Document for Operation

Survey Operation Manual for Topographic Mapping Using Satellite Ortho Images

February 2022

Infrastructure Management Department

Japan International Cooperation Agency

Survey Operation Manual for Topographic Mapping Using Satellite Ortho Images

Revision history

Outline	Release date	Creation organization
Creation	December, 2006	Japan International Cooperation Agency
Enactment	February 28, 2022	Japan International Cooperation Agency

These Specifications have been prepared using “Public Survey Manual for Digital Ortho Development (Draft)” and “Guidelines on Topographic Map Revision Using High-Resolution Satellite Images” which are the technical materials of the Geographical Survey Institute upon permission by the Director General of the Geographical Survey Institute.

(Approval no. Geographical Survey Institute Planning and Coordination Division No. 288, November 22, 2006)

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[Preface] General

1. Introduction

There are high expectations for satellite images that deliver benefits of wide and periodical data acquisition as new information sources for development and updating of topographic maps. Some satellites provide stereo pair image data and these images can be applied with the technology to develop topographic maps from aerial photos.

Due to technical innovations and changes in the trends in international cooperation in recent years, the statuses of overseas projects on topographic map development have become diverse. These projects actually include topographic map development in a composite project with a consulting case on regional development and so forth, project requests to develop topographic map in regions with difficult access due to various different reasons and project requests for topographic map development without the technical transfer on stereo plotting besides the topographic map development projects by plotting using the proper stereo pair images.

As an exceptional method to flexibly address such changes in the needs of overseas projects, it is now possible to develop topographic maps by using ortho-rectified satellite images (referred to as satellite ortho images) as the base map and digital plotting with single images instead of stereo ones.

Many studies have been conducted on the topographic map development method using satellite ortho images in the recent years and knowledge is being accumulated on its versatility and scope. However, there is no consistent method or established precision control method from preparation of satellite ortho images to precision control at interpretation and plotting and quality evaluation on the outcome, and thus these uncertain items need to be clarified before implementing topographic map development using satellite ortho images. Disregarding these points, more and more people are beginning to have the misunderstanding that the topographic map development method using satellite ortho images is a newer method than the original stereo mapping and has wide applicability due to the benefits of satellite images. The table below shows a comparison between the features of the conventional stereo image method and the satellite ortho method on topographic map development items.

No.	Item	Stereo image method	Satellite ortho image method
1	Plotting facility	Special photogrammetric instrument	Normal PC/WS (with CAD software)
2	Technology	Conventional digital photogrammetric technology	Photographic image interpretation technology

3	Thematic accuracy	High	Low. Supplemental materials are essential and there is load on field survey or supplemental survey
4	Work process	Conventional digital work process	Preparation of ortho image data and elevation data need to be implemented separately.
5	Quality evaluation	Certain level of evaluation possible	Evaluation method, etc. has not been established.

（1） Plotting facility

Topographic map development using stereo image method is an application of topographic map development by normal air photography survey and requires expensive facilities such as the stereo plotting device. However, topographic map development using satellite ortho image method requires devices to prepare satellite ortho images instead of the stereo plotting device because mapping is done on satellite ortho images. But devices with digitalizing functions and additional information collection to interpret map features from satellite ortho images will also be required.

（2） Technology

Stereo image technology requires experienced skills to handle the facilities and overall knowledge on photogrammetry. On the other hand, satellite ortho image plotting method mainly requires photograph interpretation technology, but the processes can be divided or computerized since it is completely identical to the conventional digital photogrammetry.

（3） Thematic accuracy

It goes without saying that stereo image method is higher in positional accuracy and thematic accuracy in interpretation and plotting. There are items that are extremely difficult to interpretation on satellite ortho images and there may be large burden requiring supplementary interpretation materials, fieldsurvey and supplemental survey.

（4） Work process

Compared to the stereo image method, satellite ortho image method requires satellite ortho image preparation work and acquisition of elevation data, etc. from existing maps and so forth in the collected materials.

（5） Quality evaluation

The quality evaluation method on the resulting topographic map has not been established for satellite ortho image mapping.

If it is determined that topographic map development method using satellite ortho images is appropriate upon considering the above, it must be confirmed that the following conditions are at least satisfied:

Conditions in which digital plotting by satellite ortho images can be applied:

- **Engineers**

  Engineers with sufficient experience to interpret the items from photographic images can be ensured.

