitate edge matching and mosaicking. The required overedge amount differs for participants in the National Digital Orthophoto Program (NDOP) and for other Federal, State and local agencies, and private entities who are not associated with NDOP but have USGS cooperative agreements.

Two specifications for image overedge exist: one for imagery produced by NDOP participants and one for imagery produced under other USGS cooperative agreements. The geographic extent for DOQs will be as follows:

- For DOQs produced under National Digital Orthophoto Program funding agreements: minimum 300 (± 30) meters beyond the extremes of the primary and secondary datum corner points.
- For DOQs produced under other cooperative agreements: a minimum of 50 meters beyond the primary and secondary horizontal datum corner point extremes.

The resulting digital orthophoto is a rectangle whose size may vary in relation to adjoining digital orthophotos.

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 NAPP or NAPP-like imagery (diapositives) will employ a scanning aperture no larger than $32\mu\text{m}$ for 3.75-minute DOQs and no larger than $60\mu\text{m}$ for 7.5-minute DOQs.

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The ground sample distances will be 1 meter for 3.75-minute DOQs and 1 or 2 meters for 7.5-minute DOQs. All quarter-quadrangle orthophotos with ground sample distances that are less than 1 meter or greater than 1 meter but less than 1.28 meters will be resampled to 1 meter. Interpolation of data to a 1-meter ground sample distance from imagery with a ground sample distance greater than 1.28 is not 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. These inputs are the following: 1) the unrectified raster image scanned from the diapositive or directly acquired from a digital sensor, 2) a digital elevation model with the same area of coverage as the digital orthophoto, 3) the photo identifiable image and ground coordinates of ground control points, 4) calibration information about the sensor collector device and, 5) a user parameter file. These five inputs are used to register the image file to the scanner and 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 data.

2.5 DATUMS AND COORDINATES

Digital orthophoto quarter-quadrangles will be cast on the North American Datum of 1983 (NAD 83), Universal Transverse Mercator (UTM) projection, with coordinates in meters. Digital orthophoto quadrangles will 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 will be NAD 83. The principal secondary horizontal datum for quarter-quadrangle digital orthophotos will be the NAD 27, the Puerto Rico Datum, the Old Hawaiian Datum, or other approved datum. The primary and secondary datums for digital orthophoto quadrangles will follow the specifications of National Mapping Division Supplemental Topographic Instruction 93-4-D, dated 8/24/93.

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

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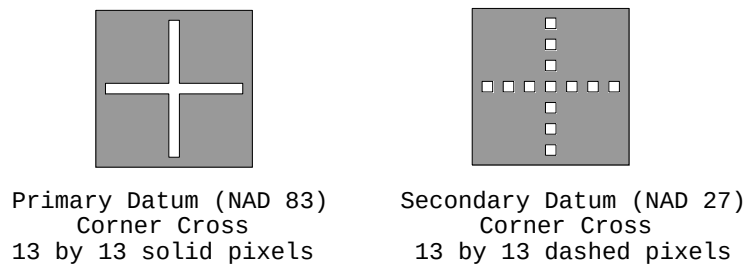


Figure 2-1 Datum Corner Points

The image header contains the primary and secondary datum corner X, Y coordinates, representing the four theoretical quadrangle corners in each datum.

2.6

ACCURACY

Digital orthophoto quadrangles and quarter-quadrangles must meet horizontal National Map Accuracy Standards (NMAS) 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 or better than a level 1 DEM, with a root-mean-square-error (RMSE) of no greater than 7.0 meters. The DOQ RMSE is the square root of the average of the squared discrepancies. These discrepancies are the differences in coordinate (X and Y) values derived by comparing the data being tested with values determined during aerotriangulation or by an independent survey of higher accuracy. All remaining inputs and processes (i.e., aerotriangulation control and methodology, scanner and sensor calibrations) used in digital orthophoto production must be sufficiently accurate to ensure that the final product meets NMAS.

2.7

GROUND SAMPLE DISTANCE

The horizontal ground resolution or ground sample distance (the area of the ground represented in each pixel in x and y components) of NDCDB digital orthophoto quarter-quadrangles will be 1 meter. This includes 3.75-minute DOQs produced by USGS and other Federal agencies participating in orthophoto production under joint funding agreements and producers of 3.75-minute DOQs participating under

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cooperative agreements with the USGS. The horizontal ground resolution for 7.5-minute digital orthophoto quadrangles will be 1 or 2 meters.

2.8 IMAGE RADIOMETRY

Image brightness values will be represented by 256 gray levels and represented by a number in a range of 0-255. A value of zero will represent black and a value of 255, white; all intermediate values are shades of gray varying from black to white. Areas where the rectification process is incomplete due to missing data (i.e., lack of elevation data, gaps), will be represented with a numeric value of 128 or zero (0).

