Specifications for Ortho-images for the Province of British Columbia

GeoBC
Version 5.0
Issue date: 2022-05-04

GeoBC

BRITISH COLUMBIA | Ministry of Land, Water and Resource Stewardship

Table of Contents

Record of Amendments

Version	Revised by	Revision Description	Approved by	Date
1.0	T. Han P. Quackenbush	Re-write based on the previous orthophoto specifications	P. Quackenbush	31-Mar-2009
2.0	T. Han	Representation of no-data areas (p.15). New items added to Appendix F – Quick check list prior to delivery (p.23) Organization name change	T. Han	31-Mar-2011
3.0	A. Christian Robert Prins	Radiometric integrity (p.8). Image format and georeferencing and file naming (p.12). Representation of no-data areas (p.15-16)	H. Steiner, PEng	31-Mar-2016
4.0	R. Prins A. Christian J. Godau	New information regarding clipping of ortho deliverables (p.15). Removed Ascii metadata file as a deliverable (p.17-18). Added MrSID format as an accepted deliverable (p.22).	H. Steiner, Peng	12-Apr-2019
5.0	B. Edwards S. Floyd S. Grant K. McLaren	Major update/re-work of ortho-image spec	R. Prins	04-May-2022

1.0 Introduction

These specifications were compiled to provide “vendors” (a term when used herein shall mean geospatial data suppliers) with common standards and clear requirements to produce ortho-images. The objective is to obtain consistent, high-quality ortho-images and supplemental deliverables to the Provincial Government of British Columbia (BC).

These ortho-image specifications supersede all previous ortho-image specifications. Note that this document is a living one, which shall be updated and maintained through ongoing feedback from industry experts and advances in camera and image-processing technology.

The term “Branch”, when used herein, shall mean GeoBC of the Ministry of Land, Water, and Resource Stewardship in the Province of British Columbia.

The Branch shall be the final authority on acceptance or rejection of submitted ortho-image data. All ortho-image material, data and products delivered to the Branch shall meet or exceed the following specifications.

To these specifications, the word “shall” indicates a mandatory requirement and “should” indicates a desirable requirement.

2.0 Purpose and Scope

Ortho-images, which combine the merits of a map and imagery, form the foundational layer of the provincial geospatial information infrastructure of BC. Ortho-image generation has experienced significant technological advances due primarily to the extended applications of digital camera, Light Detection and Ranging (LiDAR), Global Navigation Satellite System (GNSS), and computing technology. The analogue camera-based ortho-image generation using the conventional photogrammetric procedure has been replaced by workflows built on the digital inputs of image, topography, orientation, and location collected, respectively, by digital mapping camera, LiDAR, Inertial Navigation Systems (INS), and GNSS. Compared to the conventional procedure, this new dataflow does not require film scanning, alleviates the effort to conduct Aerial Triangulation (AT), and requires fewer ground control points (GCPs). This has been proven to be more efficient, in time and cost, for ortho-image production.

This specification covers the production of digital ortho-images with the intention to define the minimum requirements to satisfy different prospective users from government, industry, academia, and the public. The widespread industrial adoption of digital mapping technologies makes it possible to produce sub-meter spatial resolution ortho-images using not only traditional scanned aerial photos, but also airborne and even space-borne acquired digital images. It is the intention of the Branch to expand this specification to include ortho-image production based on different imaging sources, therefore the term ortho-image, is used throughout this specification.

3.0 Dataflow of Orthorectification

As the final product of aerial imaging mapping projects, ortho-images are generated based on varying inputs using standardized procedures of data processing to rectify image distortions associated with the image acquisition and terrain. The exact procedure and required inputs depend on the methodology employed to produce the ortho-images. This conventional method based on indirect georeferencing is summarized below in Figure 1.

An automatic method based on INS/GNSS, referred to as direct georeferencing, is more commonly utilized for it alleviates the effort of AT as illustrated in Figure 2. The use of GCPs is required for both indirect and direct georeferencing. GCP-free ortho-image operations are only accepted at the discretion of the Branch (i.e., special applications including rapid response for disaster mapping and evaluation).

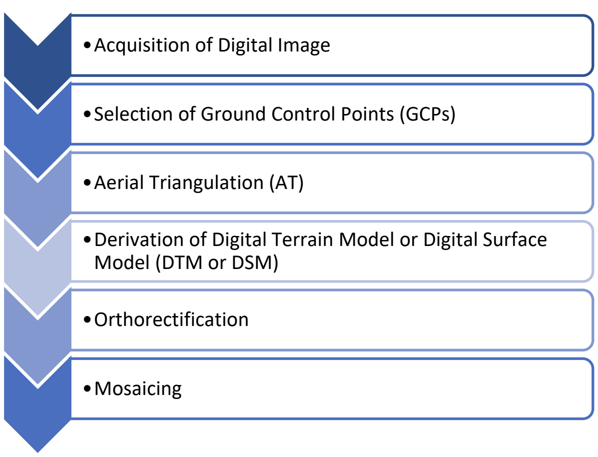


Figure 1: Example dataflow for indirectly georeferenced orthorectification

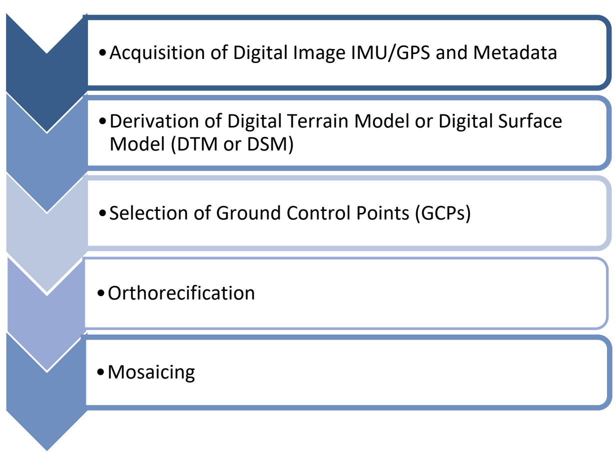


Figure 2: Example dataflow for directly georeferenced orthorectification

4.0 Project and File Management

This section describes expectations of final ortho-image deliverables regarding geographic extent and tiling, file naming conventions, acceptable image formats, data handling and shipping, and georeferencing.