- **Satellite ortho images to be used**

  It is allowed to apply this method only when satellite ortho images prepared based on Japan International Cooperation Agency Work Specifications <for National Base Mapping> and Survey Operation Manual for Digital Ortho Production (for National Base Map). Satellite ortho images for which precision cannot be confirmed shall not be used in this method.

- **Acquisition of elevation data**

  Since elevation data cannot be obtained only with satellite ortho images, it is essential that there are existing maps with certain level of precision so that the data on contours, spot heights, etc. can be obtained from them.

In addition, Survey Operation Manual for Topographic Mapping Using Satellite Images (for National Base Map) shall be referred for details about the target satellite images and their handling and Survey Operation Manual for Digital Ortho Production (for National Base Map) shall be referred for methods to prepare the satellite ortho images in the Survey Operation Manual for Topographic Mapping Using Satellite Ortho Images (referred to as "this manual" hereafter).

This manual summarizes the efficient implementation of topographic map development using satellite ortho images and ensuring of its accuracy in basic map survey of the scale roughly from 1/5,000 to 1/100,000 implemented overseas by Japan International Cooperation Agency (hereafter referred to as the Agency) by describing the details of conditions in which topographic map development using satellite ortho images can be applied.

2. Structure of this manual

This manual stipulates the standard work procedures for developing topographic maps using satellite ortho images. It comprises of the following sections:

(1) Part 1 General rules

The purpose of this manual, conditions, etc. regarding topographic map development using satellite ortho images are specified.

(2) Part 2 Topographic map development using satellite ortho images

Specific processes for plotting and editing work using satellite ortho images are specified.

Part 1 General rules

(Purpose)

Article 1 The purpose of this manual is to unify the specifications, standardize the outcomes and ensure necessary accuracy in surveys for base maps implemented overseas by Japan International Cooperation Agency (hereafter referred to as the Agency) with application of Article 10 “Special Exceptions” Japan International Cooperation Agency Overseas Work Specifications for National Base Mapping (February 2022) and specifying the conditions and standard work procedures for developing topographic maps using satellite ortho images.

[Explanation]

Article 10 of Japan International Cooperation Agency Overseas Work Specifications (for National Base Mapping) is provided as follows:

(Special Exceptions)

Article 10 The instruments and the survey methods other than those specified in the Specifications may only be used in parts of the works subject to the approval of JICA and provided that their use will not cause any problems to ensure the required accuracy and maintain the work efficiency.

2. The survey methods, references, items, processes, etc. specified in the Specifications may only change with the approval of JICA.

(Application of Japan International Cooperation Agency Work Specifications (for National Base Mapping))

Article 2 Unless otherwise specified in this manual, related stipulation of Japan International Cooperation Agency Work Specifications (for National Base Mapping), Survey Operation Manual for Digital Ortho Production (for National Base Map) and Survey Operation Manual for Topographic Mapping Using Satellite Images (for National Base Mapping) shall be applied.

[Explanation]

This manual describes only the conditions and unique items for plotting using satellite ortho images in the overall process of standard topographic map development. For items not specified in this manual, it is necessary that Japan International Cooperation Agency Work Specifications (for National Base Mapping), Survey Operation Manual for Digital Ortho Production (for National Base

Map) and Survey Operation Manual for Topographic Mapping Using Satellite Images (for National Base Map) be applied.

(Topographic map development using satellite ortho images)

Article 3 Topographic map development using satellite ortho images refer to the topographic map development work to implement digital plotting on single images using satellite images converted into orthophotograph (called satellite ortho images) as the base instead of stereo mapping only when normal stereo plotting is difficult or when it is necessary to create topographic maps including data on roads and artificial structures, etc. except for elevation data (contours, spot heights, etc.) in overseas survey projects natural(base mapping) implemented by the Agency.

This shall include the following work processes (image acquisition, control point survey, aerial triangulation, elevation data preparation and ortho image production) which are implemented to prepare satellite ortho images with specified level of accuracy.