2.9 IMAGE MOSAICKING

When a mosaic of two or more digital orthophoto chips is made, the brightness values of the other chips will be adjusted to match that of the reference chip. The join lines between the overlapping chips will be chosen to minimize tonal variations. Localized adjustment of the brightness values will be done to reduce tonal differences between join areas.

2.10 DATA QUALITY

2.10.1 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 will be verified by visual inspection of the digital orthophoto with the original unrectified image to determine if the digital orthophoto has the same image quality as the source image(s).

2.10.2 Accuracy Verification

The accuracy of a DOQ is affected by several factors: photo scale, ground control, camera characteristics and the elevation model used to orthorectify the image. Therefore the producers of DOQs will ensure that all critical components have known accuracies suitable for the construction of an orthophotograph. On most standard USGS-produced DOQs, nine well-defined points are tested.

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Visual verification will be done for image accuracy and completeness, to ensure that no gaps exist in either the image area or the overedge coverage. Duplicate or missing image content is an indication of poor DEM or unsuitable control and will be corrected.

Occasionally, because of DEM spikes or excessive relief in the image, an anomaly or artifact best described as an "image smear" may appear on an orthorectified image. Basically, the steepness of the terrain is such that some ground image is effectively hidden from view (e.g., on the backside of the mountain or the sides of a steep cliff). This can be especially prominent near the edges of a photograph. Where the ground is hidden from the camera position, the resampling algorithm uses the visible imagery to fill the void. For an elevation spike, the image will be warped in a region that corresponds to the DEM cell size. This sometimes results in a "smeared" or "stretched" area on the image.

When these artifacts occur, all reasonable means to correct them will be applied. Many artifacts occur in the overedge of DOQs and can usually be eliminated by rectifying the adjacent photograph to improve central perspective geometry. When a DEM spike error is detected, correcting the DEM can easily eliminate the smear. However attempting to correct stretched or smeared artifacts due to excessive relief should be weighed against how much smearing occurs, the time it takes to correct the artifact, and the features affected. It may not be cost-effective or necessary depending upon where the artifact manifests itself, e.g., outside the quadrangle boundaries. Quantifying the amount of acceptable smearing in an image can be a difficult process. Until reliable methods to predict the location and amount of smearing are established, a case by case visual inspection will determine whether to accept, remake, or reject an image. It will be necessary to remake or reject any image with smears if artifacts appear as listed below:

- In areas where man-made planimetric features are evident
- In areas where significant natural features appear
- The artifacts are of such an extent as to render the DOQ unusable

2.11 ARCHIVE AND DISTRIBUTION FORMAT
The standard DOQ for entry into the National Digital Cartographic

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Data Base (NDCDB) consists of an ASCII header line(s) followed by 8-bit image data.

2.11.1 Header Format

The header (metadata) is affixed to the beginning of the image data and is composed of a variable number of ASCII-text metadata entries. To simplify in-place header editing, each entry is 80 characters long and ends with an asterisk (*) as character 79 and an invisible newline character as character 80.

The header line will be equal in length to the length of an image line. If the sum of the byte count of the header is less than the sample count of one DOQ image line, then the remainder of the header is padded with the requisite number of 80 character blank entries, each terminated with an asterisk and newline character. If the number of 80 character blank-padded entries is not an even multiple of one image line, then a partial blank padded entry, terminating asterisk, and newline character is added to the header just before the terminating 80 character keyword entry that begins with END_USGS_HEADER (see Appendix 2-B).

As an example, an orthophoto with an image line length of 6076 samples is used. The number of metadata entries is forty-five 80 character units, totaling 3600 bytes and lacking 2476 bytes to equal the image line. The header line would be padded with 30 blank-padded, 80-character entries, and one unequal entry of 76 characters, equaling a sum of 2476 blank-pads. The total byte count of the metadata would be 6076, which would then equal the length of one DOQ image line. If the header has more bytes than one line of DOQ image samples, then the header will be blank-padded to equal the samples in two DOQ image lines, and so forth.

The number of lines and keyword entries within the header is deliberately undefined to allow flexibility for accommodating header expansion and contraction within a data set and for promoting this header format on other USGS raster data.

The DOQ header begins with the keyword, BEGIN_USGS_DOQ_HEADER and is ended with the keyword, END_USGS_HEADER. Section 2.12 defines the Header Data Format and Appendix 2-A defines the file format specifications. The examples found in Appendix 2-B illustrate the structure of a DOQ keyword header complete with blank padding.