4.1 Project Resources

The Branch maintains an FTP site with project references such as product specific specifications (i.e., GeoBC Digital Data Naming Convention), as well as some examples of project deliverables (i.e., positional accuracy report). The FTP site for ortho-image related specifications and examples can be found here:

- **ftp://ftp.geobc.gov.bc.ca/sections/outgoing/dis/**

4.2 Geographic Extent and Tiling

The spatial coverage of an ortho-image is defined by the corresponding mapping project area of interest (AOI), and by the British Columbia Geographic System (BCGS) mapsheets at either 1:20,000 or 1:2,500 tiles. Areas within a BCGS tile that fall outside the AOI shall contain black pixels with RGB values of [0, 0, 0] (see Figure 3). Ortho-images shall contain valid imagery to the full extent of an AOI plus an additional 5.0m buffer of valid imagery outside the AOI to avoid edge issues (see Figure 4).

To facilitate image mosaicking and colour balancing an ortho-image shall provide valid ortho-imagery for the entire bounding box of a BCGS mapsheet tile. This shall be accomplished by overlaying a vector file representing the bounding box of the corresponding BCGS grid tile on top of the corresponding ortho-image (see Figure 3).

Complete seamless coverage of the entire mapping area (AOI and tile bounding boxes) shall be achieved.

Figure 3: The diagonal red line represents the edge of an AOI and the blue grid represents the BCGS tile of a 1:2,500 BCGS Mapsheet Tile.

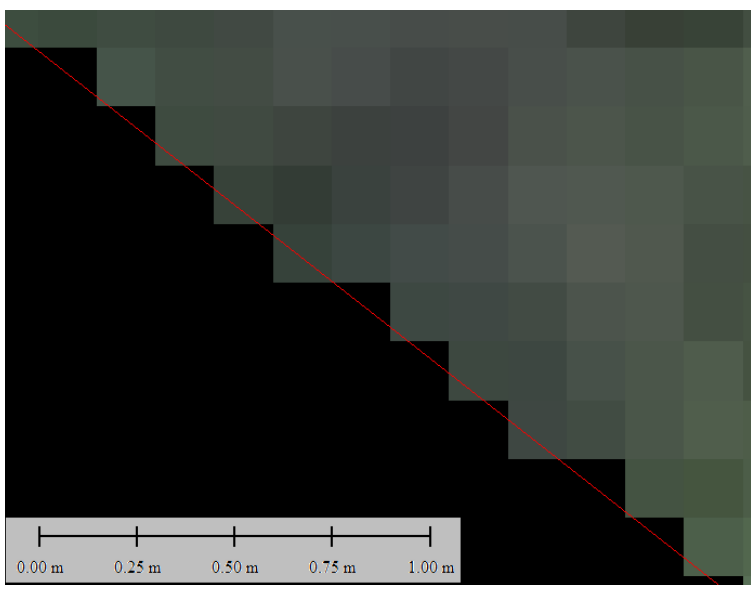


Figure 4: The diagonal red line represents the edge of an AOI. The green pixels represent valid imagery. This is an example of an edge issue and can be avoided by applying a 5m buffer of valid imagery around the AOI

4.3 File Naming Conventions

File naming for the ortho-images and products can be found in the latest GeoBC Digital Data Naming Convention Specifications [1] available to vendors through the Branch FTP site (see Section 4.1).

All delivered products to the Branch shall adhere to the specifications in the latest GeoBC Naming Convention Specifications [1] unless otherwise specified in a project contract.

4.4 Acceptable Image Formats

The two image formats accepted by the Branch for ortho-images are uncompressed GeoTIFF (in compliance with the GeoTIFF Specification and Revision 1.1 [2]), and JPEG compressed GeoTIFF. The header of each ortho-image in GeoTIFF format should include the proper tags and keys representing the required georeferencing and geo-coding information as listed in Appendix A – Example of GeoTIFF Header. GeoTIFF ortho-images shall not be delivered with any overviews included. JPEG compressed TIFF images shall have a compression ratio of 10:1 (one tenth the original size of the original uncompressed GeoTIFF), unless the vendor deems 10:1 yields insufficient quality, or otherwise specified in a contract.

4.5 Data Handling and Shipping

Data shall be delivered on one or more NTFS format USB 3.0 hard drives, with no less than 2TB of storage. Drives shall be formatted before use and contain no superfluous files. Submitted storage devices and their packaging shall be labelled with the following at a minimum:

- Project name and contract number
  - i.e., "Vancouver Island OP11BMRS011"
- Delivery number and date
  - If re-submissions of data occur, include delivery number
- Description of contents
  - A tabulated list of the contained data deliverables

The folder structure of the delivered hard drive shall not contain any spaces in naming, and where required to, use underscores (_) or dashes (-). Folders shall clearly define the products contained (e.g., 3-band_natural_uncompressed, 4-band_compressed, stereo_model_setups, etc).

Data must be shipped via courier to the address specified in the contract and arrive on or before the contract delivery deadline. The vendor shall notify the Branch that the data has been sent, along with a detail of contents, any associated tracking number(s) and/or digital copy of the shipping confirmation.

