Kingdom of Thailand
Ministry of Agriculture and Cooperatives
Royal Irrigation Department

# PROJECT FOR COMPREHENSIVE FLOOD MANAGEMENT PLAN FOR THE CHAO PHRAYA RIVER BASIN (SUB-COMPONENT 1-1 AERIAL SURVEY BY LIDAR)

## FINAL REPORT

**August 2012**

**JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)**

**PASCO CORPORATION**
**KOKUSAI KOGYO CO., LTD.**
**ASIA AIR SURVEY CO., LTD.**

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# Project for comprehensive flood management plan for the Chao Phraya River Basin

## (Sub-Component 1-1 Aerial Survey by LiDAR)

## Final Report

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PASCO Corporation
Kokusai Kogyo Co., Ltd.
Asia Air Survey Co., Ltd.

Currency exchange rate

Currency unit: Thai Baht

1 THB = 2.487 yen (August 2012)

# Table of Contents

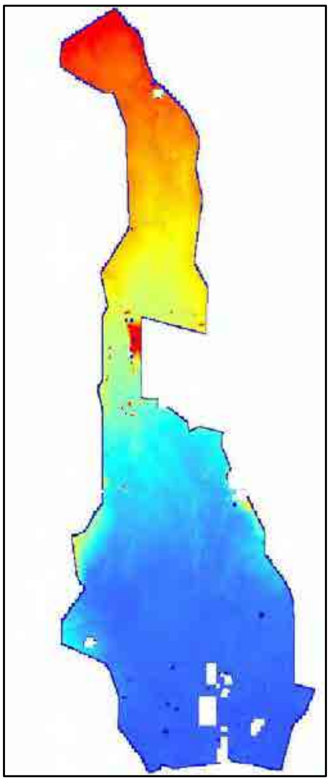
# 1. Outline of Work

## 1.1. Objective of Work

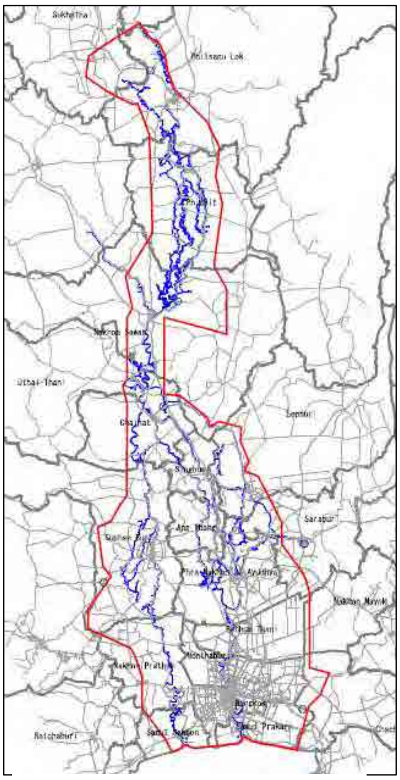
This Work shall be performed to examine the possibility of allowing a certain amount of flooding with a focus on controlling overflowing of the river into farmland area for the region that was affected by the flood that occurred in 2011. In order to determine the feasibility and formulate plans, detailed topographic data of the flooded region needs to be utilized. However, topographic map data that can currently be used has an accuracy of 2 meters in the difference of elevation, which is inadequate for the evaluation of suitable areas in the mid and lower portions of the flat Chao Phraya River, necessitating the creation of new detailed topographic data by means of airborne laser scanning.

## 1.2. Target Area

Area to be photographed: Chao Phraya River Basin Flooded Region: 24,700km$^2$



Location of the survey work



Target area of the work

**Implementing Organization in Recipient Country (Counterpart)**

Royal Irrigation Department, Ministry of Agriculture and Cooperatives (RID)

Entrance to Royal Irrigation Department

Royal Irrigation Department
Technology Office Building

## 1.3. Details and Amount of Work

### (1) Details and Amount of Work

It was decided that the Work Regulation Rules (Publication No. 413 dated March 31, 2008) of the Ministry of Land, Infrastructure, Transport and Tourism should be used as the technical standard for the survey work.

| Survey Item | Volume | Remarks |
|---|---|---|
| (1) Measuring Plan | 24,700 km$^2$ | Scan Density: 2.0m×2.0m<br>Average Sidelap of flight path: 30%<br>Completed in February |
| (2) GPS Base Stations | 11 points | Installation completed in February for constant observation at the time of measurement |
| (3) Control Points for Correction | 989 points | Placed on public land<br>Installation completed in March<br>Observation and calculation completed in May |
| (4) Airborne Laser Scanning | 24,700 km$^2$ | Airborne laser scanning system provided with digital camera will be used.<br>Flight permit obtained in February<br>Measurement of the whole area (excluding the areas where measurement is prohibited) completed in May |
| (5) 3D Data Creation | 24,700 km$^2$ | Ground Coordinate Unit: 1cm<br>Data created from March to July |
| (6) Original Data Creation | 24,700 km$^2$ | Standard Unit: 1cm<br>Data created from April to August |
| (7) Ground Data Creation | 24,700 km$^2$ | Data created from April to August |
| (8) Grid Data Creation | 24,700 km$^2$ | 2m grid |

| | | |
|---|---|---|
| | | Elevation: Rounded off to 0.1m units<br>Data created from May to August |
| (9) Contour Line Data Creation | 24,700 km$^2$ | Index contour lines: 5m (changed from 10m through discussions with RID)<br>Intermediate contour lines: 1m (changed from 2m through discussions with RID)<br>Data created from May to August |
| (10) Digital Aerial Photography | 24,700 km$^2$ | Airborne laser scanning system provided with digital camera shall be used.<br>Photographed simultaneously with (4), excluding the areas where measurement is prohibited |
| (11) Orthophoto Data Creation | 24,700 km$^2$ | Ground Resolution: 50cm<br>Data created from April to July |

### (2) Final Outputs

During this Work, the following reports and other outputs shall be prepared and submitted.

| Outputs | Content | Copies | Submission |
|---|---|---|---|
| (1) Inception Report | Implementing plan of the work including basic policy, methods, processes, and personnel plans of the Work. | English: 20 | Submitted on February 8, 2012 |
| (2) Final Report | Overall results of the Work and technology transfer results | Japanese: 10<br>English & DVD: 20 | Submitted on August 27, 2012 |
| (3) Airborne Laser Scanning Survey Data | Digital Data Files<br>- Original data<br>- Ground data<br>- Grid data<br>Orthophoto Data<br>Position Data File<br>Contour Line Data<br>Water Surface Polygon<br>Stored Data List | 24,700 km$^2$<br>Stored on a HDD for delivery | Submitted on August 24, 2012 |
| (4) Index Map of Measurement | Map showing the areas and flight paths which were scanned for measurements | 3 | Submitted on August 27, 2012 |

# 2. Work Implementation Status

## 2.1 Work Implementation Details

### 2-1-1 Preparation of Inception Report

After studying the Scope of Work and the collected materials, an inception report was created. The report was finalized by incorporating the results of preliminary explanation to JICA and prepared in Japanese and English. It comprised the following details:

- Target area of the work
- Work details and work volume
- Basic policy of work implementation
- Method of work implementation
- Work flowchart
- Work schedule
- Personnel plan
- Equipment procurement plan
- Work implementation structure

### 2-1-2 Explanation of / Discussion on Inception Report

On February 8, 2012, the inception report was explained to the Royal Irrigation Department (RID), which is the counterpart agency, and related organizations and a meeting was held with them to discuss the work details and implementation policy to obtain an approval. For the purpose of explanation and discussion, a presentation was given, using a PowerPoint file summarizing the content of the report.

The discussion details and results were summarized into the minutes on which signatures of both parties were given. (See Appendix-1.)

### 2-1-3 Discussion on Specifications

The survey details and methods were explained to the Royal Thai Survey Department (RTSD), which prescribes the survey work standard in Thailand, in addition to the RID and a meeting was held with them to discuss the survey control of airborne laser scanning survey to be newly established in this survey, the scope of survey and the specifications of the outputs to obtain an approval.

1) Survey control

As a result of discussions among the RID, the RTSD and the Study Team, the survey control was established as described below in consideration of standardization to facilitate the sharing of data with related organizations in Thailand and abroad.

Table 2.1.1 Survey Control

| Item | This survey |
|---|---|
| Projection method | UTM (Universal Transverse Mercator)<br>Zone 47N |
| Reference ellipsoid | WGS84 |
| Geodetic datum | WGS84 (ITRF2008) |
| Height reference | Mean Sea Level (in accordance with the existing benchmark) |

2) Target area of survey

The target area of survey was determined as described below through discussions between the related organizations and the Study Team and with the approval of JICA.

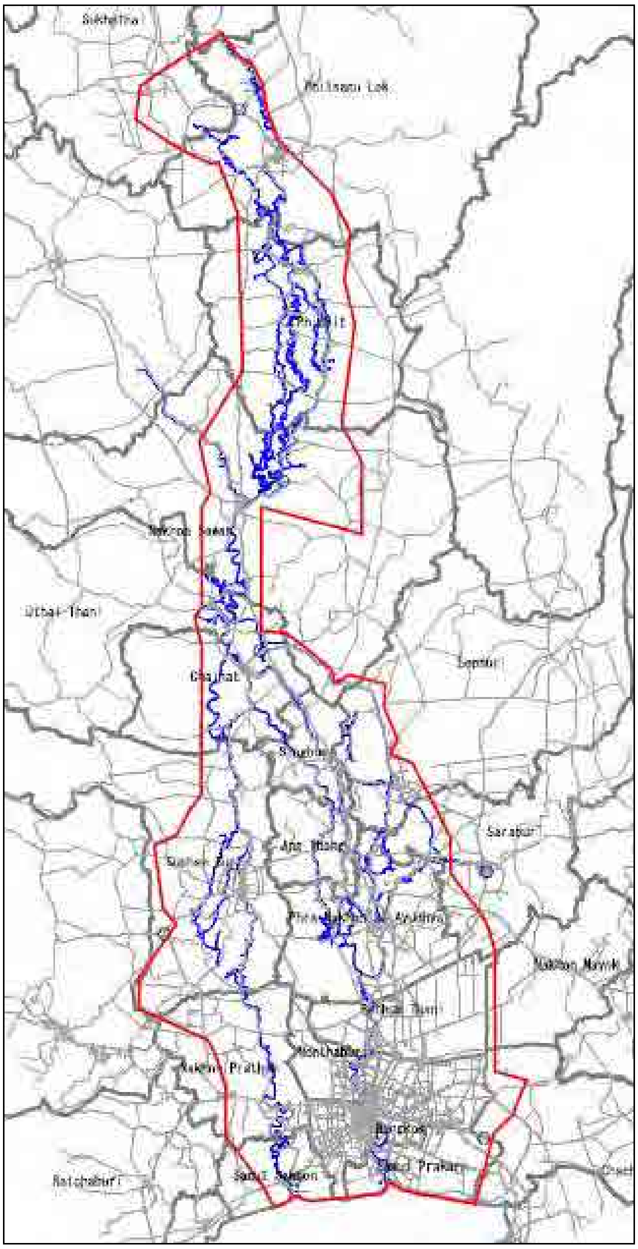


Figure 2.1.1 Target Area of the Survey

3) Specifications and outputs

Since this project is the first airborne laser scanning survey in Thailand, it was decided to perform the survey in accordance with the survey work regulations in Japan ("Work Regulation Rules" of the Ministry of Land, Infrastructure, Transport and Tourism).

With respect to the data creation unit of the outputs, it was decided that the data should be created by using the map sheets that divide the whole country into map sheets of 2km east to west and 2km north to south (1:4000 map sheets), which are used by the Department of Land Development (DOL).

### 2-1-4 Collection and Organization of Existing Materials

Existing materials needed for this project were collected and organized as described in the following table.

Table 2.1.2 List of Collected Existing Materials

| No. | Name of Materials | Type | Organization of Publication | Published |
|---|---|---|---|---|
| 1 | 1:50,000 map (96 maps covering the target area) (paper map + scan data) | Survey result | RTSD | Depends on the map |
| 2 | 1:50,000 index map (paper map) | Survey result | RTSD | |
| 3 | 1:250,000 map (10 maps covering the target area) (paper map) | Survey result | RTSD | Depends on the map |
| 4 | 1:250,000 index map (paper map) | Survey result | RTSD | July 2541 (1998) |
| 5 | Reference point data, Reference point description (Reference point data for 15 points covering the target area) (paper + scan data) | Survey result | RTSD | Depends on the point |
| 6 | Reference point index map (first class) released on a website (scan data) | Survey result | RTSD | 2550 (2007) |
| 7 | Reference point index map (second class + index map of Reference points with elevation) (scan data) | Survey result | RTSD | |
| 8 | Benchmark data, benchmark description (data of 115 benchmarks around 40 locations needed for a primary network of control points for correction) (paper) | Survey result | RTSD | Depends on the point |
| 9 | Same as above (point shape file) | Survey result | RTSD | Latest |
| 10 | Leveling route network diagram (whole nation) (scan data) | Survey result | RTSD | Before 2553 (2010) |
| 11 | Leveling route network diagram (Bangkok) (scan data) | Survey result | RTSD | 2554 (2011) |
| 12 | Administrative division data (province, district) (polygon shape file) | Background information | RID | Latest |

### 2-1-5 Preparation of Final Report

Summarizing the implementation results of this work, a final report was created. The report was finalized by incorporating the results of preliminary explanation to JICA and prepared in Japanese and English. It comprised the following details:

- Target area of the work
- Work details and work volume
- Work implementation details
- Work implementation methods
- Work flowchart
- Work schedule and record
- Personnel plan and record
- Recommendation and Conclusion

### 2-1-6 Explanation of / Discussion on Final Report

The final report was explained to the Royal Irrigation Department (RID), which is the counterpart agency, and related organizations and a meeting was held with them to discuss the work details and results of implementation to obtain an approval. For the purpose of explanation and discussion, a presentation was given, using a PowerPoint file summarizing the content of the report.