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2.11.2 Image Data Format

A line of DOQ image data is composed of samples (pixels) that extend from West to East. All DOQ image lines contain the same number of samples. The total DOQ image is composed of lines ordered from North to South. The number of samples and lines composing the image is included in the metadata header affixed to the image (keyword SAMPLES_AND_LINES). Data are lines 1 - N, where N equals the number of lines of image data. See Appendix 2-C for examples of how lines are ordered and stored.

2.12 HEADER DATA FORMAT

The DOQ header contains the file-specific (inventory), mandatory element contents required by the Federal Geographic Data Committee's (FGDC) Content Standards for Digital Geospatial Metadata (6/8/94). The DOQ does not contain a full FGDC-compliant metadata file as it does not include mandatory data series (collection) FGDC elements. Those data are considered generic, i.e., common across a data type or series. Descriptions of both inventory and collection-level metadata entries for USGS DOQs may be found in the USGS Technical Instructions, Standards for the Preparation of Digital Geospatial Metadata, Part 6, Digital Orthophoto Quadrangles.

Collection level metadata files are available via the World Wide Web on the National Geospatial Data Infrastructure (NSDI), National Geospatial Data Clearinghouse. When a DOQ is produced and archived, inventory or file-specific information from its header will be appended to the collection file. The WWW address for the National Geospatial Data Infrastructure (NSDI), National Geospatial Data Clearinghouse is as follows:

<http://nsdi.usgs.gov/nsdi/wais/maps/doqmet.HTML>

The DOQ header is designed to include information about the image that allows a user to easily identify, display, and register other geo-referenced data to the DOQ. In addition, it contains information deemed useful but not covered in the June 8, 1994, version of the FGDC standard and therefore, the header contains element names not found in the FGDC standard. To avoid creating a header that mixed FGDC and non-FGDC element names and, to give each element a unique descriptor, DOQ header keywords generally do not match the element names in the FGDC metadata standard. However, every effort has been made to ensure that each keyword's content meets that standard. Where applicable, the equivalent FGDC element

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name will be noted in the appropriate DOQ keyword description of Appendix 2-A.

The DOQ header consists of N number of entries of information relating to the 1) identification, 2) display, 3) registration, and 4) other pertinent properties of the DOQ. The USGS DOQ header must begin with an entry having the BEGIN_USGS_DOQ_HEADER keyword and end with an entry having the END_USGS_HEADER keyword. While the number of metadata entries contained in the header is undefined and may differ from image to image, the standard DOQ must contain the mandatory elements described in Sections 2.12.1 - 2.12.4. Each keyword entry in the header is 80 characters in length and terminated by an ASCII newline character included in the character count of the line.

The format of each keyword entry is as follows:

keyword data comments newline

A **keyword** is a unique string of non-blank, ASCII characters. Each keyword defines a fixed number of parameters that follow the keyword on the line. Keywords may be repeated. Other DOQ producers may employ additional keywords for their internal use but an NDCDB DOQ requires, at minimum, the mandatory keywords described in Sections 2.12.1 - 2.12.4.

Parameters are strings of ASCII characters representing values or text. Text parameters containing embedded blank characters must be enclosed in double quotation marks, e.g., "Half Moon Bay". Valid values for the parameters are described in Appendix 2-A.

Comments composed of any ASCII characters may follow the last parameters defined by a keyword. Blank characters separate the keyword from the parameters, multiple parameters, and the last parameter from the comment.

Producing agencies will place keywords in the Identification, Display, Registration, and Informational sequence shown in Sections 2.12-1 -2.12.4.

A keyword header entry is composed of 80 characters including the newline character as character 80. DOQ producing agencies will put an asterisk (*) in column 79 to help in-place editing of the header.

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2.12.1 Identification

Data grouped under the Identification section hold the minimum elements required for uniquely identifying the image, including the geographic coverage of the image, 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, and the production date of the DOQ.

BEGIN_USGS_DOQ_HEADER

The USGS DOQ header begins with the keyword BEGIN_USGS_DOQ_HEADER. It identifies the data as a USGS DOQ and begins the header.

QUADRANGLE_NAME

This is the name of the DOQ as designated by the Geographic Cell Names Data Base. The 3.75-minute quarter-quadrangle cell name is based upon the 7.5-minute cell name followed by the appropriate directional quadrant, specified as NE, NW, SW, or SE that is the parameter for the keyword QUADRANT (see below). A 7.5-minute quadrangle name may contain a directional quadrant as part of their proper quadrangle name.

QUADRANT

The 3.75-minute quadrant directional, either NW, NE, SE, or SW. See QUADRANGLE_NAME keyword description. A quadrant entry is not applicable to 7.5-minute orthophotos.