[Explanation]

1. This is the method to develop topographic maps in which data that cannot be interpreted from the single satellite ortho images among the data to be expressed on the topographic map is interpreted with reference to supplementary materials of aerial photograph, satellite image stereo pair, existing topographic maps, etc. to develop, organize and input data that can be directly interpreted from the satellite ortho images, data obtained from supplementary materials and data obtained from field survey on the base of satellite ortho images.
2. The examples of cases in which normal stereo plotting is difficult are provided as follows:
   - When aerial photographing is difficult
   - When maps covering a wide area needs to be developed urgently
   - When instruments necessary for stereo plotting cannot be ensured
   - When technical transfer on stereo plotting and related techniques is difficult
3. If there is no major secular changes in the topography in regions subjected to topographic map development, it shall be possible to obtain data regarding elevation such as contours from the existing topographic maps on which certain level of precision is ensured. For features such as traffic network and artificial structures other than contours, topographic map data is to be obtained by plotting on the satellite ortho images.
4. Satellite ortho images used in topographic map development using satellite ortho images are satellite images that have been prepared according to the specified work procedures and accuracy control procedures (planning and preparation, image acquisition, control point survey, aerial triangulation, preparation of digital terrain model, and preparation of ortho images) stipulated in

Japan International Cooperation Agency Work Specifications for National Base Mapping and that satisfy the accuracy requirement necessary for use as the base.

5. Using satellite ortho images as the base, shapes and positions of necessary features for the topographic map are interpreted to develop the map based on input by digitizing system. This work is called plotting using satellite ortho images. The attributes of features are classified and recorded using classification codes simultaneously with plotting.

   The digitizing system is also used to take the topographic data from existing materials such as inputting of contours data on existing maps, etc.

(Instruments, etc. to be used)

Article 4 The major instruments to be used in plotting using satellite ortho images shall be the following or have equivalent functions:

(1) Digitizing system

The digitizing system refers to the system comprising of computer programs with functions to read coordinates and input shapes, a computer and its peripheral devices and it shall have performance to ensure the specified accuracy.

(2) Scanning system

The scanning system refers to the system comprising of a scanner with functions to acquire and record collected materials, etc. in image formats, a computer program and a computer and it shall ensure the specified accuracy.

<Article 4 Operation criteria>

1. The following provides the standard configuration and functions of the digitizing system:
   (1) The digitizing system shall comprise of a computer, a display, a mouse/tablet/digitizer, a CAD software program and so forth.
   (2) It shall have functions to input and record the X, Y, and Z coordinate values and specified codes.
   (3) It shall have functions to correct the difference between the measurement values (mechanical coordinate value) and coordinate values on the map manuscript.

Item	Performance (precision)	Reading range
Resolution Reading precision	0.1mm or smaller 0.25% or smaller (between 2 optional points)	It should be possible to read inside of the neat lines on map manuscript or materials.

2. The following provides the standard configuration and functions of the scanning system.:
   (1) The scanning system shall comprise of a computer, a display to show images, a CCD image sensor and so forth.

(2) The scanning system shall have the following precision in performance:

Item	Performance (precision)	Reading range
Resolution Reading precision	0.1mm or smaller 0.25% or smaller (between any 2 points)	It should be possible to read inside of the neat lines on map manuscript or materials.

(Planning)

Article 5 The organization implementing survey (hereafter referred to as "the executing organization") must develop a proper work plan on work methods, major instruments to be used, work force, schedule and so forth and submit it to the Agency and obtain its approval prior to beginning the work. The same shall apply when it wishes to change the work plan.

(Process control)

Article 6 The executing organization must implement proper process control based on the work plan in the previous article.

2 The executing organization must report the progress to the Agency as necessary.

Part 2 Topographic mapping using satellite ortho images

Chapter 1 General

Outline

(Outline)

Article 7 Preparation of a topographic map using satellite ortho images refers to the work of preparing a topographic map by using the single-image satellite ortho images as the base instead of the normal stereo plotting map features in the digital plotting process by preparing the ortho images of satellite images with certain precision (hereafter referred to as “satellite ortho images”).

(Accuracy standard for satellite ortho images, etc.)

Article 8 A satellite ortho image is the orthographic projection image of a satellite image using elevation data, ground control points and so forth.

2 The following shall be used as the standard accuracy of the satellite ortho images to be used in topographic map development:

<Article 8 Operation criteria>

The horizontal positional accuracy of a satellite ortho image varies depending on the combination of ground of the ortho image resolution, grid interval of the digital terrain model and accuracy of the spot height. It may also be influenced by the topographic features and thus the method for acquiring the elevation needs to be determined with consideration of the topographic features.