The discussion details and results were summarized into the minutes on which signatures of both parties were given. (See Appendix-2.)

### 2-1-7 Handling of Acquired Data

It is mandatory to work on the acquired measurement data under the management of the staff of the RTSD to prevent the leakage of information based on the national security of Thailand. As security officers, a total of 16 staff members of the RTSD were permanently stationed at the project office within the counterpart as well as at the airport office and the aircraft throughout the project period as described below.

| | | |
|---|---|---|
| Project office | | 2 people |
| Airport office (four aircraft) | | 4 people |
| Aircraft (four aircraft) | | 4 people |
| Data processing place | | |
| Japan | PASCO | 1 person |
| | Kokusai Kogyo | 1 person |
| | Asia Air Survey | 2 people |
| Philippines | PASCO | 2 people |

Also, as the data needed to be hand-carried by the security officers for delivery, the security officers traveled between Bangkok and Japan (Sapporo, Tokyo and Okinawa) whenever necessary.

## 2.2 Details of Survey Implementation

The implementation workflow of this survey is described below.

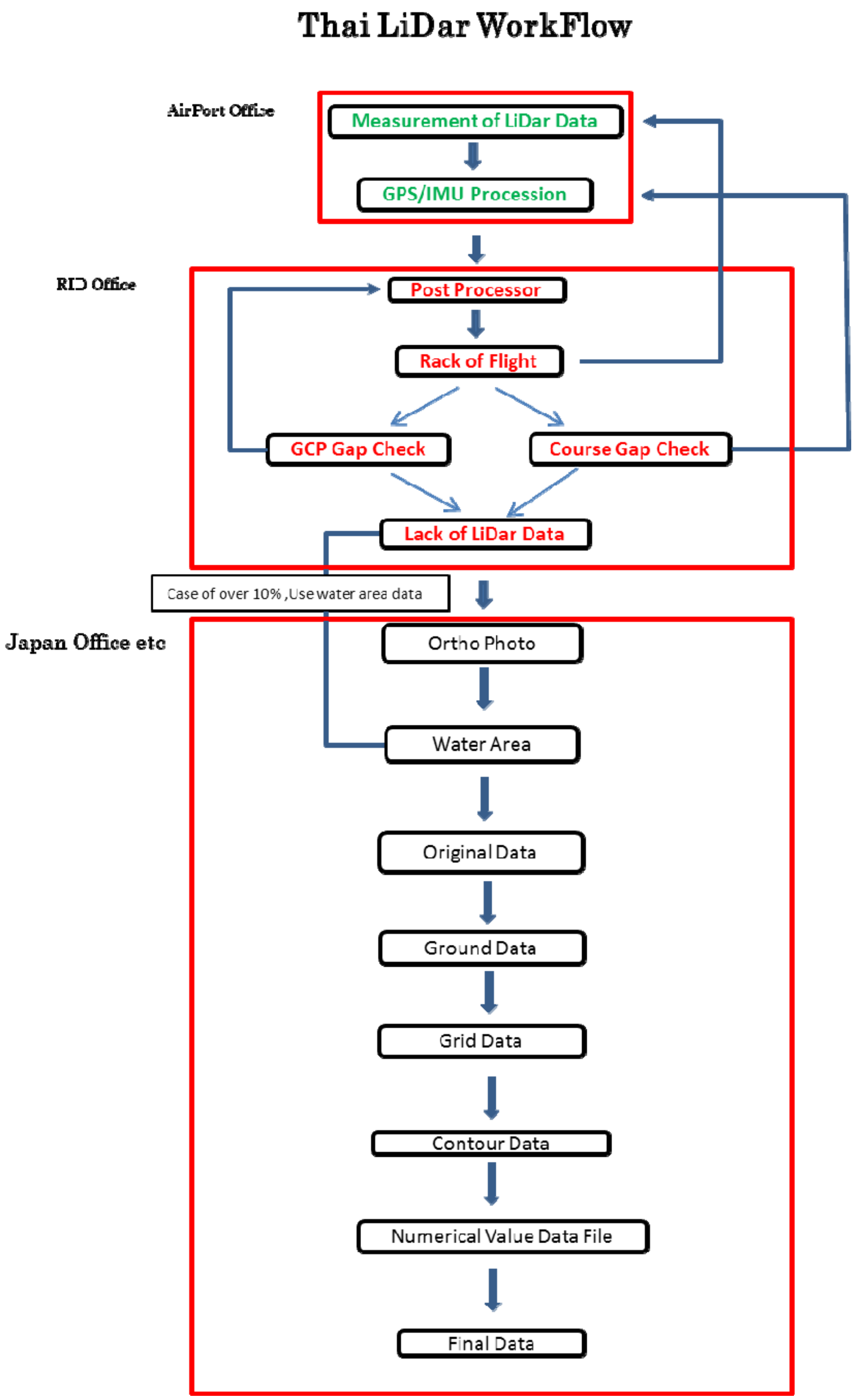


Figure 2.2.1 Implementation Workflow

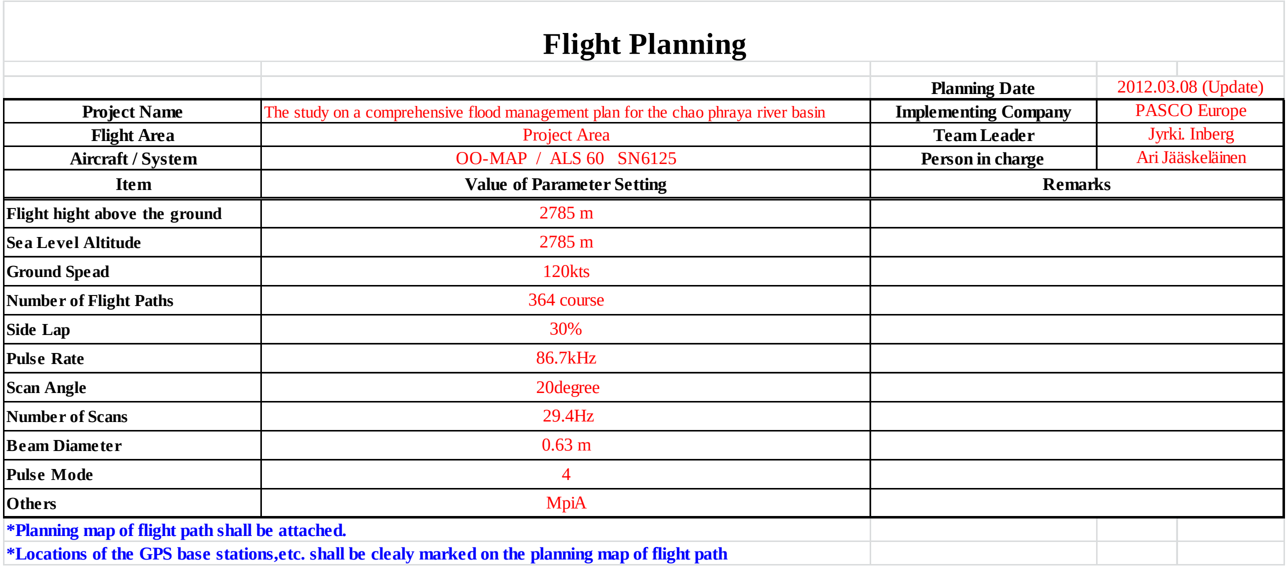
### 2-2-1 Measurement Plan

The measurement plan was created for the measuring specifications, flight paths, location of GPS base stations and GPS observation, taking the location of GPS satellites and other such details into consideration.

The scan density was set to have a grid of 2m×2m or less, with one or more laser points irradiated. Furthermore, the standard flight path duplication (side lap ratio) was set at 30%. The measurement was to be carried out with two base airports, namely Don Muang Airport in the south and Phitsanulok Airport in the north, taking the weather and air area into consideration.

The flight plan for airborne laser scanning is shown below. In principle, the flight altitude was set at 2,785m (428 courses). However, a plan with the flight altitude as low as 500m (2,017 courses in total) was also developed to provide for unfavorable weather in order to avoid measurement delays caused by clouds.

Table 2.2.1 Flight Plan (Terrain Clearance 2,785m)



**Flight Planning**

| | | | |
|---|---|---|---|
| | | **Planning Date** | 2012.03.08 (Update) |
| **Project Name** | The study on a comprehensive flood management plan for the chao phraya river basin | **Implementing Company** | PASCO Europe |
| **Flight Area** | Project Area | **Team Leader** | Jyrki. Inberg |
| **Aircraft / System** | OO-MAP / ALS 60 SN6125 | **Person in charge** | Ari Jääskeläinen |
| **Item** | **Value of Parameter Setting** | **Remarks** | |
| **Flight hight above the ground** | 2785 m | | |
| **Sea Level Altitude** | 2785 m | | |
| **Ground Spead** | 120kts | | |
| **Number of Flight Paths** | 364 course | | |
| **Side Lap** | 30% | | |
| **Pulse Rate** | 86.7kHz | | |
| **Scan Angle** | 20degree | | |
| **Number of Scans** | 29.4Hz | | |
| **Beam Diameter** | 0.63 m | | |
| **Pulse Mode** | 4 | | |
| **Others** | MpiA | | |

***Planning map of flight path shall be attached.**

***Locations of the GPS base stations,etc. shall be clealy marked on the planning map of flight path**

## Table 2.2.2 Flight Plan (Terrain Clearance 500m)

### Flight Planning

| | | | |
|---|---|---|---|
| | | **Planning Date** | 2012.03.08 (Update) |
| **Project Name** | The study on a comprehensive flood management plan for the chao phraya river basin | **Implementing Company** | PASCO Europe |
| **Flight Area** | Project Area | **Team Leader** | Jyrki. Inberg |
| **Aircraft / System** | OO-MAP / ALS 60 SN6125 | **Person in charge** | Ari Jääskeläinen |

| **Item** | **Value of Parameter Setting** | **Remarks** |
|---|---|---|
| **Flight hight above the ground** | 500m | |
| **Sea Level Altitude** | 500m | |
| **Ground Spead** | 150kts | |
| **Number of Flight Paths** | 1904course | |
| **Side Lap** | 30% | |
| **Pulse Rate** | 148.9 kHz | |
| **Scan Angle** | 20 degree | |
| **Number of Scans** | 59.4 Hz | |
| **Beam Diameter** | 0.12 m | |
| **Pulse Mode** | 4 | |
| **Others** | SpiA | |