4.6 Georeferencing

The accepted projections for georeferencing are the Universal Transverse Mercator (UTM) and BC Albers Equal Area Conic using North American Datum of 1983 Canadian Spatial Reference System (NAD83 CSRS). Unless stated in the contract, the vertical datum shall be CGVD2013, and the geoid used shall be the latest version of CGG2013 found on Natural Resources Canada geoid models website.

A vendor may use direct or indirect georeferencing methods. If the latter is performed, it shall be produced according to the Specifications for Aerial Triangulation for the Province of BC [3] available to vendors through the Branch FTP site (see Section 4.1).

5.0 Quality Assurance Requirements

Ortho-image quality is assessed by the following considerations:

- Spectral bands and coverage
- Radiometric integrity
- Spatial resolution
- Geometric integrity and edge matching
- Colour balancing and enhancement
- Positional accuracy
- Ground control
- Graphic artifacts
- Completeness of metadata

5.1 Spectral Bands and Coverage

A spectral band is a well-defined continuous wavelength range in the spectrum of solar electromagnetic energy captured by a camera or sensor. The spectral coverage is the total wavelength range covered by all the spectral bands.

These specifications define spectral bands to be in the range of visible to near infrared. Standard images shall contain three spectral bands: red, green, and blue (RGB). Specialized images shall contain four spectral bands: red, green, blue, and near infrared (RGBiR), or as otherwise specified in the contract.

5.2 Radiometric Integrity

The radiometric integrity of an ortho-image is evaluated in terms of the following three metrics: resolution, range, and distribution.

Radiometric resolution of an imaging system determines the systems ability to discriminate differences in grey-scale values and is expressed in bits. The greater the bit number, the greater the number of grey scale values a sensor can distinguish. For example, 8-bit imagery can distinguish between 0-255 discrete values (0 being black and 255 being white). Ortho-images delivered to the Branch may be 8-bit or 16-bit imagery, however, this may vary from project to project according to contract.

Radiometric range defines how many grey levels are utilized by an ortho-image. The nominal radiometric range is defined by bit depth, however the radiometric range utilized by the ortho-image is often narrower than the nominal one. Increasing the radiometric range gives a richer set of colours to an ortho-image.

Radiometric distribution is often expressed by a histogram of the ortho-image, revealing the occurrence of the utilized grey levels across the entire radiometric range.

5.3 Spatial Resolution

Spatial resolution measured as ground sampling distance (GSD) refers to the minimum distance between two adjacent features or the minimum size of features that can be discerned on an ortho-image. The spatial resolution of an ortho-image is closely related to several parameters: pixel size of raw digital images, spatial resolution of the derived DTM/DSM, and the desired mapping scale. The pixel size of the raw digital images is determined by the sensitivity of the sensor in digital cameras capturing the digital images.

The spatial resolution of source imagery delivered to the Branch shall be a high enough resolution to allow for ortho-images to meet the specified GSD of a particular project.

$$\boldsymbol{GSD} = (SW * H)/(FL * IW)$$

where:

SW = Sensor Width (cm)

H = Flying Height Above Ground Level (cm)

FL = Focal Length (cm)

IW = Image Width (pixels)

5.4 Geometric Integrity and Edge Matching

Ortho-images may be generated with geometric flaws such as broken or deformed linear features (roads and streams), leaning trees and buildings, smearing, blurs, or double imagery. These geometric flaws are often due to images collected under low sun angles, using a DTM/DSM of inadequate spatial resolution and accuracy, applying an inappropriate rectification algorithm, mosaicking spatially misaligned images, or rectifying digital images with inconsistent spatial accuracies. A vendor shall take steps to reduce the likelihood of these geometric flaws as much as possible.

To avoid DTM/DSM related geometric flaws, breaklines or other DTM/DSM densification approaches shall be performed. The Branch suggests using a DTM/DSM grid density of four times the ortho-image pixel resolution. A DSM should be used to maintain geometric integrity of ortho-images that cover urban areas with tall buildings.

Horizontal displacement along linear features between seamlines greater than three times the production ortho-image GSD shall be cause for rejection of the ortho-images.

5.5 Colour Balancing and Enhancement

Illumination variations may cause colour unbalancing within an ortho-image or across multiple ortho-images illustrated as hot spots and Newton Rings. Radiometric normalization should be considered to reduce these colour imperfections so that they are not visibly recognizable.

Changes in tonal variations between image files shall be gradual. Abrupt tonal variations shall be cause for rejection of the ortho-images.

An ortho-image shall be enhanced in such a way that the priority land covers are rendered as close as possible to their natural colours.

5.6 Positional Accuracy

The positional accuracy of an ortho-image is evaluated in terms of radial root-mean-square error ($RMSE_{xy}$) [4]. $RMSE_{xy}$ is calculated using the RMSE of both x (easting) and y (northing). Formulas for $RMSE_x$ and $RMSE_y$ are in the Glossary of Terms.

Table 1 shows the horizontal accuracy requirement of ortho-images as related to produced ortho-image pixel size.

Table 1: Ortho-image accuracy requirement

Ortho-image Pixel Size (m)	$RMSE_{xy}$ at 63% Confidence Level
$\mathcal{X}$	$\leq (2 * \mathcal{X}) * 1.4142$

Calculation of accuracy values shall be presented in the form of a positional accuracy report. See Appendix B – Example of Positional Accuracy Report. A spreadsheet with example values is available the Branch FTP site. See Section 4.1 for the address of the FTP site.