[Explanation]

1. The ortho image to be used in satellite ortho image shall conform to the mapping scale. The standard corresponding scales (levels) and image resolutions are provided in the table below:

Map information level	Tolerable horizontal accuracy (on the map information level)	Ground resolution
5000	2.5m or smaller	0.8m or smaller
10000	5.0m or smaller	1.0m or smaller
25000	12.5m or smaller	2.5m or smaller
50000	25.0m or smaller	5.0m or smaller
100000	50.0m or smaller	10.0m or smaller

2. Major satellite image products that correspond to the ground resolutions are provided as follows

(as of December 2006):

Name	Product	Resolution	Remarks
IKONOS (Pan)	Digital geo-images (Geo Ortho Kit)	1.0m	RPC model data included
QuickBird-2 (Pan)	Basic images	0.61 ～ 0.72m	Orbit data included RPC model data included
OrbView-3 (Pan)	OrbView BASIC Enhanced	1.0m	RPC model data included
SPOT-5 (HRG-P)	SPOT Scene Level 1A/1B/2A	2.5m	Orbit data included
SPOT-1/2/3 (HRV Pan)	SPOT Scene Level 1A/1B/2A	10m	Orbit data included
SPOT-4 (HRVIR Pan)	SPOT Scene Level 1A/1B/2A	10m	Orbit data included
ALOS （※） (PRISM)	PRISM Level 1A/1B1/1B2	2.5m	Orbit data included RPC model data included

(Work processes and their order)

Article 9 Work flows as follows. However, they can be changed or omitted in part if the Agency instructs or approves so.