***Planning map of flight path shall be attached.**

***Locations of the GPS base stations,etc. shall be clealy marked on the planning map of flight path**

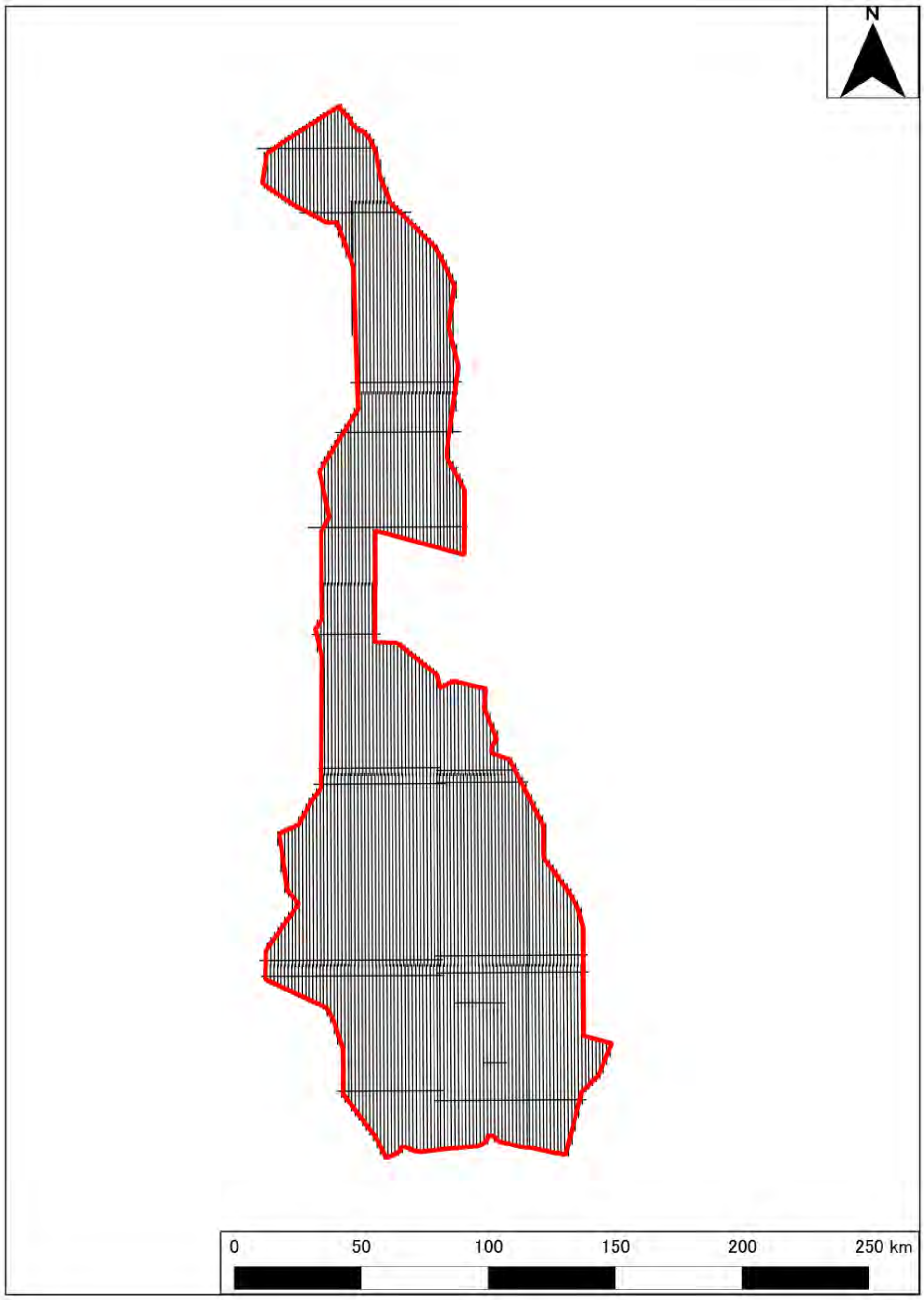


Figure 2.2.2 Measurement Course (Terrain Clearance 2,785m, 428 courses)

GPS base stations are points installed for GPS observations that are carried out synchronizing with the airborne laser scanning. An accurate location of the aircraft can be calculated by base line analysis of the GPS base station data combined with the airborne GPS data. In order to exhaustively cover the area to be measured, the points were distributed at about 45km intervals.

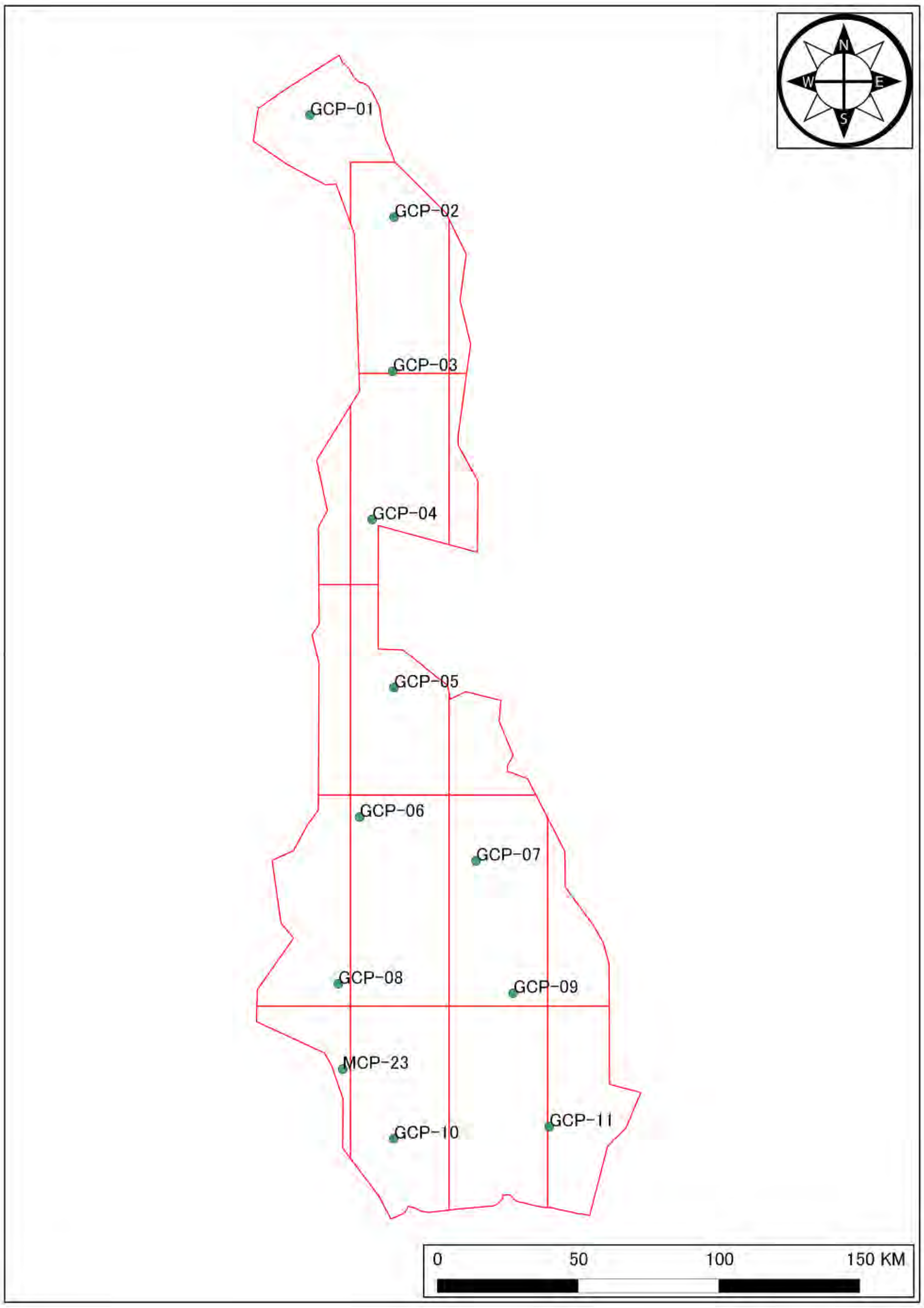


Figure 2.2.3　GPS base station Location Map

An application for flight permit was filed on February 10, adding the information on the aircraft and equipment to be used, the measurement plan, the pilots and the navigators and the permit was granted on February 24.

**ด่วนมาก**

ที่ คค ๐๕๐๔/๖๓๐๙

ถึง บริษัท โรยัลสกายเวยส์ จำกัด

ตามที่หนังสือบริษัท ฯ ที่ RSWLO 550223-2 ลงวันที่ ๒๓ กุมภาพันธ์ ๒๕๕๕ ขออนุญาตใช้อากาศยานแบบ Piper PA31-350 เครื่องหมายสัญชาติและทะเบียน HS-RSI ทำการบินสำรวจทางอากาศให้กับกรมชลประทานโดยได้รับความช่วยเหลือจากองค์การความร่วมมือระหว่างประเทศของประเทศญี่ปุ่น (JICA) ณ บริเวณลุ่มแม่น้ำเจ้าพระยา แม่น้ำท่าจีน แม่น้ำป่าสัก และพื้นที่ตามจังหวัดต่างๆ ที่เกี่ยวข้อง นับแต่วันที่ ๒๖ กุมภาพันธ์ ๒๕๕๕ ถึงวันที่ ๓๑ สิงหาคม ๒๕๕๕ ความละเอียดแจ้งแล้ว นั้น

กรมการบินพลเรือนอาศัยอำนาจตามเงื่อนไขประกอบใบอนุญาตให้ประกอบกิจการค้าขายในการเดินอากาศของบริษัท ฯ ข้อ ๒ (๓) พิจารณาแล้ว อนุญาตให้บริษัท ฯ ทำการบินได้ตามที่เสนอขอ โดยให้ปฏิบัติตามใบอนุญาตให้ประกอบกิจการค้าขายในการเดินอากาศและเงื่อนไข ฯ ใบรับรองผู้ดำเนินการเดินอากาศ (Air Operator Certificate) และข้อกำหนดการปฏิบัติการ (Operations Specifications) อย่างเคร่งครัด

จึงเรียนมาเพื่อทราบ

สำนักกำกับกิจการขนส่งทางอากาศ
โทร. ๐๒ ๒๘๖ ๘๕๕๗
โทรสาร ๐๒ ๒๘๗ ๓๑๓๙
ไปรษณีย์อิเล็กทรอนิกส์ atreg@aviation.go.th

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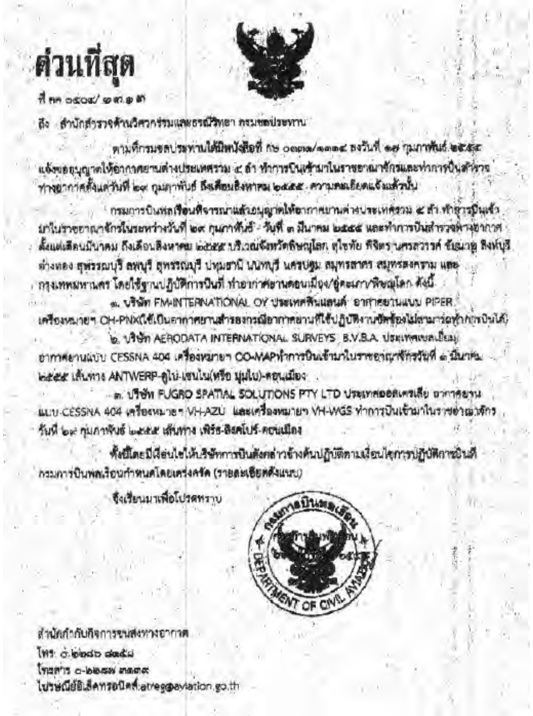


**ด่วนที่สุด**

ที่ คค ๐๕๐๔/ ๒๓๑๓

ถึง สำนักสำรวจด้านวิศวกรรมและธรณีวิทยา กรมชลประทาน

ตามที่กรมชลประทานได้มีหนังสือที่ กษ ๐๓๒๓/๑๓๓๔ ลงวันที่ ๑๗ กุมภาพันธ์ ๒๕๕๕ แจ้งขออนุญาตให้อากาศยานต่างประเทศรวม ๔ ลำ ทำการบินเข้ามาในราชอาณาจักรและทำการบินสำรวจทางอากาศตั้งแต่วันที่ ๒๙ กุมภาพันธ์ ถึงเดือนสิงหาคม ๒๕๕๕ ความละเอียดแจ้งแล้วนั้น

กรมการบินพลเรือนพิจารณาแล้วอนุญาตให้อากาศยานต่างประเทศรวม ๔ ลำ ทำการบินเข้ามาในราชอาณาจักรในระหว่างวันที่ ๒๙ กุมภาพันธ์ - วันที่ ๓ มีนาคม ๒๕๕๕ และทำการบินสำรวจทางอากาศ ตั้งแต่เดือนมีนาคม ถึงเดือนสิงหาคม ๒๕๕๕ บริเวณจังหวัดพิษณุโลก สุโขทัย พิจิตร นครสวรรค์ ชัยนาท สิงห์บุรี อ่างทอง สุพรรณบุรี ลพบุรี สุพรรณบุรี ปทุมธานี นนทบุรี นครปฐม สมุทรสาคร สมุทรสงคราม และกรุงเทพมหานคร โดยใช้ฐานปฏิบัติการบินที่ ท่าอากาศยานดอนเมือง/อู่ตะเภา/พิษณุโลก ดังนี้

๑. บริษัท FM-INTERNATIONAL OY ประเทศฟินแลนด์ อากาศยานแบบ PIPER เครื่องหมายฯ OH-PNX(ใช้เป็นอากาศยานสำรองกรณีอากาศยานที่ใช้ปฏิบัติงานขัดข้องไม่สามารถทำการบินได้)

๒. บริษัท AERODATA INTERNATIONAL SURVEYS B.V.B.A. ประเทศเบลเยี่ยม อากาศยานแบบ CESSNA 404 เครื่องหมายฯ OO-MAP ทำการบินเข้ามาในราชอาณาจักรวันที่ ๓ มีนาคม ๒๕๕๕ เส้นทาง ANTWERP-ดูไบ-เชนไน(หรือ มุมไบ)-ดอนเมือง

๓. บริษัท FUGRO SPATIAL SOLUTIONS PTY LTD ประเทศออสเตรเลีย อากาศยานแบบ CESSNA 404 เครื่องหมายฯ VH-AZU และเครื่องหมายฯ VH-WGS ทำการบินเข้ามาในราชอาณาจักรวันที่ ๒๙ กุมภาพันธ์ ๒๕๕๕ เส้นทาง เพิร์ธ-สิงคโปร์-ดอนเมือง

ทั้งนี้โดยมีเงื่อนไขให้บริษัทการบินดังกล่าวข้างต้นปฏิบัติตามเงื่อนไขการปฏิบัติการบินที่กรมการบินพลเรือนกำหนดโดยเคร่งครัด (รายละเอียดดังแนบ)

จึงเรียนมาเพื่อโปรดทราบ

สำนักกำกับกิจการขนส่งทางอากาศ
โทร: ๐-๒๒๘๖ ๘๕๕๗
โทรสาร ๐-๒๒๘๗ ๓๑๓๙
ไปรษณีย์อิเล็กทรอนิกส์ atreg@aviation.go.th

### 2-2-2 Survey of Primary Control Network (GCP/MCP) and Control Points for Correction

The workflow of the survey of control points for correction is shown below.