Accuracy shall be calculated using the following formulas:

- Horizontal accuracy will be evaluated based on the horizontal RMSE (63% confidence level). This value shall be reported in ground distance (metres).

$$RMSE_{xy} = \sqrt{(RMSE_X^2 + RMSE_Y^2)}$$

- Additionally, horizontal accuracy shall be reported at the 95% confidence level. This value shall also be reported in ground distance (metres).

$$\text{Horizontal accuracy at 95\% confidence level} = RMSE_{xy} * 2.4477$$

To facilitate accuracy evaluation, a minimum of three GCPs shall be used within each enclosed AOI polygon (unless otherwise stated in a contract). Photo targets shall be used during acquisition and large enough to be seen in images to verify the horizontal accuracy of GCPs. A site photo shall be taken of the GNSS equipment set up over each GCP. This photo shall show all GNSS equipment involved and be taken with a viewing angle parallel to the ground. GCPs shall be spatially well distributed throughout the entire AOI.

5.7 Ground Control

All aerial imagery survey missions shall be referenced to GNSS observed control points. GNSS ground control surveys that fulfill minimum Branch requirements shall adhere to the following guidelines:

- In the case of differential GNSS processing, project control shall be referenced to at least one Primary Geodetic Control Point: fixed Canadian Base Network (CBN), Canadian Active Control System (CACS) Station, or British Columbia Active Control System (BCACS) station.
- In the case of single point positioning (observed on Secondary Geodetic Control or GCP), Natural Resource Canada's (NRCan) Precise Point Positioning (PPP) post-processing service shall be used.
- Vertical datum used shall be CGVD2013 for all submitted control.
- Refer to the latest published geoid model from the Geodetic Survey of Canada.
- GNSS observations shall be conducted by an experienced designated professional (e.g., Geomatics Technologist, Professional Land Surveyor, Geomatics Engineer, etc.).
- Unless otherwise specified in the project contract, the GeoBC approved geodetic datum and epochs follows those outlined and adopted by Natural Resources Canada.
    - 2002 for all British Columbia excluding Vancouver Island, where epoch 1997 shall be used.

A ground control report shall be delivered and include the following information:

- Instrumentation
- Instrument model
- Manufacturer precisions
- Instrument calibration results (if applicable)
    - CRS Information
    - Horizontal and vertical datum, including horizontal epoch reference
    - Geoid model
    - Projection
- Control point information

    - Coordinates (orthometric)
    - Final accuracies
        - Horizontal accuracy ($RMSE_{xy}$, 63% confidence level)
        - Vertical accuracy ($RMSE_Z$, 68% confidence level)
    - Type of reference station used (i.e., CBN, CACS, BCACS, or PPP point)
    - Reference station coordinates
    - Digital images of control points, if marked, with point identification information
- Detailed explanation of processing methodology (i.e., Precise Point Positioning or differential processing, and any additional processing methods)
- Processing report
    - Software or application used
    - All input parameters
    - Full output results for all collected points
    - All default reports generated by the software used for processing
- Adjustment report (if applicable)
    - Software of application used
    - All input parameters (i.e., precision weighting, a-priori scale factor, etc.)
    - Full output results
    - All default reports generated by the software used for adjustment
- Signature by a designated professional (geomatics technologist, land surveyor, geomatics engineer)

Ground control points (GCPs) shall be delivered to the Branch as a georeferenced point feature layer in shapefile format. An example of GCP shapefile can be found on the Branch FTP site (see Section 4.1). Each GCP shapefile shall be named according to the latest GeoBC Digital Data Naming Convention Specification [1]. Attributes for each GCP point in the shapefile shall follow the header formatting below, and include the following fields shown in Table 2.

Table 2: GCP attributes

Attribute Field Name	Field Type	Description
point_id	Text	Name or ID of point. Value shall be unique and persistent.
obs_date	Text	Local date of GNSS observations, in format **YYYY-MM-DD**, e.g., 2022-04-19
contract	Text	Project contract number, e.g., OP22BMRS024
gc_type	Text	Either "**NVA"** (non-vegetated) or "**VVA"** (vegetated)
descrip	Text	Description of marker e.g., nail, paint line, cut block, brass cap, no mark
checkpoint	Text	**"check"** if used as verification point in accuracy assessment of the LiDAR data, otherwise null
processing	Text	Processing type used (RTK, PPK, PPP, etc.)
h_v_datum	Text	Define the horizontal datum (epoch) and vertical datum, separated with "/" e.g., NAD83(CSRS)v4e2002/CGVD2013
geoid	Text	Name of geoid model (**CGG2013**)
projection	Text	UTM zone, in the format **UTMz##** (where ## is zone number, e.g., UTMz09)
coord_e	Float	UTM easting coordinate in metres to 3 decimal places
coord_n	Float	UTM northing coordinate in metres to 3 decimal places
coord_ht	Float	CGVD2013 orthometric height coordinate in metres to 3 decimal places
stdev_e	Float	Standard deviation of easting in metres to 3 decimal places
stdev_n	Float	Standard deviation of northing in metres to 3 decimal places
stdev_ht	Float	Standard deviation of orthometric height in metres to 3 decimal places

5.8 Graphic Artifacts

Artifacts can be introduced into ortho-images due to poor weather conditions, poor rectification algorithms, careless georeferencing, and missing data. The vendor shall minimize the presence of artifacts where possible, otherwise these shall be cause for rejection of ortho-images:

- Image gap, image flare, blooming, missing pixels, vertical smearing, cloud cast shadow and other graphic imperfections should not be visible.
- Gaps between images shall not be filled using images acquired from different years.
- Each ortho-image must include any available imagery from neighbouring map tiles necessary to ensure seamless tiling.
- Tiles shall overlap to avoid gaps.
- Ortho-images tiles must fill the bounding box of the associated BCGS grid tile specific to the projection used rather than the grid tile itself (see Figure 3).

Completeness of Metadata

The metadata associated with each ortho-image is stored in the GeoTIFF header. This information provides a complete background regarding the ortho-image history and production that are essential for quality control purposes and are of interest to ortho-imagery users. The header information includes but is not limited to:

- Horizontal spacing (pixel size)
- Number of spectral bands and colour interpretation
- Coordinate system (projection method and parameters)
- Linear units
- Corner and origin coordinates

See Appendix A – Example of GeoTIFF Header for an example of a GeoTIFF header.