WEST_LONGITUDE

The western-most boundary of the 3.75- or 7.5-minute quadrangle excluding the overedge. USGS DOQs possess approximately 300 meters of overedge imagery beyond the primary and secondary datum corners, whichever is larger, to facilitate edge matching and mosaicking. These bounding coordinates define the extent of the 3.75- or 7.5-minute quadrangles, **not** the extent of the entire image.

EAST_LONGITUDE

The eastern-most boundary of the 3.75- or 7.5-minute quadrangle excluding the overedge.

NORTH_LATITUDE

The northern-most boundary of the 3.75- or 7.5-minute quadrangle excluding the overedge.

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SOUTH_LATITUDE

The southern-most boundary of the 3.75- or 7.5-minute quadrangle excluding the overedge.

PRODUCTION_DATE

The date the DOQ was produced.

2.12.2

Display

Header content under the Display section contains data necessary for displaying the image. With this information, a user with the suitable viewing software and hardware can display the DOQ.

RASTER_ORDER

The raster data order. The data will be organized by line, each line containing a series of pixels from west to east. The order of lines will be from north to south.

BAND_ORGANIZATION

The default storage formats for digital orthophotos are as a "**Single file**" for gray-scale images and band interleaved by pixel (**BIP**) for 3-band color infrared images, natural color or multiple-band images. Eight-bit single band color images from natural color or CIR RGB images and 24-bit RGB images reconstituted from 8-bit composite images are not acceptable.

BAND_CONTENT

The defaults for band types and storage sequence are **BLACK&WHITE** for images from panchromatic film or single file gray-scale produced by combining the bands from color source images. For multiple-band DOQs, the BAND_CONTENT keyword is repeated for each band with one parameter per band in the band order, **RED**, **BLUE**, then **GREEN**. Single band content for monochrome DOQs will be indicated by either **RED**, **GREEN**, or **BLUE**. Provision also is made in this field for various band types and combinations: e.g., separate color bands, 3-band color plus black and white. The order of colors for band storage is always red, green, blue, followed by monochrome, if applicable.

BITS_PER_PIXEL

The number of bits per sample. The default is **8** bits per pixel.

SAMPLES_AND_LINES

The number of samples (columns) and lines (rows) of data of a single band of the data set, ordered as specified in RASTER_ORDER

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description.

2.12.3 Registration

Content grouped under this section are required for geo-referencing the data and geometrically aligning (registering) two or more images.

HORIZONTAL_DATUM

This keyword gives the primary horizontal datum, which for USGS digital orthophoto quarter-quadrangles, will be **NAD83**. The primary datum for digital orthophoto quadrangles will be NAD83, NAD27, or other approved datum.

HORIZONTAL_COORDINATE_SYSTEM

Provides the ground X-Y coordinate reference system of the DOQ. The USGS DOQ default coordinate system is the Universal Transverse Mercator, **UTM**.

COORDINATE_ZONE

The zone identifier for the horizontal coordinate system. The default for USGS DOQs would be the appropriate UTM zone number.

HORIZONTAL_UNITS

The planar distance units of the coordinate system. The default units are **meters**.

HORIZONTAL_RESOLUTION

The coordinate system resolution (that area of the ground represented by a pixel) in units specified in HORIZONTAL_UNITS. For 3.75-minute DOQs, the requirement is **1.0**.

SECONDARY_HORIZONTAL_DATUM

The secondary horizontal datum will be the former principal horizontal datum for the geographic area (i.e., **NAD27**, Old Hawaiian, Puerto Rico). The secondary horizontal datum for 3.75-minute digital orthophoto quadrangles will be either NAD27 or other approved datum.

XY_ORIGIN

Contains ground coordinates of the first pixel in the first line of data (pixel 1,1) in the primary horizontal datum and units.

SECONDARY_XY_ORIGIN

Contains ground coordinates of the first pixel in the first line of

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data (pixel 1,1) in the secondary horizontal datum and units.

2.12.4 Other Information

Most of the data found in this section are required by the Content Standards for Digital Geospatial Metadata and are considered useful. Not all are necessary to identify, display, or register the image.

NATION

The Federal Information Processing Standard (FIPS) Publication 10-3 (1977) abbreviations for the names of the nation or nations of coverage: US, MX, and CA. This keyword will be repeated if a DOQ is in two countries. Only one country value is permitted per 80 character entry.

STATE

The State(s) of coverage using code specifications described in the Federal Information Processing Standard (FIPS) Publications 6-4. Each State will be coded as a 2-digit alpha code. This keyword will be repeated if a DOQ is in more than one state. Only one state value is permitted per 80 character entry.

The order of multiple States in the header will be based on the (approximated) square mileage of the States contained in the image: i.e., the State with the largest area within the image first followed by the State with the second largest area and so on. Only the States actually contained within the 3.75-minute quadrangle area are coded in the header.