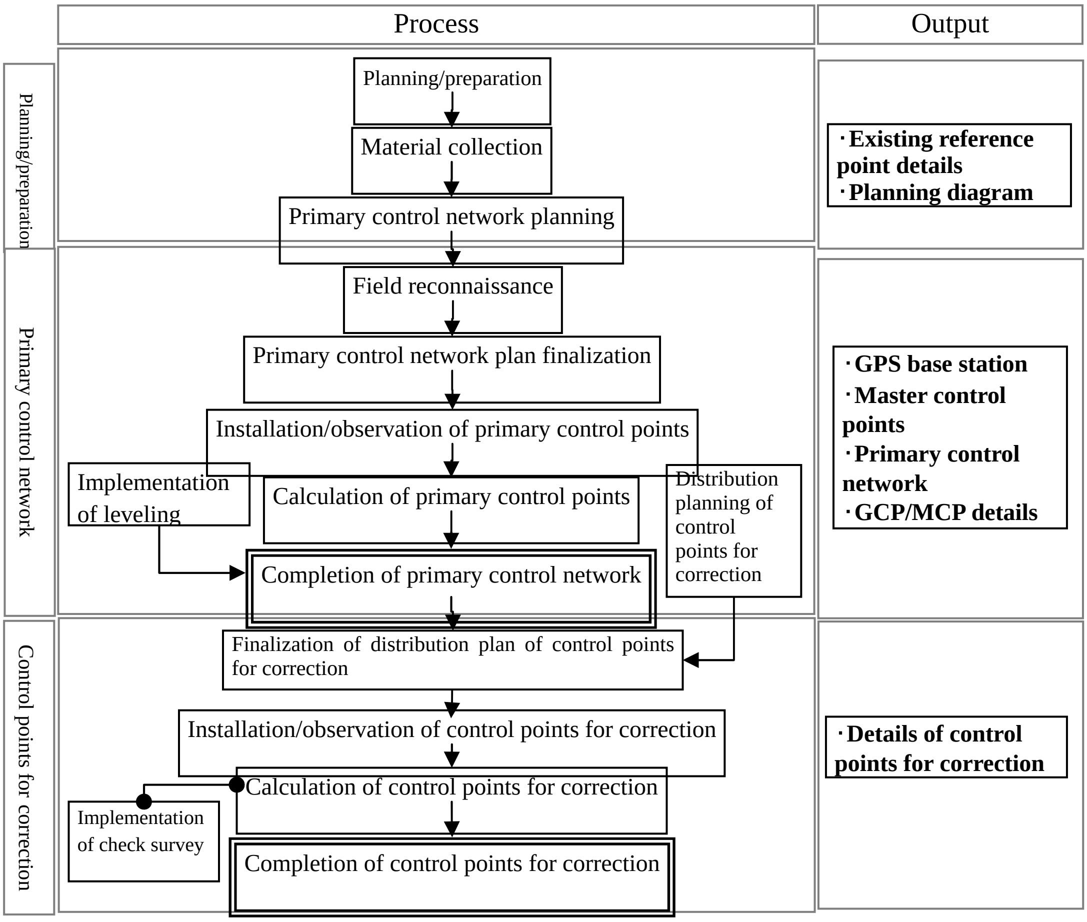
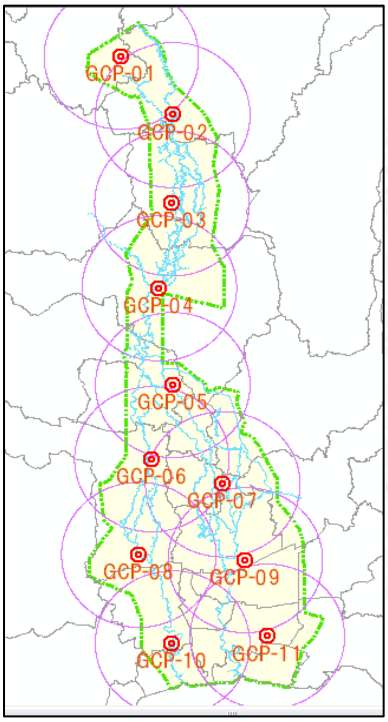


Figure 2.2.4 Workflow

### 2-2-3 Installation/Observation of GPS base station (GCP)

In order to identify the position of the laser distance meter by kinematic GPS surveying, GPS base stations need to be set up on the ground when an aircraft is flying. Since the area to be surveyed longitudinally stretches more than 400km from north to south, it was decided that 11 GPS base stations (GCP), each covering a circle of 45km radius, should be installed. It was also decided that data from GPS observation at the GPS base stations (GCP) should be obtained throughout the airborne laser scanning flight time and that data from both the GPS base stations and GPS observation unit on the aircraft should be obtained at one second intervals. Furthermore, the work was carried out to ensure that the number of GPS satellites would be five or more when data was acquired.



Description of GPS Base-Station

| | | | | |
|---|---|---|---|---|
| Point Name | [illegible] | | Operator | [illegible] |
| Date of Observation | 1 March 2012 | | Person in Charge | [illegible] |
| Address | [illegible] | | | |
| Coordinate System | UTM 47N (WGS 1984) | | | |
| Coordinate (m) | X | [illegible] | MSL Height (m) | [illegible] |
| | Y | [illegible] | Ellipsoid Height (m) | [illegible] |
| Coordinate | Lat | [illegible] | | |
| | Lon | [illegible] | | |
| Type of GPS Receiver | [illegible] | | Analysis Software | [illegible] |
| Rate of Observation | 1 Second | | Positive angle of elevation More than | 15 degree |
| Instrument Height | [illegible] m | | Duration | [illegible] |
| Horizontal Location | | | Photo of Observation | |

Description of GPS Base Station (GCP)

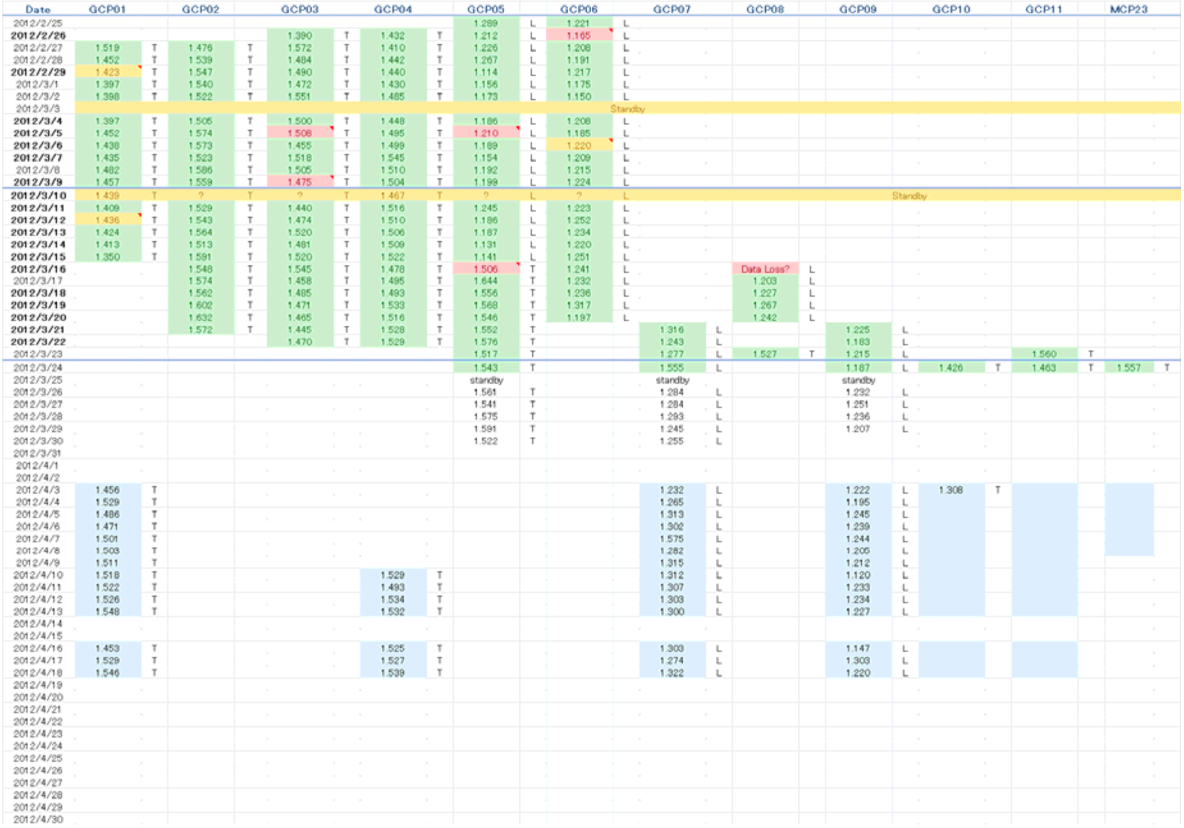
Observation

GPS Base Station (GCP)

Figure 2.2.5 GPS Base Station (GCP) Distribution Map

In synchronization with the airborne laser scanning, GPS observation was carried out at the ground control points that had been set up beforehand. The observation interval was set at one second and the elevation mask was set at 15 degrees.

Figure 2.2.6 Implementation of Ground GPS Observation (March 20, GCP-03)