6.0 Quality Control Procedures

Quality Control (QC) provides routine and consistent checks to ensure data integrity, correctness, and completeness. Before compiling deliverables, a quality control check shall be implemented to provide confidence of the dataset.

6.1 Format and File Naming

Delivered ortho-images shall follow the appropriate naming convention as outlined in the latest GeoBC Digital Data Naming Conventions Specification [1].

6.2 GeoTIFF Header and Metadata

Delivered ortho-images shall contain and be assessed for completeness and correctness of metadata, which is stored in the GeoTIFF header.

6.3 Ortho-image Compatibility

Ortho-images should be easily viewed using any GIS software to ensure compatibility and ease of use.

6.4 Spatial Coverage

A spatial coverage check ensures that each ortho-image appears in the correct location and does not exhibit any void areas at or along the edges of a tile or the AOI. This can be conducted by overlaying a vector file representing the bounding box of the corresponding BCGS grid tile on top of the corresponding ortho-image (see Figure 3).

6.5 Radiometric Integrity

A histogram should be employed to examine the radiometric properties of each ortho-image, specifically the range and distribution. Irregularly shaped histograms that significantly deviate from a general Gaussian distribution may be cause for rejection. Indicators of these unusual histograms include:

- Too skinny, indicating the radiometric range is too narrow leading to low image contrast.
- Significantly distorted towards 0, indicating that too many pixels assume low grey levels causing an image to look dark, leading to possible information loss for targets of low illumination.
- Significantly distorted towards 255, indicating that too many pixels assume high grey levels causing an image to look over exposed, leading to information loss for targets of intense illumination.

Appendix C – Examples of Unacceptable Histograms provides examples of histogram distributions that are considered unacceptable.

6.6 Positional Accuracy

For each ortho-image, positional accuracy is evaluated based on the delivered positional accuracy report outlined in Section 5.6.

See also: Appendix B – Example of Positional Accuracy Report.

6.7 Ground Control

A GCP index shapefile containing all GCPs is evaluated based on the specifications outlined in Section 5.7.

6.8 Colour Balancing

Ortho-images shall be inspected for imperfections related to colour balancing. There shall be no significant colour discrepancies between tiles or across seamlines.

6.9 Representation of Valid Data and No-data Areas

No-data areas may occur in an ortho-image due to missing imagery caused by cloud, smoke, haze, the inability to fully acquire a project scope, among other factors. No-data areas will occur when part of a tile falls outside of the AOI (see Figure 3). These no-data areas shall be filled with void pixels whose RGB digital numbers are [0, 0, 0]. Ortho-images where the no-data value is not [0, 0, 0] may be cause for rejection.

Valid data areas within the overall image extents must not include pixels with RGB digital numbers [0, 0, 0]. In the case of 8-bit imagery, minimum and maximum pixel values should be limited to RGB values of [10, 10, 10] and [245, 245, 245], respectively. Ortho-images with pixel values of [0, 0, 0] found within valid image area shall be cause for rejection.

6.10 Testing and Thresholds for Error

Testing of the quality assurance requirements in ortho-images shall be performed on 5-10% randomly selected BCGS tiles over the project AOI.

Of the randomly selected 5-10% of all delivered ortho-image tiles, no more than 5% may contain errors including but not limited to those listed below:

- Radiometric integrity of ortho-images does not meet requirements
- Ortho-images do not have contiguous coverage in the entire bounding box of a BCGS mapsheet tile
- Improper projections or re-projections of ortho-images
- Ortho-images where GSD requirement is not met
- Ortho-images with pixel values of [0, 0, 0] found within valid image
- Ortho-images where the no-data value is not [0, 0, 0]

Exceeding the 5% error threshold shall be cause for rejection of the entire dataset.

7.0 Deliverables and Supplementary Reports

This section outlines the requirements for typical ortho-image deliverables and supporting documents. All submitted deliverables, reports and metadata are subject to change depending on the project, and it is the responsibility of the vendor to ensure products are delivered as they pertain to the project contract.

All required supplementary reports shall adhere to the naming in the latest GeoBC Digital Data Naming Conventions Specifications [1], unless otherwise specified in a project contract.

Several examples and templates for the following supplementary deliverables may be found on the Branch FTP site (see Section 4.1).

7.1 Ortho-image Seamlines

Seamlines used for orthomosaicking shall be provided to the Branch and delivered in shapefile format.

7.2 Positional Accuracy Report

The spreadsheet shall include the $RMSE_{xy}$ calculated using the $RMSE_x$ (easting) and $RMSE_y$ (northings) coordinate differences obtained from the comparison between ground control targets (GNSS control, independent from checkpoints used for georeferencing ortho-images) and the corresponding coordinate measurement of these points from the ortho-image.

An example of a positional accuracy report can be found on the Branch FTP site (see Section 4.1).

7.3 Site Photos

Four site photos per GCP shall be delivered in PDF format as stated in Section 5.6. Each photo shall be named based on its GCP name and cardinal direction the site photo is facing (i.e., BC01_North).

7.4 Ground Control

A GCP index shapefile and ground control report shall be submitted in accordance with the specifications outlined in Section 5.7.