NW_QUAD_CORNER_XY

Contains the primary horizontal datum ground X and Y coordinates of the NW theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

NE_QUAD_CORNER_XY

Contains the primary horizontal datum ground X and Y coordinates of the NE theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

SE_QUAD_CORNER_XY

Contains the primary horizontal datum ground X and Y coordinates of the SE theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

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SW_QUAD_CORNER_XY

Contains the primary horizontal datum ground X and Y coordinates of the SW theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

SECONDARY_NW_QUAD_XY

Contains the secondary horizontal datum ground X and Y coordinates of the NW theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

SECONDARY_NE_QUAD_XY

Contains the secondary horizontal datum ground X and Y coordinates of the NE theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

SECONDARY_SE_QUAD_XY

Contains the secondary horizontal datum ground X and Y coordinates of the SE theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

SECONDARY_SW_QUAD_XY

Contains the secondary horizontal datum ground X and Y coordinates of the SW theoretical quadrangle corner in units specified under HORIZONTAL_UNITS, Section 2.12.3.

RMSE_XY

Contains the relative horizontal accuracy of the digital orthophoto expressed as an RMSE in the units specified under keyword HORIZONTAL_UNITS.

IMAGE_SOURCE

This keyword identifies the image source data type; either **"Black and White film"**, **"CIR film"**, or **"Natural Color film"**.

SOURCE_IMAGE_ID

For film image sources, this keyword contains the film identification, roll, and exposure number. If more than one image is used for the DOQ, this keyword is repeated with SOURCE_IMAGE_DATE.

SOURCE_IMAGE_DATE

Contains the date of the imagery (expressed as YYYY MM DD). When the digital orthophoto is mosaicked from multiple image chips (more

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than one SOURCE_IMAGE_ID), the SOURCE_IMAGE_DATE should follow the associated SOURCE_IMAGE_ID entry.

SOURCE_DEM_DATE

The production date of the source DEM. This date could be used to determine whether the DEM is from the NDCDB archive or whether it was built specifically for DOQ production. The difference between existing, archived DEMs and DEMs built just prior to DOQ production is that the archived DEMs have been fully edited to meet USGS DEM specifications while newly built DEMs may only have been partially edited. An example is a new DEM that has water bodies that have not been leveled, and therefore would not meet full DEM specifications.

AGENCY

Identifies the production mapping center or agency responsible for checking and submitting the digital orthophoto to the NDCDB.

PRODUCER

Lists the mapping center, other governmental agency, or contractor that produced the digital orthophoto.

PRODUCTION_SYSTEM

The names of the hardware and software components, including software version numbers, used to make the orthophoto.

COMPRESSION

Identifies the compression type name, version number, and decompression type name of compressed images. If the image is uncompressed, omit COMPRESSION keyword. DOQs are archived uncompressed. However, some compressed DOQs are distributed on CD-ROM.

STANDARD_VERSION

The date of the DOQ standard to which the file complies. The version date is the date on the latest change notice.

METADATA_DATE

This keyword contains the date that the metadata for the image was created or last updated.

DATA_FILE_SIZE

Indicates the size of the data set, including the keyword header, in bytes.

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BYTE_COUNT

This keyword contains the total number of bytes comprising the header, including the associated blank fill.

END_USGS_HEADER

This keyword ends the DOQ header.

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APPENDIX 2-A Digital Orthophoto Header Descriptions

Domain descriptions in bold and marked with an asterisk (*) indicate standard USGS DOQ values.
FGDC *Content Standards for Digital Geospatial Metadata* (6/8/94) data element name equivalents are in brackets, e.g., [FGDC Metadata Element], in the Element Description column.

Keyword	Element Description		Type	Domain/Example
IDENTIFICATION				
BEGIN_USGS_DOQ_HEADER	data type identification			
QUADRANGLE_NAME	data set name [Title]	Quadrangle name	text ¹	7.5-minute cell name e.g. "Half Moon Bay"
QUADRANT		Quadrant		Quadrant directional if image is quarter-quadrangle NW, NE, SE, SW
WEST_LONGITUDE	western-most boundary of the 3.75- or 7.5-minute quadrangle, excluding overedge [West Bounding Coordinate]		compound numeric	signed degrees, minutes, seconds DDD MM SS.SSS e.g. -110 03 45.000
EAST_LONGITUDE	eastern-most boundary of the 3.75- or 7.5-minute quadrangle, excluding overedge [East Bounding Coordinate]		compound numeric	DDD MM SS.SSS e.g. -110 00 00.000

¹A text data type field must be enclosed in double quotation marks if it contains spaces. If more than one text field is specified for a keyword (see COMPRESSION keyword example), each field must be enclosed in double quotation marks.