| Date | GCP01 | | GCP02 | | GCP03 | | GCP04 | | GCP05 | | GCP06 | | GCP07 | | GCP08 | | GCP09 | | GCP10 | | GCP11 | | MCP23 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2012/2/25 | | | | | | | | | 1.289 | L | 1.221 | L | | | | | | | | | | | | |
| 2012/2/26 | | | | | 1.390 | T | 1.432 | T | 1.212 | L | 1.165 | L | | | | | | | | | | | | |
| 2012/2/27 | 1.519 | T | 1.476 | T | 1.572 | T | 1.410 | T | 1.226 | L | 1.208 | L | | | | | | | | | | | | |
| 2012/2/28 | 1.452 | T | 1.539 | T | 1.484 | T | 1.442 | T | 1.267 | L | 1.191 | L | | | | | | | | | | | | |
| 2012/2/29 | 1.423 | T | 1.547 | T | 1.490 | T | 1.440 | T | 1.114 | L | 1.217 | L | | | | | | | | | | | | |
| 2012/3/1 | 1.397 | T | 1.540 | T | 1.472 | T | 1.430 | T | 1.156 | L | 1.175 | L | | | | | | | | | | | | |
| 2012/3/2 | 1.398 | T | 1.522 | T | 1.551 | T | 1.485 | T | 1.173 | L | 1.150 | L | | | | | | | | | | | | |
| 2012/3/3 | Standby | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/3/4 | 1.397 | T | 1.505 | T | 1.500 | T | 1.448 | T | 1.186 | L | 1.208 | L | | | | | | | | | | | | |
| 2012/3/5 | 1.452 | T | 1.574 | T | 1.508 | T | 1.495 | T | 1.210 | L | 1.185 | L | | | | | | | | | | | | |
| 2012/3/6 | 1.438 | T | 1.573 | T | 1.455 | T | 1.499 | T | 1.189 | L | 1.220 | L | | | | | | | | | | | | |
| 2012/3/7 | 1.435 | T | 1.523 | T | 1.518 | T | 1.545 | T | 1.154 | L | 1.209 | L | | | | | | | | | | | | |
| 2012/3/8 | 1.482 | T | 1.586 | T | 1.505 | T | 1.510 | T | 1.192 | L | 1.215 | L | | | | | | | | | | | | |
| 2012/3/9 | 1.457 | T | 1.559 | T | 1.475 | T | 1.504 | T | 1.199 | L | 1.224 | L | | | | | | | | | | | | |
| 2012/3/10 | 1.439 | T | ? | T | ? | T | 1.467 | T | ? | L | ? | L | Standby | | | | | | | | | | | |
| 2012/3/11 | 1.409 | T | 1.529 | T | 1.440 | T | 1.516 | T | 1.245 | L | 1.223 | L | | | | | | | | | | | | |
| 2012/3/12 | 1.436 | T | 1.543 | T | 1.474 | T | 1.510 | T | 1.186 | L | 1.252 | L | | | | | | | | | | | | |
| 2012/3/13 | 1.424 | T | 1.564 | T | 1.520 | T | 1.506 | T | 1.187 | L | 1.234 | L | | | | | | | | | | | | |
| 2012/3/14 | 1.413 | T | 1.513 | T | 1.481 | T | 1.509 | T | 1.131 | L | 1.220 | L | | | | | | | | | | | | |
| 2012/3/15 | 1.350 | T | 1.591 | T | 1.520 | T | 1.522 | T | 1.141 | L | 1.251 | L | | | | | | | | | | | | |
| 2012/3/16 | | | 1.548 | T | 1.545 | T | 1.478 | T | 1.506 | T | 1.241 | L | | | Data Loss? | L | | | | | | | | |
| 2012/3/17 | | | 1.574 | T | 1.458 | T | 1.495 | T | 1.644 | T | 1.232 | L | | | 1.203 | L | | | | | | | | |
| 2012/3/18 | | | 1.562 | T | 1.485 | T | 1.493 | T | 1.556 | T | 1.236 | L | | | 1.227 | L | | | | | | | | |
| 2012/3/19 | | | 1.602 | T | 1.471 | T | 1.533 | T | 1.568 | T | 1.317 | L | | | 1.267 | L | | | | | | | | |
| 2012/3/20 | | | 1.632 | T | 1.465 | T | 1.516 | T | 1.546 | T | 1.197 | L | | | 1.242 | L | | | | | | | | |
| 2012/3/21 | | | 1.572 | T | 1.445 | T | 1.528 | T | 1.552 | T | | | 1.316 | L | | | 1.225 | L | | | | | | |
| 2012/3/22 | | | | | 1.470 | T | 1.529 | T | 1.576 | T | | | 1.243 | L | | | 1.183 | L | | | | | | |
| 2012/3/23 | | | | | | | | | 1.517 | T | | | 1.277 | L | 1.527 | T | 1.215 | L | | | 1.560 | T | | |
| 2012/3/24 | | | | | | | | | 1.543 | T | | | 1.555 | L | | | 1.187 | L | 1.426 | T | 1.463 | T | 1.557 | T |
| 2012/3/25 | | | | | | | | | standby | | | | standby | | | | standby | | | | | | | |
| 2012/3/26 | | | | | | | | | 1.561 | T | | | 1.284 | L | | | 1.232 | L | | | | | | |
| 2012/3/27 | | | | | | | | | 1.541 | T | | | 1.284 | L | | | 1.251 | L | | | | | | |
| 2012/3/28 | | | | | | | | | 1.575 | T | | | 1.293 | L | | | 1.236 | L | | | | | | |
| 2012/3/29 | | | | | | | | | 1.591 | T | | | 1.245 | L | | | 1.207 | L | | | | | | |
| 2012/3/30 | | | | | | | | | 1.522 | T | | | 1.255 | L | | | | | | | | | | |
| 2012/3/31 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/3 | 1.456 | T | | | | | | | | | | | 1.232 | L | | | 1.222 | L | 1.308 | T | | | | |
| 2012/4/4 | 1.529 | T | | | | | | | | | | | 1.265 | L | | | 1.195 | L | | | | | | |
| 2012/4/5 | 1.486 | T | | | | | | | | | | | 1.313 | L | | | 1.245 | L | | | | | | |
| 2012/4/6 | 1.471 | T | | | | | | | | | | | 1.302 | L | | | 1.239 | L | | | | | | |
| 2012/4/7 | 1.501 | T | | | | | | | | | | | 1.575 | L | | | 1.244 | L | | | | | | |
| 2012/4/8 | 1.503 | T | | | | | | | | | | | 1.282 | L | | | 1.205 | L | | | | | | |
| 2012/4/9 | 1.511 | T | | | | | | | | | | | 1.315 | L | | | 1.212 | L | | | | | | |
| 2012/4/10 | 1.518 | T | | | | | 1.529 | T | | | | | 1.312 | L | | | 1.120 | L | | | | | | |
| 2012/4/11 | 1.522 | T | | | | | 1.493 | T | | | | | 1.307 | L | | | 1.233 | L | | | | | | |
| 2012/4/12 | 1.526 | T | | | | | 1.534 | T | | | | | 1.303 | L | | | 1.234 | L | | | | | | |
| 2012/4/13 | 1.548 | T | | | | | 1.532 | T | | | | | 1.300 | L | | | 1.227 | L | | | | | | |
| 2012/4/14 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/15 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/16 | 1.453 | T | | | | | 1.525 | T | | | | | 1.303 | L | | | 1.147 | L | | | | | | |
| 2012/4/17 | 1.529 | T | | | | | 1.527 | T | | | | | 1.274 | L | | | 1.303 | L | | | | | | |
| 2012/4/18 | 1.546 | T | | | | | 1.539 | T | | | | | 1.322 | L | | | 1.220 | L | | | | | | |
| 2012/4/19 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/20 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/21 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/22 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/23 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/24 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/25 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/26 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/27 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/28 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/29 | | | | | | | | | | | | | | | | | | | | | | | | |
| 2012/4/30 | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 2.2.7 Implementation Status of Ground GPS Observation

### 2-2-4 Installation/Observation of Control Points for Correction

As confirmation with the accurate height information at the site is important in the airborne laser scanning survey, in accordance with the Japanese survey work regulations, 989 control points for correction (FCP) were planned with one point for every 25km$^2$ (5km x 5km).

Number of control points for correction = (Area of work area (km$^2$)/25) + 1
24,700km$^2$/25+1 = 989 points

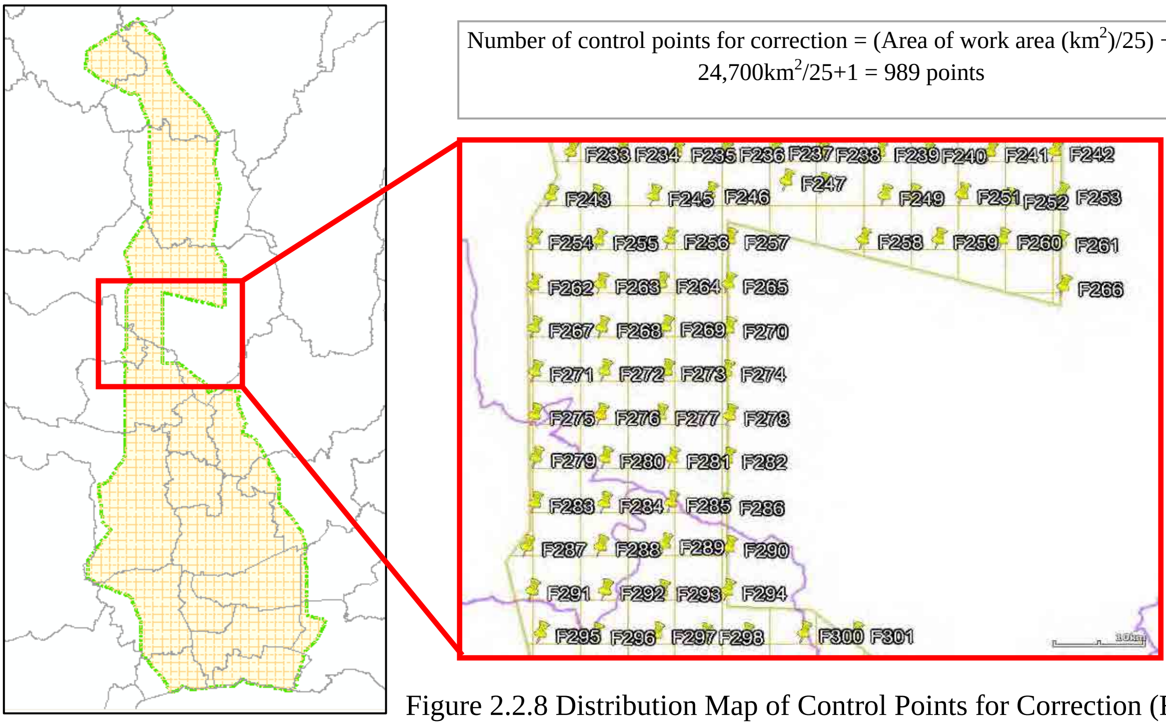


Figure 2.2.8 Distribution Map of Control Points for Correction (FCP)

It was decided that the work should be performed in accordance with the Japanese survey work regulations, which provide the survey and accuracy standards of control points for correction. The standards for survey coordinates were determined based on the existing data held by the RTSD.

The RTSD owns reference points and benchmarks (BM). However, since it is impossible to directly observe the control points for correction (FCP) that have been set up for every 25km$^2$ with the current reference points and benchmarks alone, because the area to be covered in this project is so wide, it was decided to set up a primary control network with the baseline length of about 30km.

For the primary control network, 45 new points, which consist of the abovementioned 11 GPS base stations (GCP) for the airborne laser scanning and 34 master control points (MCP) providing the basis for the calculation of the control points for correction, were installed. The observation was carried out for no less than two hours in the static GPS method.

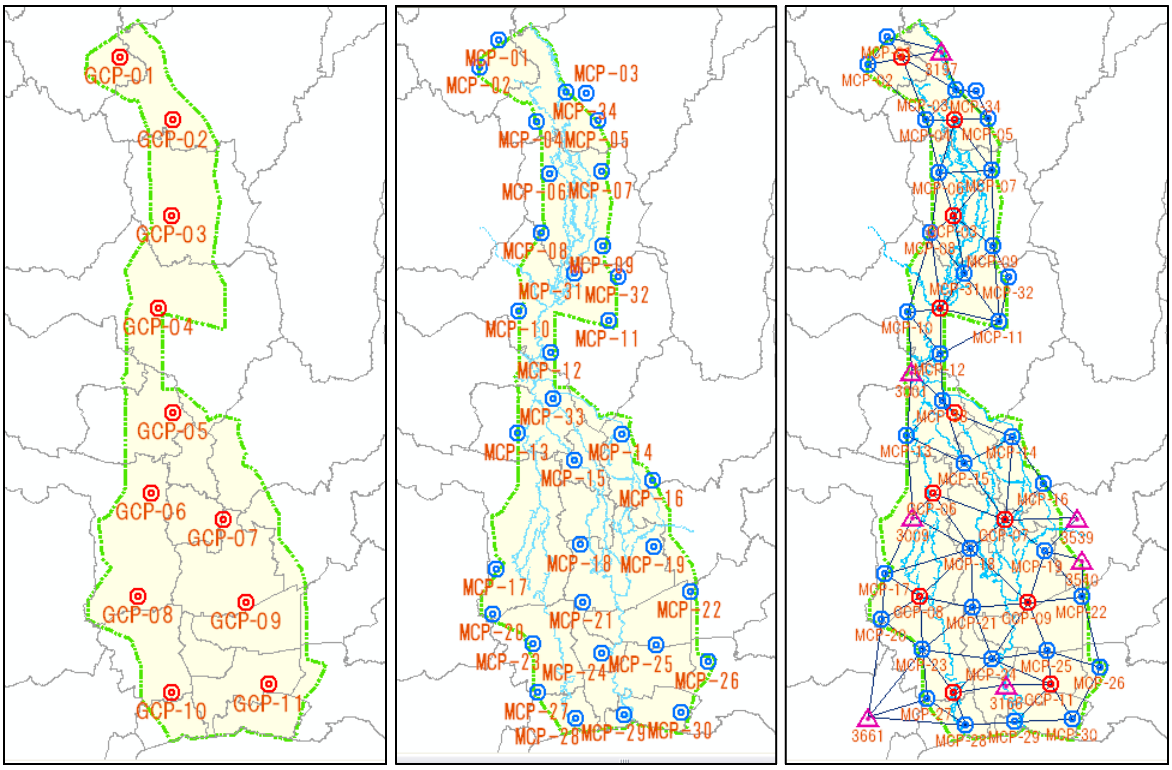


Figure 2.2.9

GPS Base Station (GCP) Distribution Map

Master Control Point (MCP) Distribution Map

Network Mean Planning Map

Description of GPS Base-Station

| | | | | |
|---|---|---|---|---|
| Point Name | MCP-15 | | Operator | [illegible] |
| Date of Observation | 1 March 2012 | | Person in Charge | [illegible] |
| Address | [illegible] | | | |
| Coordinate System | UTM 47N (WGS 1984) | | | |
| Coordinate (m) | X | [illegible] | MSL Height (m) | [illegible] |
| | Y | [illegible] | Ellipsoid Height (m) | [illegible] |
| Coordinate | Lat | [illegible] | | |
| | Lon | [illegible] | | |
| Type of GPS Receiver | [illegible] | | Analysis Software | [illegible] |
| Rate of Observation | 15 Second | | Positive angle of elevation More than | 15 degree |
| Instrument Height | [illegible] m | | Duration | [illegible] |
| Horizontal Location | | | Photo of Observation | |

Figure 2.2.10 Description of Master Control Points(MCP)

Observation

Master Control Point (MCP)

With respect to the existing data that provides the standards, direct leveling was carried out for 82.1km from seven reference points of the RTSD (3001, 3009, 3166, 3197, 3539, 3540 and 3661) and 20 benchmarks of the RTSD in the vicinity of the GPS base stations (GCP) and master control points (MCP) to indicate the elevation.