7.5 Georeferencing Report (Direct or Indirect)

A direct or indirect georeferencing report shall be submitted to the Branch, for whichever method of georeferencing is performed by the vendor. The report shall include at a minimum, but is not limited to:

- Accuracy and precision information for individual photo positioning, based on the smoothed best estimated trajectory (SBET)
- Min/Max 3D positional standard deviation for individual flight lines (start to end)
- Base station and control information
- Horizontal and vertical geodetic datum information (NAD83(CSRS), CGVD2013 should be used unless otherwise specified)
- Geoid model used to derive mean sea level heights (refer to the latest published geoid model from the Geodetic Survey of Canada.
- Name of the person responsible for processing and quality control

7.6 Final Ortho-images Quality Control Report

A final ortho-image quality control report shall be submitted to the Branch. The template for this report may be found on the Branch FTP site (see Section 4.1).

Appendix A – Example of GeoTIFF Header

```
Size is 5480, 4810
Coordinate System is:
PROJCS["NAD83(CSRS) / UTM zone 10N",
    GEOGCS["NAD83(CSRS)",
        DATUM["NAD83_Canadian_Spatial_Reference_System",
            SPHEROID["GRS 1980",6378137,298.2572221010042,
                AUTHORITY["EPSG","7019"]],
            AUTHORITY["EPSG","6140"]],
        PRIMEM["Greenwich",0],
        UNIT["degree",0.0174532925199433],
        AUTHORITY["EPSG","4617"]],
    PROJECTION["Transverse_Mercator"],
    PARAMETER["latitude_of_origin",0],
    PARAMETER["central_meridian",-123],
    PARAMETER["scale_factor",0.9996],
    PARAMETER["false_easting",500000],
    PARAMETER["false_northing",0],
    UNIT["metre",1,
        AUTHORITY["EPSG","9001"]],
    AUTHORITY["EPSG","3157"]]
Origin = (373902.149999999965075,6106313.850000000558794)
Pixel Size = (0.300000000000000,-0.300000000000000)
Metadata:
  AREA_OR_POINT=Area
  TIFFTAG_RESOLUTIONUNIT=2 (pixels/inch)
  TIFFTAG_XRESOLUTION=72
  TIFFTAG_YRESOLUTION=72
Image Structure Metadata:
  INTERLEAVE=PIXEL
Corner Coordinates:
Upper Left  (  373902.150, 6106313.850) (124d58'32.47"W, 55d 5'15.08"N)
Lower Left  (  373902.150, 6104870.850) (124d58'30.17"W, 55d 4'28.42"N)
Upper Right (  375546.150, 6106313.850) (124d56'59.80"W, 55d 5'16.57"N)
Lower Right (  375546.150, 6104870.850) (124d56'57.53"W, 55d 4'29.92"N)
Center      (  374724.150, 6105592.350) (124d57'44.99"W, 55d 4'52.50"N)
Band 1 Block=5480x1 Type=Byte, ColorInterp=Red
Band 2 Block=5480x1 Type=Byte, ColorInterp=Green
Band 3 Block=5480x1 Type=Byte, ColorInterp=Blue
```

Appendix B – Example of Positional Accuracy Report

Positional Accuracy Report	
PROJECT #:	
DATE:	2021-11-05
GEODETIC DATUM:	NAD83 CSRS
PROJECTION:	UTM
UTM ZONE:	10

GPS TARGET & COORDINATES			ORTHO-IMAGE & COORDINATES		
GCP/Aerial Target #	Easting (x)	Northing (y)	Ortho-image Tile	Target Easting (x)	Target Northing (y)
	[m]	[m]		[m]	[m]
2021-1000	348281.726	5584411.402	92k035	348282.079	5584411.321
2021-1003	358260.531	5672301.842	92n015	358260.776	5672301.819
2021-1005	424162.905	5602526.998	92k060	424163.006	5602526.902
2021-1006	436270.516	5611834.402	92j061	436270.363	5611834.268
2021-1002	373223.700	5638899.227	92k087	373223.518	5638899.004
2021-1004	392830.872	5586094.931	92k048	392831.180	5586094.308
2021-1010	383494.427	5636055.216	92k087	383494.715	5636055.000

COORDINATE DIFFERENCES			
$\Delta x_{(Easting)}$	$\Delta y_{(Northing)}$	$(\Delta x)^2_{(Easting)}$	$(\Delta x)^2_{(Northing)}$
[m]	[m]	[m]	[m]
-0.353	0.081	0.125	0.007
-0.245	0.023	0.060	0.001
-0.101	0.096	0.010	0.009
0.153	0.134	0.023	0.018
0.182	0.223	0.033	0.050
-0.308	0.623	0.095	0.388
-0.288	0.216	0.083	0.047