(1) Planning

(2) Control point survey

(3) Setting of air photo signal

(4) Acquisition of image data

(5) Pricking

(6) Field survey

(7) Aerial triangulation

(8) Preparation and acquisition of digital terrain model

(9) Orthographic transformation

(10) Mosaicking

(11) Acquisition of contours and spot height

(12) Digital plotting

(13) Digital editing

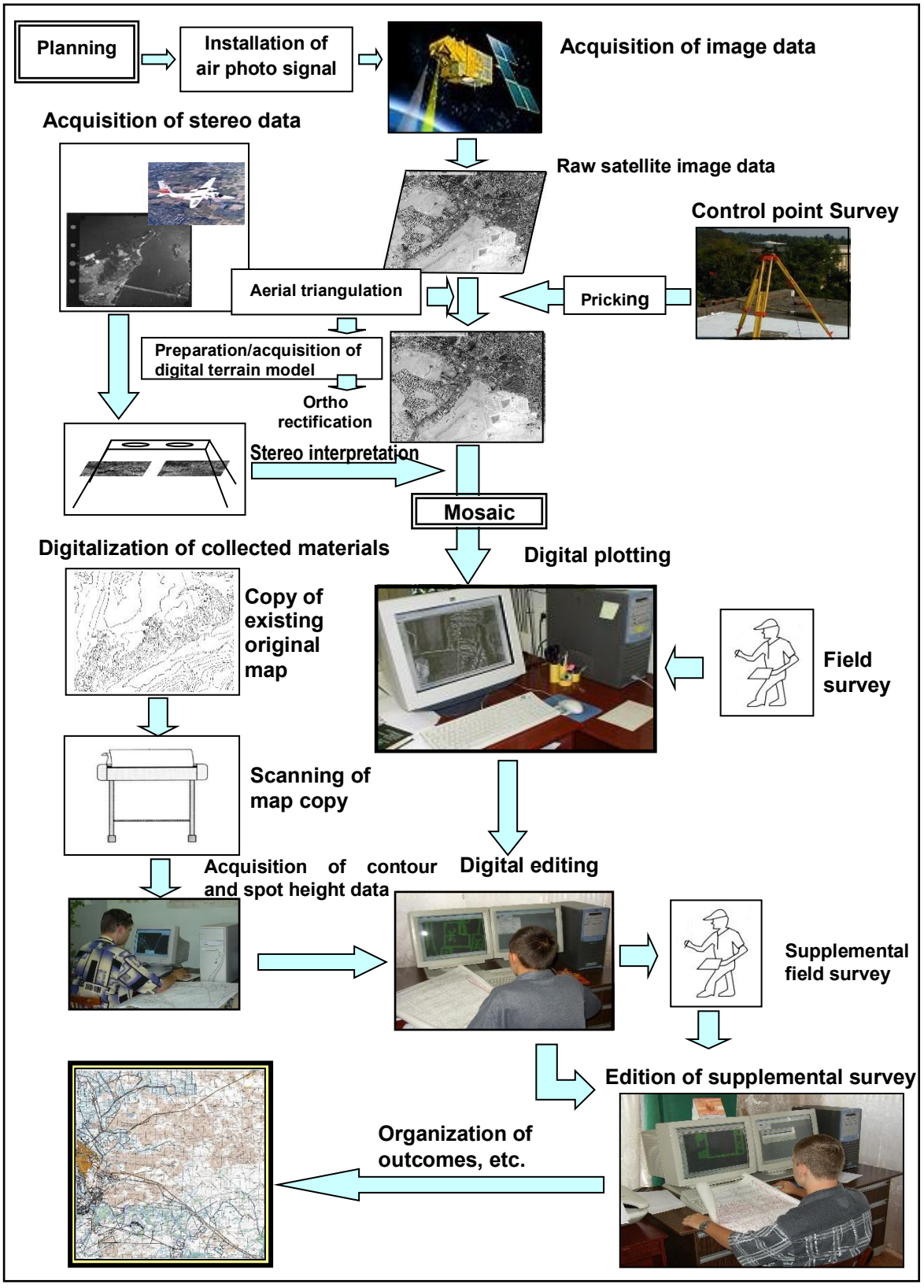
(14) Supplemental field survey

(15) Edition of supplemental survey

(16) Summary of results, etc.

[Explanation]

The standard workflow for satellite ortho image mapping is shown as follows:



(Application of various stipulations for topographic map development using satellite ortho images)

Article 10　Work Specifications (for National Base Mapping) shall be applied for Items 1, 2, 3, 5, 13 – 16 of the previous article. Survey Operation Manual for Topographic Mapping using Satellite image (for National Base Map) shall be applied for Items 4 and 7, and Survey Operation Manual for Digital Ortho reduction (for National Base Map) for Items 8, 9 and 10. Thus this manual shall describe Items 6, 11 and 12.

Chapter 2 Topographic mapping using satellite ortho images

This section describes the most important item in topographic map development using satellite ortho images and the item unique to satellite ortho mapping among the processes in Article 11, namely, Item 11 Acquisition of contours and spot heights and Item 12 Digital plotting of Article 11. It also describes Section 6 Field survey and Section 14 Supplemental field survey as supplements although Work Specifications for overseas survey shall be applied mutatis mutandis.

(Field survey, supplemental field survey) Article 11 Articles 110 – 116 and 179 – 184, Chapter 5 of Work Sepecifications for National Base Mapping shall be basically applied for field survey and supplemental field survey. However, information obtained by interpreting satellite ortho images is inferior in precision to information obtained from stereo images and thus survey needs to be implemented on topographic features that are difficult to identify on satellite ortho images.

[Explanation]

Specific examples of features that are difficult to identify on satellite ortho images are listed below. In each case, efforts shall be paid to collect and investigate the necessary data.

1. Roads, etc.
   Depending on the scale of topographic map, interpretation of linear objects such as roads, channels (including canals) and railroads is extremely difficult. It may therefore be necessary to implement field survey.
2. Buildings, etc.
   Interpretation may be difficult if the roof color or tone is similar to those of the surroundings. Thus building survey may be necessary depending on the scale.
3. Topography, etc.
   Changes in the terrain due to relative elevation difference are very difficult to interpret on satellite ortho images. Field survey must be implemented by considering the nature of satellite ortho images.
4. Vegetation, etc.
   Vegetation for which the map expression may vary by the height such as forest and grassland needs to be confirmed.
5. Small objects, etc.
   Small objects are difficult to interpret and field survey may be necessary.