Using this existing data and the result of GPS observation, the primary control network was calculated to determine the data of the 45 new points.

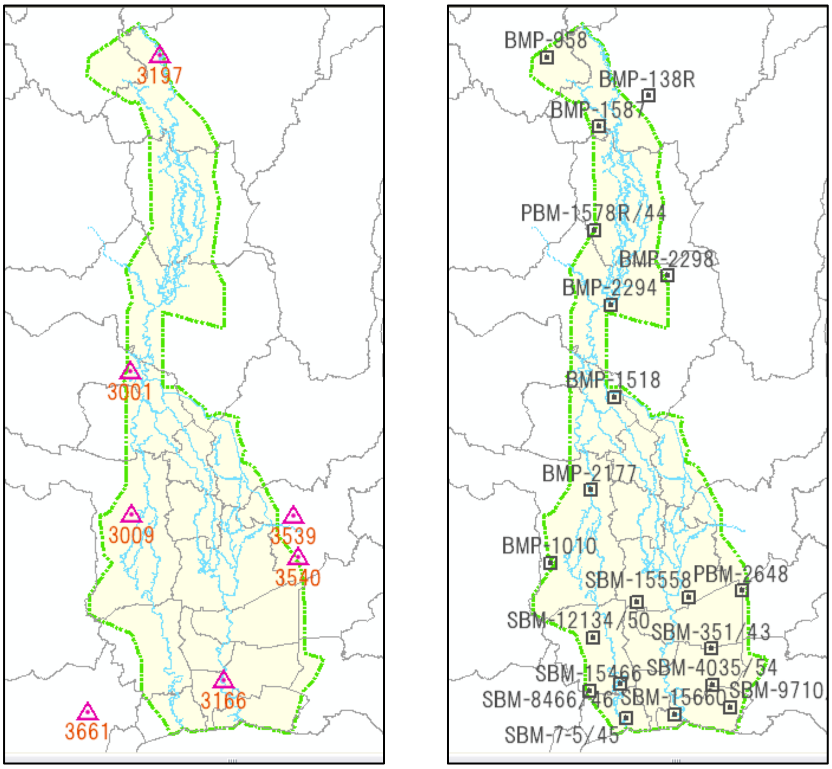


Figure 2.2.11

Existing reference point that was utilized    Existing benchmark that was utilized

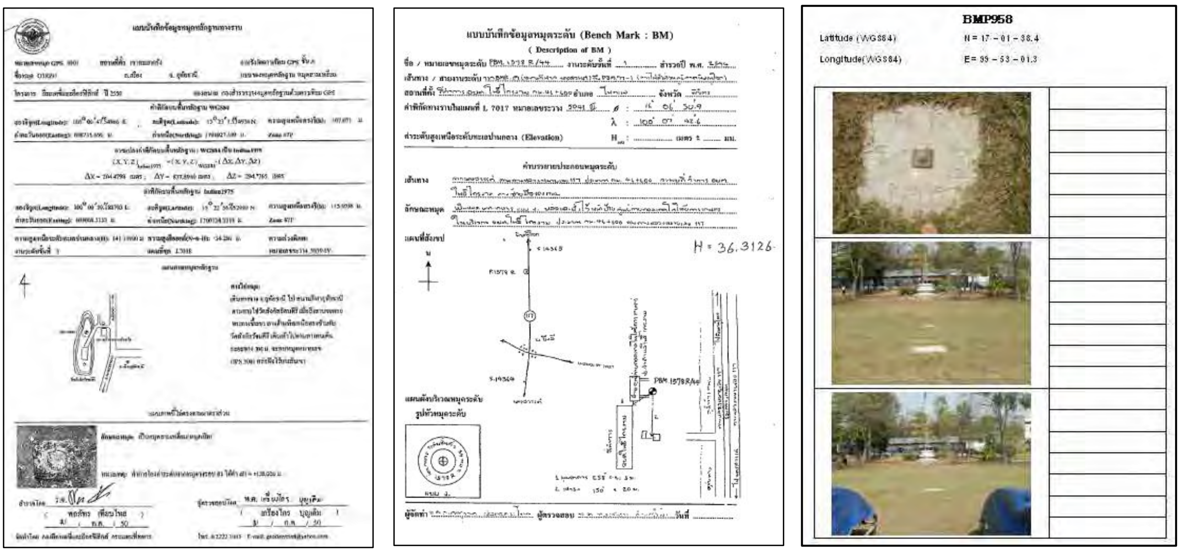


Figure 2.2.12

Description of existing reference point

Description of existing benchmark

Reconnaissance result (benchmark)

The data of the 45 new points is described in the following table.

Table 2.2.3 List of New Point Coordinates (3001 – MCP-12)

| Point Name | UTM 47N | | Ellipsoide WGS84(H) | Mean sea level (E) | Geographic | |
|---|---|---|---|---|---|---|
| | Easting | Northing | | | Longitude | Latitude |
| 3001 | 608735.656 | 1701027.309 | 106.749 | 141.209 | 100°00'47.54965"E | 15°23'01.53492"N |
| 3009 | 609756.416 | 1618019.501 | -24.186 | 9.739 | 100°01'08.96107"E | 14°38'00.03885"N |
| 3166 | 662970.524 | 1521727.911 | -17.740 | 13.733 | 100°30'26.67779"E | 13°45'37.11119"N |
| 3197 | 625647.785 | 1885006.714 | 16.553 | 52.570 | 100°10'50.29812"E | 17°02'45.05974"N |
| 3539 | 703857.161 | 1617213.927 | -6.390 | 24.689 | 100°53'33.41494"E | 14°37'14.17511"N |
| 3540 | 706076.516 | 1593113.651 | -21.086 | 9.618 | 100°54'40.82906"E | 14°24'09.55002"N |
| 3661 | 583851.988 | 1503378.501 | -26.125 | 6.775 | 99°46'30.44390"E | 13°35'52.06151"N |
| GCP-01 | 603270.288 | 1880980.222 | 8.451 | 45.305 | 99°58'12.74477"E | 17°00'38.05432"N |
| GCP-02 | 633205.499 | 1844725.093 | 5.545 | 40.843 | 100°14'57.29212"E | 16°40'52.96642"N |
| GCP-03 | 632687.328 | 1789965.022 | -3.739 | 31.187 | 100°14'28.46958"E | 16°11'11.37319"N |
| GCP-04 | 625381.849 | 1737350.285 | -7.308 | *27.006* | 100°10'12.53995"E | 15°42'40.74934"N |
| GCP-05 | 633151.066 | 1677426.585 | -16.042 | 17.605 | 100°14'21.93020"E | 15°10'09.42232"N |
| GCP-06 | 620973.377 | 1631400.156 | -24.737 | *8.876* | 100°07'26.10051"E | 14°45'13.76105"N |
| GCP-07 | 662267.966 | 1615861.343 | -25.951 | 6.365 | 100°30'23.48687"E | 14°36'40.30012"N |
| GCP-08 | 613378.669 | 1572135.952 | -30.088 | 3.290 | 100°03'03.02411"E | 14°13'06.24248"N |
| GCP-09 | 675474.543 | 1568812.223 | -27.310 | *4.189* | 100°37'33.67197"E | 14°11'06.50082"N |
| GCP-10 | 633080.699 | 1517155.462 | -30.064 | *2.072* | 100°13'50.79482"E | 13°43'13.83424"N |
| GCP-11 | 688250.253 | 1521377.685 | -29.657 | *0.986* | 100°44'28.11428"E | 13°45'20.16805"N |
| MCP-01 | 594799.580 | 1892749.977 | 12.588 | 49.663 | 99°53'28.09674"E | 17°07'02.33066"N |
| MCP-02 | 583945.575 | 1876871.822 | 10.971 | *47.980* | 99°47'18.64748"E | 16°58'27.19369"N |
| MCP-03 | 634438.948 | 1862086.232 | 10.442 | 45.914 | 100°15'42.65097"E | 16°50'17.56230"N |
| MCP-04 | 617121.725 | 1845141.558 | 6.404 | *42.301* | 100°05'54.42551"E | 16°41'09.59513"N |
| MCP-05 | 652715.658 | 1845570.663 | 6.838 | 41.418 | 100°25'56.06039"E | 16°41'16.21124"N |
| MCP-06 | 624868.006 | 1815007.972 | 0.631 | 35.986 | 100°10'10.01281"E | 16°24'47.70610"N |
| MCP-07 | 654777.083 | 1815937.034 | 1.500 | 35.712 | 100°26'58.43137"E | 16°25'11.64694"N |
| MCP-08 | 619722.695 | 1780275.137 | -0.244 | *34.827* | 100°07'10.15441"E | 16°05'58.49946"N |
| MCP-09 | 655255.002 | 1772568.113 | -0.764 | 33.134 | 100°27'04.19409"E | 16°01'40.55876"N |
| MCP-10 | 606431.128 | 1735053.110 | -4.569 | 30.097 | 99°59'35.55245"E | 15°41'29.14903"N |
| MCP-11 | 658763.694 | 1729722.941 | -3.717 | 29.562 | 100°28'52.06155"E | 15°38'25.78255"N |
| MCP-12 | 625195.050 | 1710933.064 | -8.064 | 26.023 | 100°10'01.40565"E | 15°28'21.16906"N |

*n.nnn* Is from Leveling

Table 2.2.4 List of New Point Coordinates (MCP-13 – MCP-34)

| **Point Name** | **UTM 47N** | | **Ellipsoide WGS84(H)** | **Mean sea level (E)** | **Geographic** | |
|---|---|---|---|---|---|---|
| | **Easting** | **Northing** | | | **Longitude** | **Latitude** |
| MCP-13 | 606293.329 | 1663776.380 | -17.731 | 16.536 | 99°59'19.97021"E | 15°02'49.64964"N |
| MCP-14 | 666260.369 | 1663400.549 | -20.363 | 12.406 | 100°32'47.86558"E | 15°02'26.21138"N |
| MCP-15 | 639033.487 | 1648469.468 | -21.504 | 11.729 | 100°17'33.33669"E | 14°54'26.05093"N |
| MCP-16 | 684488.297 | 1636664.654 | -0.590 | 31.405 | 100°42'51.21523"E | 14°47'52.00319"N |
| MCP-17 | 593369.596 | 1584918.181 | -27.495 | *6.606* | 99°51'57.04522"E | 14°20'04.93698"N |
| MCP-18 | 642198.708 | 1599178.814 | -28.451 | 4.237 | 100°19'09.62463"E | 14°27'41.49798"N |
| MCP-19 | 685402.468 | 1598151.144 | -24.340 | 7.224 | 100°43'12.02092"E | 14°26'58.74948"N |
| MCP-20 | 591508.318 | 1559026.076 | -23.464 | 10.372 | 99°50'51.77229"E | 14°06'02.45070"N |
| MCP-21 | 643638.915 | 1565829.938 | -26.269 | *6.075* | 100°19'51.32458"E | 14°09'36.00454"N |
| MCP-22 | 706532.888 | 1572244.300 | -25.762 | *4.743* | 100°54'50.30845"E | 14°12'50.50343"N |
| MCP-23 | 614957.080 | 1541831.771 | -28.546 | *4.384* | 100°03'51.11410"E | 13°56'39.75029"N |
| MCP-24 | 654958.687 | 1535910.553 | -16.733 | 15.114 | 100°26'02.78071"E | 13°53'20.22609"N |
| MCP-25 | 686285.591 | 1540864.430 | -28.582 | *2.338* | 100°43'27.39075"E | 13°55'54.66381"N |
| MCP-26 | 716449.703 | 1531061.735 | -27.713 | 1.984 | 101°00'09.37132"E | 13°50'28.07925"N |
| MCP-27 | 618004.314 | 1513125.283 | -27.042 | *5.316* | 100°05'28.30424"E | 13°41'05.02663"N |
| MCP-28 | 639714.229 | 1498376.092 | -30.341 | *1.320* | 100°17'28.29149"E | 13°33'01.55406"N |
| MCP-29 | 667588.503 | 1500445.449 | -29.305 | *1.706* | 100°32'55.88499"E | 13°34'03.62370"N |
| MCP-30 | 700881.918 | 1501797.228 | -29.696 | *0.338* | 100°51'23.56444"E | 13°34'40.05022"N |
| MCP-31 | 639173.105 | 1757039.284 | -0.473 | 33.802 | 100°17'59.89917"E | 15°53'18.76488"N |
| MCP-32 | 664620.161 | 1755020.538 | 0.816 | *34.165* | 100°32'14.89047"E | 15°52'07.47321"N |
| MCP-33 | 626931.700 | 1684113.688 | -18.725 | *15.146* | 100°10'54.76191"E | 15°13'48.14559"N |
| MCP-34 | 646128.623 | 1861830.081 | 8.107 | *43.159* | 100°22'17.50260"E | 16°50'06.69673"N |

*n.nnn* Is from Leveling

In order to determine the location of the 989 control points for correction (FCP), regarding the newly established 45 points (GCP/MCP) as known points, a more detailed network of control points for correction was organized.