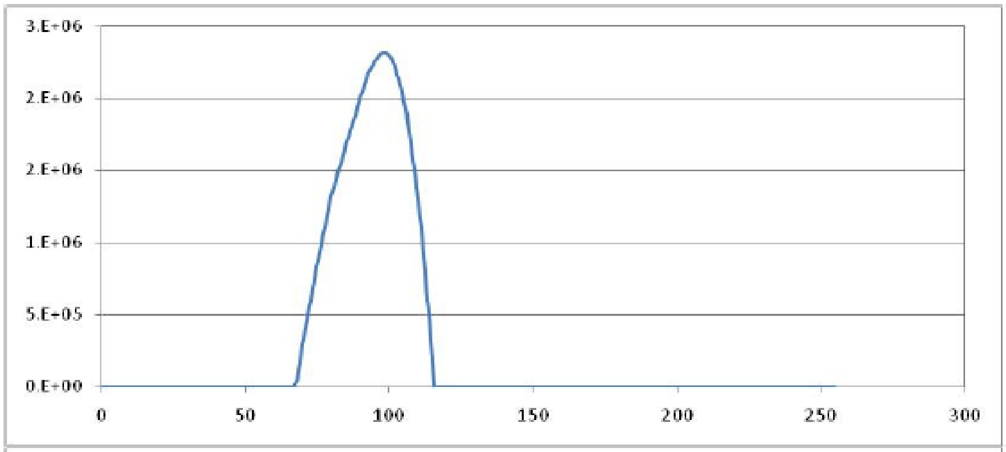
Ortho-image Pixel Size
[m]
0.30

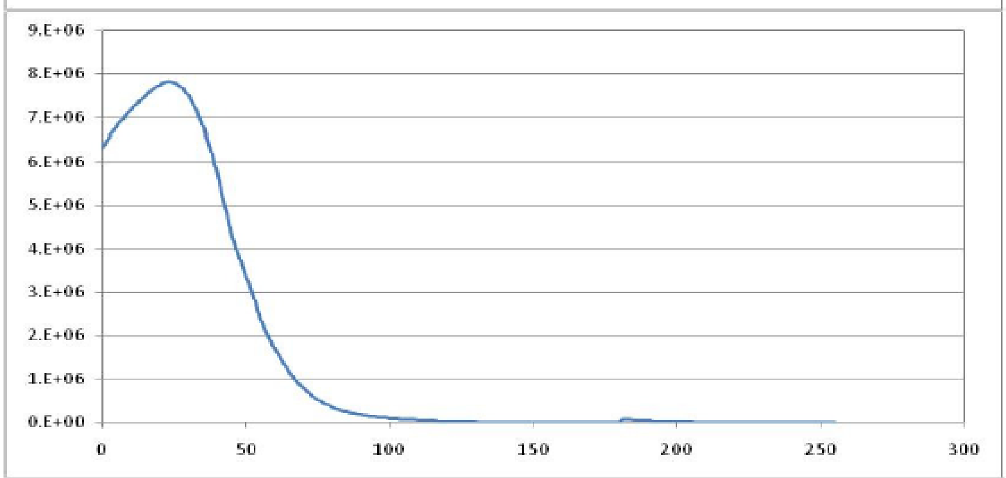
$RMSE_{xy}$ Accuracy Requirement
[m]
0.849

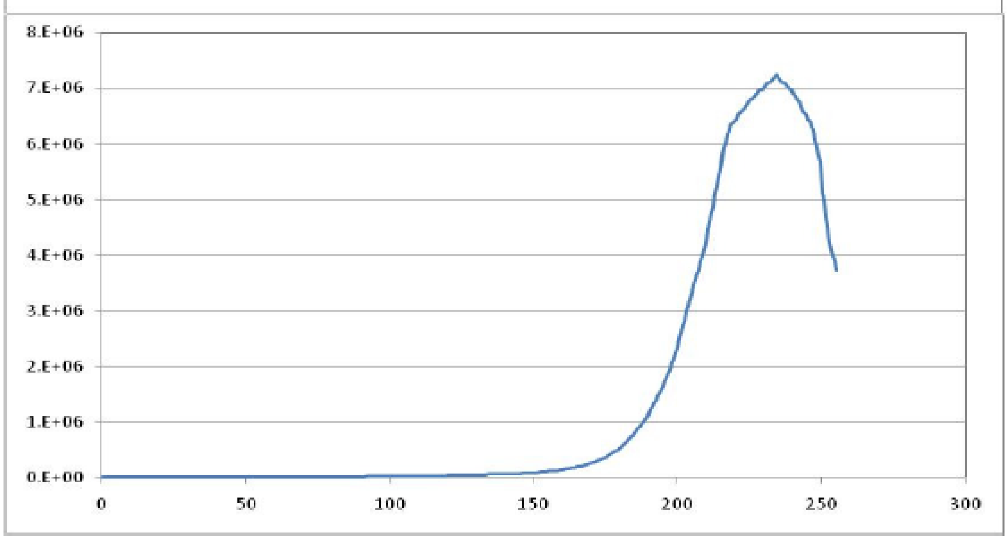
$RMSE_x$	$RMSE_y$
[m]	[m]
0.248	0.272

$RMSE_{xy}$	Accuracy at 95% Confidence Level
[m]	[m]
0.368	0.901

Appendix C – Examples of Unacceptable Histograms







References

[1] Ministry of Land, Water, and Resource Stewardship, "GeoBC Digital Data Naming Conventions," GeoBC, Victoria, 2022.

[2] Open Geospatial Consotrium, "OGC GeoTIFF Standard," 2019.

[3] GeoBC, Ministry of Natural Resources Operations, "Specifications for Aerial Triangulation," GeoBC, Victoria, 2011.

[4] American Society for Photogrammetry and Remote Sensing, "ASPRS Positional Accuracy Standards for Digital Geospatial Data," *Photogrammetric Engineering & Remote Sensing,* vol. 81, no. 3, pp. A1-A26, March 2015.

[5] Federal Geographic Data Committee, "Content Standard for Digital Geospatial Metadata," 1998.

Glossary of Terms

accuracy - The closeness of an estimated value (measured or computed) to a standard or accepted (true) value of a particular quantity. Related to the source data and DEM products quality. Accuracy reported at the 68% confidence level means that 68% of the positions in the dataset will have an error with respect to true ground position that is equal to or smaller than the reported accuracy value.

- **positional accuracy** - The accuracy of the position of features, including horizontal and vertical positions, with respect to horizontal and vertical datums.

area of interest (AOI) – entire geographic extent of a defined project, intended for the capture of geospatial data/information

BCGS grid/mapsheet – an index grid covering the geographic extent of the Province of BC. Intended to organize the collection, storage, and management of submitted geospatial data to the Province of BC. Available at various scales, such as 1:20,000, 1:2,500.