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Keyword	Element Description	Type	Domain/Example
NORTH_LATITUDE	northern-most boundary of the 3.75- or 7.5-minute quadrangle, excluding overedge <i>[North Bounding Coordinate]</i>	compound numeric	DD MM SS.SSS e.g. 38 03 45.000
SOUTH_LATITUDE	southern-most boundary of the 3.75- or 7.5-minute quadrangle, excluding overedge <i>[South Bounding Coordinate]</i>	compound numeric	DD MM SS.SSS e.g. 38 03 45.000
PRODUCTION_DATE	the date the data was produced <i>[Publication Date]</i>	date	YYYY MM DD
DISPLAY			
RASTER_ORDER	raster data order <i>[Format Information Content]</i>	text	left_right/top_bottom*
BAND_ORGANIZATION	raster data organization <i>[Format Information Content]</i>	text	"single file" = single file BIP = band interleaved by pixel* BSQ = band sequential BIL = band interleaved by line
BAND_CONTENT	data content of each band (repeat keyword as necessary) <i>[Format Information Content]</i>	text	BLACK&WHITE RED GREEN BLUE
BITS_PER_PIXEL	bits per pixel of raster data <i>[Format Information Content]</i>	numeric	8 *

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Keyword	Element Description	Type	Domain/Example
SAMPLES_AND_LINES	number of samples (columns) and lines (rows) <i>[Row and Column Count]</i>	compound numeric	SSSS LLLL e.g. 6320 7665
REGISTRATION			
HORIZONTAL_DATUM	name of primary horizontal datum <i>[Horizontal Datum Name]</i>	text	NAD83 = North American Datum 1983* NAD27 = North American Datum 1927 WGS72 = World Geodetic System 1972 WGS84 = World Geodetic System 1984 "Old Hawaii Datum" "Puerto Rico Datum"
HORIZONTAL_COORDINATE_SYSTEM	coordinate system in which data is presented <i>[Horizontal Datum Name]</i>	text	UTM = Universal Transverse Mercator* SPCS = State Plane Coordinate System Geographic = geographic
COORDINATE_ZONE	coordinate system zone <i>[UTM Zone Number]</i>	numeric	1-60 = UTM zone numbers Other coordinate system zone numbers

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Keyword	Element Description	Type	Domain/Example
HORIZONTAL_UNITS	coordinate system units <i>[Planar System Units]</i>	text	meters * feet "international feet" "survey feet" radians "arc seconds"
HORIZONTAL_RESOLUTION	coordinate system (pixel) ground distance specified in horizontal units <i>[Abscissa and Ordinate Resolution]</i>	numeric	USGS DOQ default is 1.0
SECONDARY_HORIZONTAL_DATUM	name of the secondary horizontal datum <i>[Horizontal Datum Name]</i>	text	NAD83 = North American Datum 1983 NAD27 = North American Datum 1927* WGS72 = World Geodetic System 1972 WGS84 = World Geodetic System 1984 "Old Hawaii Datum" "Puerto Rico Datum"

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Keyword	Element Description	Type	Domain/Example
XY_ORIGIN	HORIZONTAL_DATUM x and y coordinates of upper left pixel in HORIZONTAL_UNITS [XY_ORIGIN does not have a FGDC metadata element counterpart but this data may be stored under <i>Supplemental_Information</i>]	<i>compound numeric</i>	e.g. 676442.0 4152645.0
SECONDARY_XY_ORIGIN	SECONDARY_HORIZONTAL_DATUM x and y coordinates of upper left pixel in HORIZONTAL_UNITS [SECONDARY_XY_ORIGIN does not have a FGDC metadata element counterpart but this data may be stored under <i>Supplemental_Information</i>]	compound numeric	e.g. 676442.0 4152640.0
OTHER INFORMATION			
NATION	FIPS PUB 10-3 two-letter nation code (repeat as necessary) [Place_Keyword]	text	US, CA, MX
STATE	FIPS PUB 6-4 two-letter alpha State code. (repeat as necessary) [Place_Keyword]	text	e.g. CA