The observation for the control points for correction (FCP) was also carried out for no less than one hour in the static GPS method. As a general rule, the plans called for the distribution of points in a grid as shown in the distribution map above, but it was decided that this should be flexibly modified, considering the condition of topography and objects on the ground as well as the availability of public land for observation.

The observation result of the control points for correction is shown below.

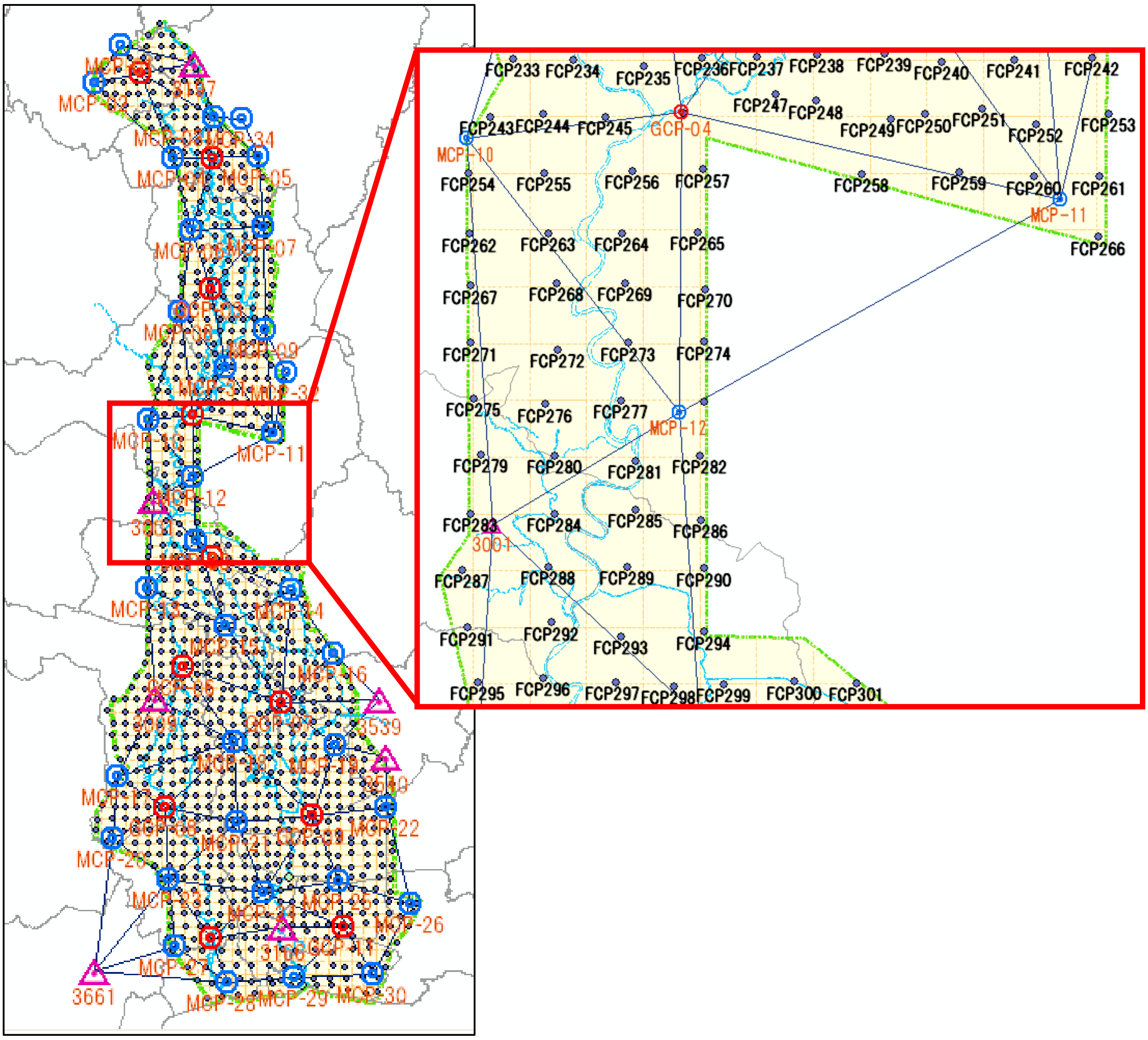


Figure 2.2.13 Control Points for Correction (FCP) Observation Result

Also, it was confirmed that coordinate values have been calculated and determined within the limitation for all the control points for correction with respect to the loop closure and network adjustment.

The data of the 989 new points (extracted) is as follows.

Table 2.2.5 List of New FCP Coordinates

| Point Name | Observation Date | Coordinate (m) | | Height (m) | | Coordinate | |
|---|---|---|---|---|---|---|---|
| | | E | N | Ellip. H | MSL H | Latitude | Longitude |
| F001 | 2012/4/2 | 611,589.671 | 1,901,318.064 | 14.718 | 51.374 | 17° 11’ 38.38278″ N | 100° 02’ 57.78966″ E |
| F002 | 2012/4/2 | 606,990.366 | 1,896,815.840 | 11.912 | 48.720 | 17° 09’ 12.68853″ N | 100° 00’ 21.31116″ E |
| F003 | 2012/4/2 | 612,226.021 | 1,896,885.353 | 10.809 | 47.446 | 17° 09’ 14.04647″ N | 100° 03’ 18.51417″ E |
| F004 | 2012/3/8 | 616,756.491 | 1,896,964.462 | 15.166 | 51.639 | 17° 09’ 15.80347″ N | 100° 05’ 51.85203″ E |
| F005 | 2012/3/8 | 598,806.335 | 1,891,969.424 | 11.101 | 48.106 | 17° 06’ 36.32376″ N | 99° 55’ 43.54997″ E |
| F006 | 2012/4/2 | 605,764.829 | 1,891,923.328 | 10.933 | 47.775 | 17° 06’ 33.70605″ N | 99° 59’ 38.98849″ E |
| F007 | 2012/4/2 | 612,034.196 | 1,891,728.441 | 9.421 | 46.053 | 17° 06’ 26.29284″ N | 100° 03’ 11.07735″ E |
| F008 | 2012/4/7 | 616,771.660 | 1,891,883.915 | 10.373 | 46.821 | 17° 06’ 30.50026″ N | 100° 05’ 51.39503″ E |
| F009 | 2012/4/2 | 621,930.079 | 1,891,932.184 | 13.181 | 49.414 | 17° 06’ 31.10389″ N | 100° 08’ 45.93368″ E |
| F010 | 2012/3/8 | 592,067.285 | 1,887,154.984 | 13.157 | 50.239 | 17° 04’ 00.67996″ N | 99° 51’ 54.80105″ E |
| F011 | 2012/3/8 | 599,177.018 | 1,886,989.885 | 12.712 | 49.695 | 17° 03’ 54.24307″ N | 99° 55’ 55.28705″ E |
| F012 | 2012/3/8 | 604,814.378 | 1,887,026.018 | 9.590 | 46.444 | 17° 03’ 54.51815″ N | 99° 59’ 05.99246″ E |
| F013 | 2012/3/8 | 610,574.840 | 1,886,875.181 | 9.424 | 46.087 | 17° 03’ 48.63877″ N | 100° 02’ 20.82571″ E |
| F014 | 2012/3/8 | 616,664.242 | 1,887,577.236 | 8.027 | 44.451 | 17° 04’ 10.39742″ N | 100° 05’ 46.94120″ E |
| F015 | 2012/3/8 | 624,403.707 | 1,887,328.635 | 12.753 | 48.842 | 17° 04’ 00.84765″ N | 100° 10’ 08.69108″ E |
| F016 | 2012/3/8 | 586,986.020 | 1,882,174.518 | 12.800 | 49.863 | 17° 01’ 19.33369″ N | 99° 49’ 02.20139″ E |
| F017 | 2012/3/8 | 593,977.017 | 1,882,044.765 | 9.744 | 46.759 | 17° 01’ 14.12360″ N | 99° 52’ 58.62429″ E |
| F018 | 2012/4/3 | 600,228.665 | 1,881,704.018 | 10.285 | 47.210 | 17° 01’ 02.08825″ N | 99° 56’ 30.00086″ E |
| F019 | 2012/3/10 | 606,225.453 | 1,881,522.558 | 8.576 | 45.354 | 17° 00’ 55.21731″ N | 99° 59’ 52.77517″ E |
| F020 | 2012/3/10 | 611,894.790 | 1,882,049.058 | 8.219 | 44.795 | 17° 01’ 11.38256″ N | 100° 03’ 04.59719″ E |
| F021 | 2012/4/2 | 617,173.365 | 1,881,402.141 | 7.571 | 43.927 | 17° 00’ 49.39003″ N | 100° 06’ 02.98702″ E |
| F022 | 2012/4/2 | 621,762.183 | 1,881,792.223 | 10.780 | 46.944 | 17° 01’ 01.22578″ N | 100° 08’ 38.24304″ E |
| F023 | 2012/3/7 | 626,678.064 | 1,882,377.415 | 11.953 | 47.905 | 17° 01’ 19.31162″ N | 100° 11’ 24.60281″ E |
| F024 | 2012/4/3 | 583,845.558 | 1,876,722.283 | 11.215 | 48.221 | 16° 58’ 22.34085″ N | 99° 47’ 15.24530″ E |
| F025 | 2012/4/3 | 588,471.059 | 1,876,896.213 | 11.578 | 48.576 | 16° 58’ 27.37971″ N | 99° 49’ 51.67029″ E |
| F026 | 2012/3/8 | 591,655.951 | 1,877,051.174 | 8.806 | 45.784 | 16° 58’ 31.97521″ N | 99° 51’ 39.38251″ E |
| F027 | | | | | | | |
| F028 | | | | | | | |
| F029 | | | | | | | |
| F030 | | | | | | | |
| F031 | | | | | | | |
| F032 | | | | | | | |
| F033 | | | | | | | |
| F034 | | | | | | | |
| F035 | | | | | | | |
| F036 | | | | | | | |
| F037 | | | | | | | |
| F038 | | | | | | | |
| F039 | | | | | | | |
| F040 | | | | | | | |
| F041 | | | | | | | |
| F042 | | | | | | | |
| F043 | | | | | | | |
| F044 | | | | | | | |
| F045 | | | | | | | |
| F046 | | | | | | | |
| F047 | | | | | | | |
| F048 | | | | | | | |
| F049 | | | | | | | |
| F050 | | | | | | | |
| F051 | | | | | | | |