BCGS Tile – an individual tile at a specified scale of the (BCGS grid/mapsheet)

confidence level – the percentage of data values (i.e., points) within a dataset that is estimated to meet the stated accuracy. For example, accuracy reported at the 68% confidence level means that 68% of the positions in the dataset will have an error on true ground position that is equal to or smaller than the reported accuracy value.

control point - A surveyed point used to adjust a dataset geometrically to establish its positional accuracy relative to the real world. Control points are independent of, and shall never be used as, checkpoints on the same project.

coordinates – A group of 3D numbers that define a point in 3D space. Traditionally, a vertical coordinate would be defined as a 3D coordinate, that is, an x/y coordinate with an associated z-value.

dataset - Identifiable collection of data.

datum - A set of reference points on the Earth's surface from which position measurements are made and (usually) an associated model of the shape of the Earth (reference ellipsoid) to define a geographic coordinate system. Horizontal datums are used for describing a point on the Earth's surface, in latitude and longitude or another coordinate system. Vertical datums are used to measure elevations or depths.

easting - Distance in a coordinate system, eastwards (positive) or westwards (negative) from a north-south reference line.

error - Measured quantity value minus a reference quantity value.

format - Language construct that specifies the representation, in character form, of data objects in a record, file, message, storage device, or transmission channel.

geographic information system (GIS) - A system of spatially referenced information, including computer programs that acquire, store, manipulate, analyse, and display spatial data.

georeferencing - Geopositioning an object using a Correspondence Model derived from a set of points for which both ground and image coordinates are known.

global navigation satellite system (GNSS) - A constellation of radio-emitting satellites used to determine positions of receivers. The satellites transmit signals that allow a receiver to calculate its location through trilateration.

Global Positioning System (GPS) – A GNSS owned by the United States government.

ground control point (GCP) - Newly established, on-site survey points used for geometric adjustment of digital imagery, no previously existing marker. These points are defined as non-vegetated points traditionally located in open or urban terrain including bare soil, short grass, asphalt, and concrete surfaces. These are described with markers, paint lines and/or targets.

ground sampling distance (GSD)- the minimum distance between two adjacent features or the minimum size of features that can be discerned on an aerial image.

inertial measurement unit (IMU) - The combination of a 3-axis accelerometer combined with a 3-axis gyro. An onboard processor, memory, and temperature sensor may be included to provide a digital interface, unit conversion and to apply a sensor calibration model. The IMU by itself does not provide any kind of navigation solution (position, velocity, attitude), it only actuates as a sensor.

inertial navigation system (INS) - A self-contained navigation system comprised of several subsystems: IMU, navigation computer, power supply, interface, etc. Uses measured accelerations and rotations to estimate velocity, position, and orientation. An unaided INS (without GNSS input) loses accuracy over time, due to gyroscopic drift.

metadata - Any information that is descriptive or supportive of a geospatial dataset, including formally structured and formatted metadata files. For example, eXtensible Markup Language (XML), formatted Federal Geographic Data Committee (FGDC) metadata [5], reports (collection, processing, Quality Assurance/Quality Control (QA/QC)), and other supporting data (i.e.,, survey points, shapefiles).

no-data areas – Areas where no valid imagery exists. Typically represented as black pixels with values of [0, 0, 0].

ortho-image – term used to reflect the various imaging source possibilities to produce an 'orthophoto'

radiometric range – Defines how many grey levels are utilized by an ortho-image. The nominal radiometric range is defined as a bit depth. However, the radiometric range of an ortho-image is often narrower than the nominal one. The wider the range, the richer set of colours an ortho-image represents.

resolution – Ability of a sensor to render a sharply defined image.

- **spatial resolution** - minimum distance between two adjacent features or the minimum size of features that can be discerned on an ortho-image. The spatial resolution of an ortho-image is closely related to the pixel size of digital images to be rectified, the spatial resolution of the DTM used for the rectification, and the desired mapping scale
- **spectral resolution** – the ability of a sensor to define fine wavelength intervals
- **radiometric resolution** – Determines how finely an ortho-image can represent or distinguish differences of grey levels. Usually expressed in numbers of bits.

root-mean-square error (RMSE) - The square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. The RMSE is used to estimate the absolute accuracy of both horizontal ($RMSE_x$ and $RMES_y$), as with GNSS-surveyed checkpoints of higher accuracy than the data being tested.

The standard equations for calculating horizontal and vertical RMSE are provided here:

$RMSE_x$ the horizontal root-mean-square error in the x direction (easting):

$$\sqrt{\sum \frac{(X_i - X_i')^2}{n}}$$

where:

X_i is the set of n x coordinates being evaluated,

X_i' is the corresponding set of checkpoint *x* coordinates for the points being evaluated, *n* is the number of x coordinate checkpoints, and

i is the identification number of each checkpoint from 1 through n.

RMSE$_y$ The horizontal root-mean-square error in the y direction (northing):

$$\sqrt{\sum \frac{\left(Y_i - Y_i'\right)^2}{n}}$$

where:

Y_i is the set of n y coordinates being evaluated,

Y_i' is the corresponding set of checkpoint y coordinates for the points being evaluated,

n is the number of y coordinate checkpoints, and

i is the identification number of each checkpoint from 1 through n.

RMSE$_{xy}$ the horizontal root-mean-square error that includes both x and y coordinate errors:

$$RMSE_{xy} = \sqrt{(RMSE_X^2 + RMSE_Y^2)}$$

where:

$RMSE_x$ is the RMSE in the x direction, and

$RMSE_y$ is the RMSE in the y direction.

quality - Degree to which a set of inherent characteristics fulfils requirements. Accuracy (exactitude) and precision (repeatability) are the means used to evaluate the quality of the source data and DEM products.

quality control (QC) - Set of activities for ensuring quality in products. The activities focus on identifying defects in the actual products produced. The verification of the quality of the deliverables is part of the QC.

valid data areas (see also no-data area) – Any portions of a project/area of interest that includes valid imagery data (i.e., has been acquired). No pixels of [0, 0, 0] may exist inside valid data areas.

List of Figures

List of Tables