(Acquisition of contours and spot heights)

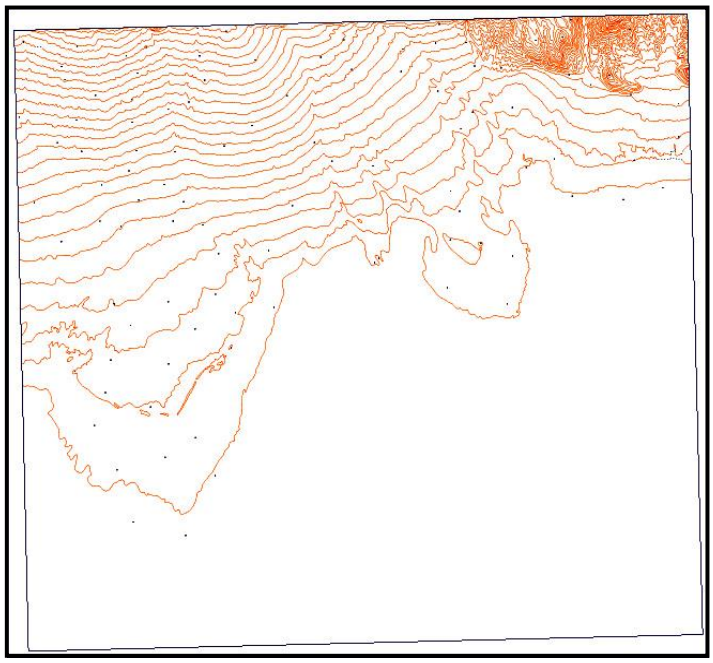
Article 12 If the accuracy of the existing map and similar collected materials has been confirmed and it is possible to obtain contours and spot heights from these materials, contour and independent spot heights shall be obtained according to Articles 200 – 208 of Work Specifications for National Base Mapping.

[Explanation]

An example of the procedure to obtain necessary data such as contours and independent spot heights to develop a topographic map is provided below:

1. Preparation of positive film of existing map
   To avoid scanning the original map directly, a copy shall be prepared.
2. Acquisition of raster data of existing map
   Raster data shall be obtained by digitalizing the positive film of the existing map copy using a large scanner.
3. Acquisition of contours and spot heights
   Contours and spot heights shall be obtained from the raster data.

Example of obtained contours and spot heights output



(Digital plotting)

Article 13 Digital Plotting of satellite ortho images shall be implemented using supplemental materials by while stereoscopic view is obtained on topographic features that can be obtained by identifying and interpreting from the satellite ortho image which is the base data with

consideration of scale of the topographic map to be prepared and displacement in planimetric position due to relative elevation difference .

[Explanation]

１． Plotting method

There are 2 possible plotting methods as follows:

（１） Plotting using the map manuscript

As to plotting using the map manuscript (information on satellite ortho image is copied onto the overlay), work may be conducted by setting up the mapping scale to a larger scale than the intended scale for the topographic map in order to minimize the errors.

（２） Plotting by on screen digitization

As to plotting by on screen digitization, it is possible to plot by setting up a free scale on the screen. However, it is also possible to display ortho image in larger scale than the intended scale for the topographic map to minimize error in this case.

２． Displacement in planimetric positions due to relative elevation difference for topographic features

When satellite images that are not looking at nadir are used, topographic features with heights such as buildings are shown in slant postures. For building data with scale of 1:5000 or larger, the position of the roof on the image may be displaced from the true position of the building if it is digitized without correction since the roof outline is obtained as the position. Even when satellite ortho images are used, the positional accuracy of the image is the accuracy on land surface. Therefore, it must be confirmed that this displacement stays within the tolerable error range.

Examples of items which can be identified on satellite ortho images are listed as follows. Although they may depend on the type of satellite and resolution, these are roughly the items that can be identified. However, items listed here may not be identifiable or items that are not listed may be identifiable depending on the type of satellite and resolution. Some items may also require confirmation by field survey depending on the situation of interpretation.

(1:2,500 and 1:5,000 map items)

Major classification	Classification	Map feature
Transport facilities	Roads	Roads or larger, roads in specific premises such as parks, roads in construction
	Road facilities	Road bridges, median strips, boulevard trees
	Railroads	Railroads
	Railroad facilities	Railroad bridges
Buildings	Buildings	Buildings, robust buildings
Water-related features	Water-related features	Shorelines

(1:25,000 map items)

Large classification	Classification	Map feature
Terrain	Terrain on land	Gravel land, craters/fumaroles, wetlands, glacier snow
	Terrain in water	Shorelines, rivers, channels in space, lakes, ponds, etc.
Transport facilities	Roads	Roads with widths 25m or larger, roads with widths smaller than 25m, etc.
	Railroads	Railroads, stations, railroad bridges, etc.
Buildings, etc.	Buildings	Independent buildings, buildings collectively drawn

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FY 2021 Edition
Publication date: February 28, 2022
Authors: Urban and Regional Development Group,
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