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Keyword	Element Description	Type	Domain/Example
NW_QUAD_CORNER_XY	HORIZONTAL_DATUM x and y coordinates of NW quadrangle corner in HORIZONTAL_UNITS [NW_QUAD_CORNER_XY does not have a FGDC metadata element counterpart but this data may be stored under <i>Supplemental_Information</i>]	compound numeric	e.g. 473228.05 4400056.95
NE_QUAD_CORNER_XY	HORIZONTAL_DATUM x and y coordinates of NE quadrangle corner in HORIZONTAL_UNITS [see NW_QUAD_CORNER_XY element description]	compound numeric	e.g. 478582.44 4400040.14
SE_QUAD_CORNER_XY	HORIZONTAL_DATUM x and y coordinates of NW quadrangle corner in HORIZONTAL_UNITS [see NW_QUAD_CORNER_XY element description]	compound numeric	e.g. 478563.10 4393103.58
SW_QUAD_CORNER_XY	HORIZONTAL_DATUM x and y coordinates of SW quadrangle corner in HORIZONTAL_UNITS [see NW_QUAD_CORNER_XY element description]	compound numeric	e.g. 473203.87 4393120.38

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Keyword	Element Description	Type	Domain/Example
SECONDARY_NW_QUAD_XY	SECONDARY_HORIZONTAL_DATUM x and y coordinates of NW quadrangle corner in HORIZONTAL_UNITS [SECONDARY_NW_QUAD_XY does not have a FGDC metadata element counterpart but this data may be stored under <i>Supplemental_ Information</i>]	compound numeric	e.g. 473227.35 4399847.41
SECONDARY_NE_QUAD_XY	SECONDARY_HORIZONTAL_DATUM x and y coordinates of NE quadrangle corner in HORIZONTAL_UNITS [see SECONDARY_NW_QUAD_XY element description]	compound numeric	e.g. 478581.88 4399830.60
SECONDARY_SE_QUAD_XY	SECONDARY_HORIZONTAL_DATUM x and y coordinates of SE quadrangle corner in HORIZONTAL_UNITS [see SECONDARY_NW_QUAD_XY element description]	compound numeric	e.g. 478562.54 4392894.17
SECONDARY_SW_QUAD_XY	SECONDARY_HORIZONTAL_DATUM x and y coordinates of SW quadrangle corner in HORIZONTAL_UNITS [see SECONDARY_NW_QUAD_XY element description]	compound numeric	e.g. 473203.17 4392910.07

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Keyword	Element Description	Type	Domain/Example
RMSE_XY	the relative horizontal accuracy of the DOQ in horizontal units <i>[Horizontal Accuracy Value]</i>	numeric	e.g. 3.2
IMAGE_SOURCE	description of the type of source data, film or digital. <i>[Type of source media]</i>	text	"Black & White film" "CIR film" "Natural Color film" other - free text
SOURCE_IMAGE_ID	source image identification (repeat as necessary; the presence of more than one source image id indicates that the DOQ is a mosaic.)) <i>[Title]</i>	text	for film source, this should include program identification, roll, and exposure number e.g. "NAPP 2370-112"
SOURCE_IMAGE_DATE	the date of the source image (repeat as necessary following SOURCE_IMAGE_ID) <i>[Calendar Date]</i>	date	YYYY MM DD
SOURCE_DEM_DATE	the date the source DEM was produced <i>[Calendar Date]</i>	date	YYYY MM DD
AGENCY	name of oversight agency <i>[Originator]</i>	text	"U.S. Geological Survey" "Western Mapping Center (WMC)"

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Keyword	Element Description	Type	Domain/Example
PRODUCER	the name of the producer (USGS mapping centers will include the center abbreviation; contractors will use their organization's name) <i>[Supplemental Information]</i>	text	"Western Mapping Center (WMC)" "John Doe Mapping Company"
PRODUCTION_SYSTEM	the names of the hardware and software, including version numbers, used in the production of the DOQ <i>[Native Data Set Environment]</i>	text	free text e.g."DV1.2 3/93 0V1.1 04/93"
COMPRESSION	Compression technique and parameters: data format, format version (this keyword is present only if the data is compressed) <i>[File Compression Technique]</i>	text	line contains three fields: • compression format name • format version number • decompression name e.g."CJPEG" "JFIFV1.01" "DJPEG"
STANDARD_VERSION	the date (if the version of the standard is identified only by date) of the DOQ standard to which the file complies <i>[Format version date]</i>	date	YYYY MM
METADATA_DATE	the date the metadata were created or last updated <i>[Metadata Date]</i>	date	YYYY MM DD

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Keyword	Element Description	Type	Domain/Example
DATA_FILE_SIZE	the size of the data set in bytes including header <i>[Native_Data_Set_Environment]</i>	numeric	e.g. 54198774
BYTE_COUNT	the size of the header, including the associated blank fill, in bytes [no FGDC metadata equivalent, place under <i>Supplemental_Information]</i>	numeric	e.g. 6076
END OF HEADER			
END_USGS_HEADER			

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APPENDIX 2-B Example of a USGS Keyword Header

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BEGIN_USGS_DOQ_HEADER
QUADRANGLE_NAME "QUINCY WEST" 3.75 or 7.5-min.name*
QUADRANT NE quadrant indicator if cell size = 3.75minutes*
WEST_LONGITUDE -91 26 15.000 signed deg., min. & sec.*
EAST_LONGITUDE -91 22 30.000 signed deg., min. & sec.*
NORTH_LATITUDE 40 0 0.000 signed deg., min. & sec.*
SOUTH_LATITUDE 39 56 15.000 signed deg., min. & sec.*
PRODUCTION_DATE 1995 07 13 yyyy mm dd*
RASTER_ORDER LEFT_RIGHT/TOP_BOTTOM video display order*
BAND_ORGANIZATION "SINGLE FILE" single file or BSQ, or BIL or BIP*
BAND_CONTENT BLACK&WHITE black&white or red green blue*
BITS_PER_PIXEL 8 *
SAMPLES_AND_LINES 6076 7641 number of columns and rows*
HORIZONTAL_DATUM NAD83 primary horizontal datum*
HORIZONTAL_COORDINATE_SYSTEM UTM *
COORDINATE_ZONE 15 coordinate system zone number*
HORIZONTAL_UNITS METERS coordinate system units*
HORIZONTAL_RESOLUTION 1.0 coordinate system geometric resolu. in horiz. units*
SECONDARY_HORIZONTAL_DATUM NAD27 secondary horizontal datum*
XY_ORIGIN 633063.000 4429328.000 coord. of upper left pixel-pri. datum*
SECONDARY_XY_ORIGIN 633079.000 4429113.000 coord.-upper left pixel-sec datum*
NATION US nation code*
STATE IL state fips codes*
STATE MO state fips codes*
NW_QUAD_CORNER_XY 633377.438 4428926.385 X-Y coords. of pri. NW quad corner*
NE_QUAD_CORNER_XY 638712.782 4429021.805 X-Y coords. of pri. NE quad corner*
SE_QUAD_CORNER_XY 638839.205 4422084.460 X-Y coords. of pri. SE quad corner*
SW_QUAD_CORNER_XY 633498.995 4421989.077 X-Y coords. of pri. SW quad corner*
SECONDARY_NW_QUAD_XY 633380.942 4428716.377 X-Y coords. - sec. NW quad cor.*
SECONDARY_NE_QUAD_XY 638716.426 4428811.800 X-Y coords. - sec. NE quad cor.*
SECONDARY_SE_QUAD_XY 638842.847 4421874.579 X-Y coords. - sec. SE quad cor.*
SECONDARY_SW_QUAD_XY 633502.497 4421779.193 X-Y coords. - sec. SW quad cor.*
RMSE_XY 0.82 doq horiz. accuracy*
IMAGE_SOURCE "black & white film" b&w, color, infra-red or other*
SOURCE_IMAGE_ID "NAPP 2231- 2" source image identification*
SOURCE_IMAGE_DATE 1991 03 24 source image date as yyyy mm dd*
SOURCE_DEM_DATE 1995 07 00 source DEM date*
AGENCY "Western Mapping Center (WMC)" name of oversight agency*
PRODUCER "Western Mapping Center (WMC)" name of DOQ producer*
PRODUCTION_SYSTEM "DV1.2 03/93 OV1.1 04/93" name of the production HW & SW*
STANDARD_VERSION 1996 12 version of DOQ standard*
METADATA_DATE 1996 7 13 date created or changed, yyyy mm dd*
DATA_FILE_SIZE 46432792 data set size in bytes*
BYTE_COUNT 6076 header byte count*

```

[illegible]

*

*

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APPENDIX 2-C Examples of Band Storage

[illegible]

Figure 2-2 Example of monochrome DOQ storage. Example of a standard digital orthophoto stored as a simple monochrome image file consisting of 6094 image lines plus a single header line. Each line, including the header, is 5790 bytes in length. File size is 33.6 MB.

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[illegible]

Figure 2-3 Example of an RGB Orthophoto stored Band Interleaved by Line (**BIL**). Each band contains 6094 lines. File size is 100.9 MB.
r - red band g - green band b - blue band

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[illegible]

Figure 2-4 Example of RGB Orthophoto stored as Band Sequential (**BSQ**) with 6094 lines of each band appended to each other. File size is 100.9 MB
r - red band g - green band b - blue band

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[illegible]

Figure 2-5 Example of RGB Orthophoto stored Band Interleaved by Pixel (**BIP**). 6094 image lines plus a header line, each 17370 bytes in length. File size is 100.9 MB.
r - red band g - green band b - blue band

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References

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

Federal Geographic Data Committee, 1994, Content Standards for Geospatial Metadata (June 8): Washington, Federal Geographic Data Committee