| Point Name | Observation Date | Coordinate (m) | | Height (m) | | Coordinate | |
|---|---|---|---|---|---|---|---|
| | | E | N | Ellip. H | MSL H | Latitude | Longitude |
| F970 | 2012/4/19 | 639,030.631 | 1,499,258.686 | −30.740 | 0.952 | 13° 33’ 30.39452″ N | 100° 17’ 05.70655″ E |
| F971 | 2012/4/20 | 645,240.877 | 1,499,398.904 | −30.877 | 0.678 | 13° 33’ 33.87120″ N | 100° 20’ 32.31486″ E |
| F972 | 2012/4/20 | 650,340.392 | 1,498,319.531 | −29.748 | 1.668 | 13° 32’ 57.81774″ N | 100° 23’ 21.74223″ E |
| F973 | 2012/4/20 | 657,419.725 | 1,499,420.373 | −29.784 | 1.484 | 13° 33’ 32.30125″ N | 100° 27’ 17.43323″ E |
| F974 | 2012/4/20 | 662,695.849 | 1,498,868.234 | −25.720 | 5.404 | 13° 33’ 13.29462″ N | 100° 30’ 12.81746″ E |
| F975 | 2012/4/25 | 670,082.862 | 1,500,440.431 | −29.999 | 0.942 | 13° 34’ 02.94172″ N | 100° 34’ 18.85252″ E |
| F976 | 2012/4/25 | 676,310.670 | 1,499,515.463 | −30.010 | 0.748 | 13° 33’ 31.51565″ N | 100° 37’ 45.79540″ E |
| F977 | 2012/4/25 | 683,060.368 | 1,499,645.832 | −29.829 | 0.738 | 13° 33’ 34.26491″ N | 100° 41’ 30.31759″ E |
| F978 | 2012/4/25 | 689,792.023 | 1,499,686.187 | −28.438 | 1.928 | 13° 33’ 34.03334″ N | 100° 45’ 14.21275″ E |
| F979 | 2012/4/26 | 696,488.939 | 1,500,711.031 | −29.579 | 0.591 | 13° 34’ 05.78561″ N | 100° 48’ 57.18887″ E |
| F980 | 2012/4/26 | 703,579.636 | 1,499,865.122 | −28.448 | 1.488 | 13° 33’ 36.51739″ N | 100° 52’ 52.79129″ E |
| F981 | 2012/4/19 | 631,359.347 | 1,491,358.323 | −30.200 | 1.513 | 13° 29’ 14.55300″ N | 100° 12’ 49.21398″ E |
| F982 | 2012/4/19 | 637,390.106 | 1,492,469.075 | −29.545 | 2.063 | 13° 29’ 49.70981″ N | 100° 16’ 09.96323″ E |
| F983 | 2012/4/20 | 644,314.209 | 1,492,629.144 | −29.582 | 1.883 | 13° 29’ 53.72424″ N | 100° 20’ 00.26335″ E |
| F984 | 2012/4/20 | 651,710.907 | 1,493,591.954 | −26.970 | 4.342 | 13° 30’ 23.71537″ N | 100° 24’ 06.42878″ E |
| F985 | 2012/4/23 | 658,286.264 | 1,493,697.748 | −29.960 | 1.200 | 13° 30’ 25.90864″ N | 100° 27’ 45.11951″ E |
| F985_1 | 2012/4/23 | 659,134.261 | 1,497,688.911 | −29.972 | 1.226 | 13° 32’ 35.62270″ N | 100° 28’ 14.11703″ E |
| F986 | 2012/4/25 | 666,493.506 | 1,497,208.434 | −26.996 | 4.000 | 13° 32’ 18.51471″ N | 100° 32’ 18.78463″ E |
| F987 | | | | | | | |
| F988 | 2012/4/25 | 677,704.606 | 1,496,697.628 | −29.657 | 1.028 | 13° 31’ 59.52259″ N | 100° 38’ 31.52843″ E |
| F989 | 2012/4/25 | 683,655.414 | 1,496,757.162 | −29.222 | 1.300 | 13° 32’ 00.13902″ N | 100° 41’ 49.44156″ E |
| F990 | 2012/4/25 | 690,290.355 | 1,495,155.887 | −29.174 | 1.148 | 13° 31’ 06.51445″ N | 100° 45’ 29.70355″ E |
| F991 | 2012/4/25 | 698,014.569 | 1,493,790.095 | −28.580 | 1.512 | 13° 30’ 20.23737″ N | 100° 49’ 46.20739″ E |
| F992 | 2012/4/25 | 702,841.330 | 1,493,903.051 | −29.157 | 0.782 | 13° 30’ 22.72665″ N | 100° 52’ 26.72007″ E |

### 2-2-5 Verification of Control Points for Correction

In the northern and central regions, areas where only a few primary control points have a height indication were selected to verify the accuracy of the height of control points for correction (FCP). The southern region was excluded, because many of the primary control points in this area have a height indication. With respect to the six locations in the northern region and two locations in the central regions as indicated in the figure below, elevation obtained by direct leveling was compared with the GPS elevation. As it turned out that the elevation difference was no more than 10cm for all the points, it was determined that there was no problem in the accuracy of the control points for correction. ( ✚ Location where check survey was performed)

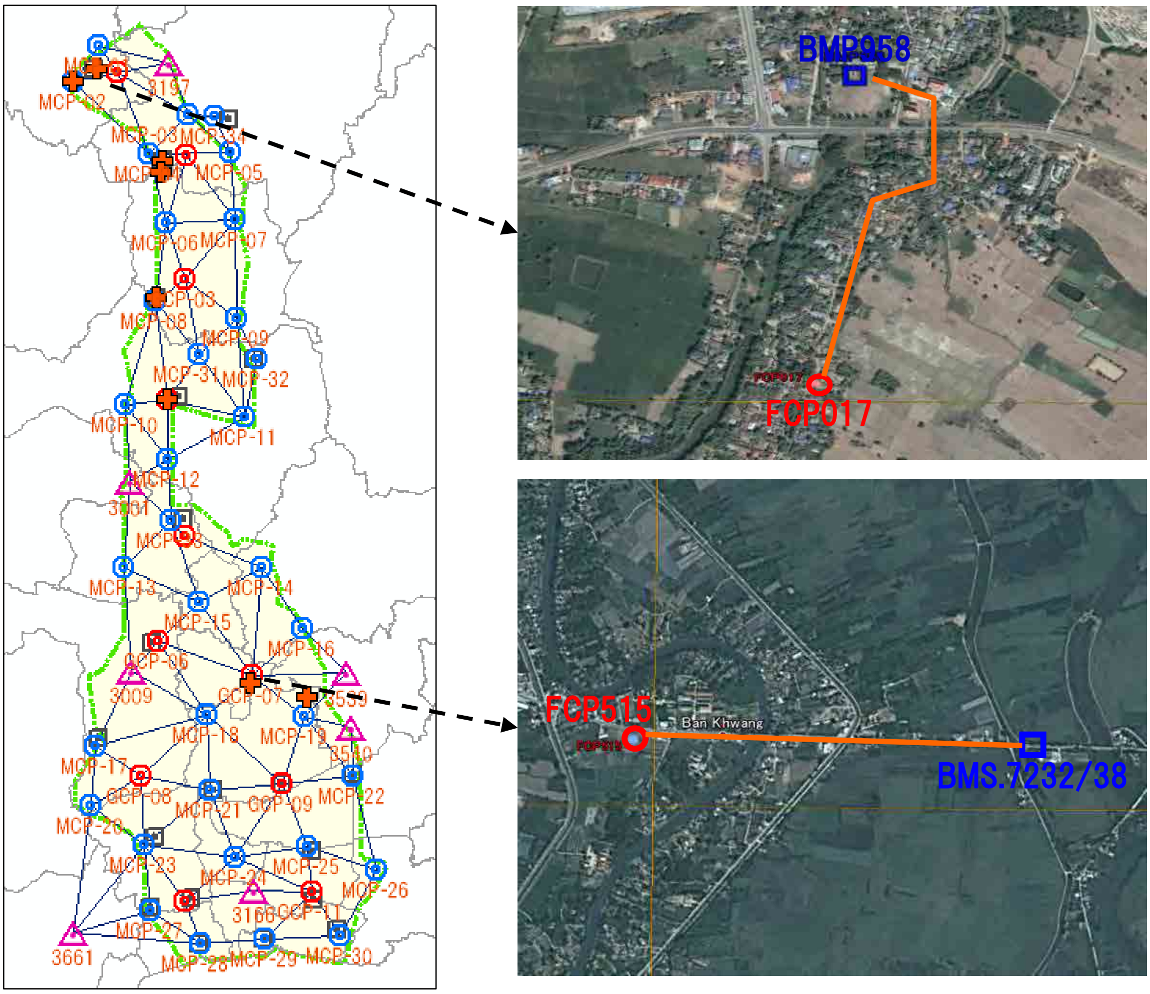


Figure 2.2.14 GCP and routes of leveling for height verification

Table 2.2.6 Results of the verification in heights

| Points to be Checked (FCP) | | | Distance (km) | Elevation (m) | | Difference (m) |
|---|---|---|---|---|---|---|
| | | | | Leveling | GPS | |
| BMP.958 | To | FCP017 | 0.8 | 46.794 | 46.759 | 0.035 |
| MCP-02 | To | FCP024 | 0.2 | 48.241 | 48.221 | 0.020 |
| BMP.1587 | To | FCP079 | 0.2 | 41.696 | 41.696 | 0.000 |
| BMP.1586 | To | FCP085 | 0.1 | 40.962 | 40.877 | 0.085 |
| BMP.1578R/44 | To | FCP162 | 0.1 | 36.108 | 36.095 | 0.013 |
| GCP-04 | To | FCP246 | 0.4 | 26.897 | 26.896 | 0.001 |
| BMS.7232A/38 | To | FCP515 | 1.6 | 8.695 | 8.682 | 0.013 |
| BMP.(RTSD) | To | FCP541 | 6.2 | 7.493 | 7.398 | 0.095 |

### 2-2-6 GPS Equipment that was used

GPS equipment used in this work is described in the following table:

Table 2.2.7 Primary Control Point (GCP/MCP)

| No. | Brand | Model | Serial No. |
|---|---|---|---|
| 1 | Trimble | 5700 | 0220264300 |
| 2 | Trimble | 5700 | 0220268118 |
| 3 | Trimble | 5700 | 0220263050 |
| 4 | Trimble | 5700 | 0220268117 |
| 5 | LEICA | GX1230 | 452768 |
| 6 | LEICA | GX1230 | 450539 |
| 7 | LEICA | GX1230 | 454467 |
| 8 | LEICA | SR530 | 4405 |
| 9 | LEICA | SR531 | 4473 |
| 10 | LEICA | SR532 | 4479 |
| 11 | LEICA | SR533 | 0727 |
| 12 | LEICA | SR534 | 0698 |

Table 2.2.8 Control Point for Correction (FCP)

| No. | Brand | Model | Serial No. |
|---|---|---|---|
| 1 | LEICA | SR530 | 4405 |
| 2 | LEICA | SR531 | 4473 |
| 3 | LEICA | SR532 | 4479 |
| 4 | LEICA | SR533 | 0727 |
| 5 | LEICA | SR534 | 0698 |
| 6 | TOPCON | HYPER GGD | 270-0181 |
| 7 | TOPCON | HYPER Ga | 457-00621 |
| 8 | TOPCON | HYPER Ga | 457-00442 |
| 9 | TOPCON | HYPER II | 689-00170 |
| 10 | TOPCON | HYPER II | 689-00154 |
| 11 | TOPCON | GB 1000 | 268-0569 |

### 2-2-7 Measurement (Airborne Laser Scanning)

Measurement should be performed with laser distance surveying unit and analysis software, and direct fixed position units that are installed in aircraft. The equipment used in this work is described in the following table.

Table 2.2.9 Equipment that was used

|  | Aircraft No. | Model | Airborne Laser Scanning Equipment | Digital Camera |
|---|---|---|---|---|
| 1 | HS-RSI | Piper PA-31-350 | Leica ALS50-II (SN58) | Leica RCD105 |
| 2 | OO-MAP | Cessna 404 | Leica ALS60 (SN6125) | Leica RCD105 |
| 3 | VH-WGS | Cessna 404 | Leica ALS50 (SN31) | ––– |
| 4 | VH-AZU | Cessna 404 | Leica ALS50-II (SN87) | ProSilica |
| Backup | OH-PNX | PiperPA-31-350 | ––– | ––– |
| Backup | ––– | ––– | Leica ALS50-II (SN68) | Leica RCD105 |

Figure 2.2.15 Aircraft and Installed Equipment

Since the laser target area of 24,700km$^2$ is very large, four aircraft and equipment were used. Measurement was carried out by referring to the airport weather information that is released every hour. One of the aircraft first took a flight to the area where the weather was expected to be favorable. If the aircraft was able to take measurements, the other three aircraft were contacted to take a flight. The northern region took priority in the measurement, which gradually proceeded to the south. In the areas under military restrictions, measurement (capturing of image data, in particular) was sometimes restricted, in which case, it was necessary to take measurements again after obtaining permission.

After the measurement was completed, the measured data would be downloaded, analyzed and processed at the airport before being transferred for data verification. In the analysis and processing, the direct georeference (GPS/IMU) was used for the analysis. Then, the flight path was verified, with the data transferred to the measurement course map, to prepare a flight record and dairy report.

The downloaded data was hand-carried to the next process to avoid the risk of hard disks being lost.

### Checking of Equipment Errors (Calibration)

Laser calibration was performed for all the airborne laser equipment to be used in this project. The measurement course map and measurement specifications for laser calibration are given below.

Figure 2.2.16 Calibration Site (HS-RSI)

Table 2.2.10 Measurement Specifications (HS-RSI)

| | |
|---|---|
| Date | March 04, 2012 |
| Calibration Area | Bangkok |
| Aircraft | HS-RSI |
| System | ALS50-II (SN58) |
| Line 1 | Altitude 500m |
| Line 2 | Altitude 500m |
| Line 3 | Altitude 500m |
| Line 4 | Altitude 500m |

Figure 2.2.17 Calibration Site (OO-MAP)

Table 2.2.11 Measurement Specifications (OO-MAP)

| | |
|---|---|
| Date | March 12, 2012 |
| Calibration Area | Bangkok |
| Aircraft | OO-MAP |
| System | ALS60 (SN6125) |
| Line 1 | Altitude 500m |
| Line 2 | Altitude 500m |
| Line 3 | Altitude 500m |
| Line 4 | Altitude 500m |
| Line 5 | Altitude 2,785m |
| Line 6 | Altitude 2,785m |

Figure 2.2.18 Calibration Site (VH-AZU)

Table 2.2.12 Measurement Specifications (VH-AZU)

| | |
|---|---|
| Date | March 30, 2012 |
| Calibration Area | Wang Noi |
| Aircraft | VH-AZU |
| System | ALS50-II (SN87) |
| Line 1 | Altitude 2,785m |
| Line 2 | Altitude 2,785m |
| Line 3 | Altitude 2,785m |
| Line 4 | Altitude 2,785m |

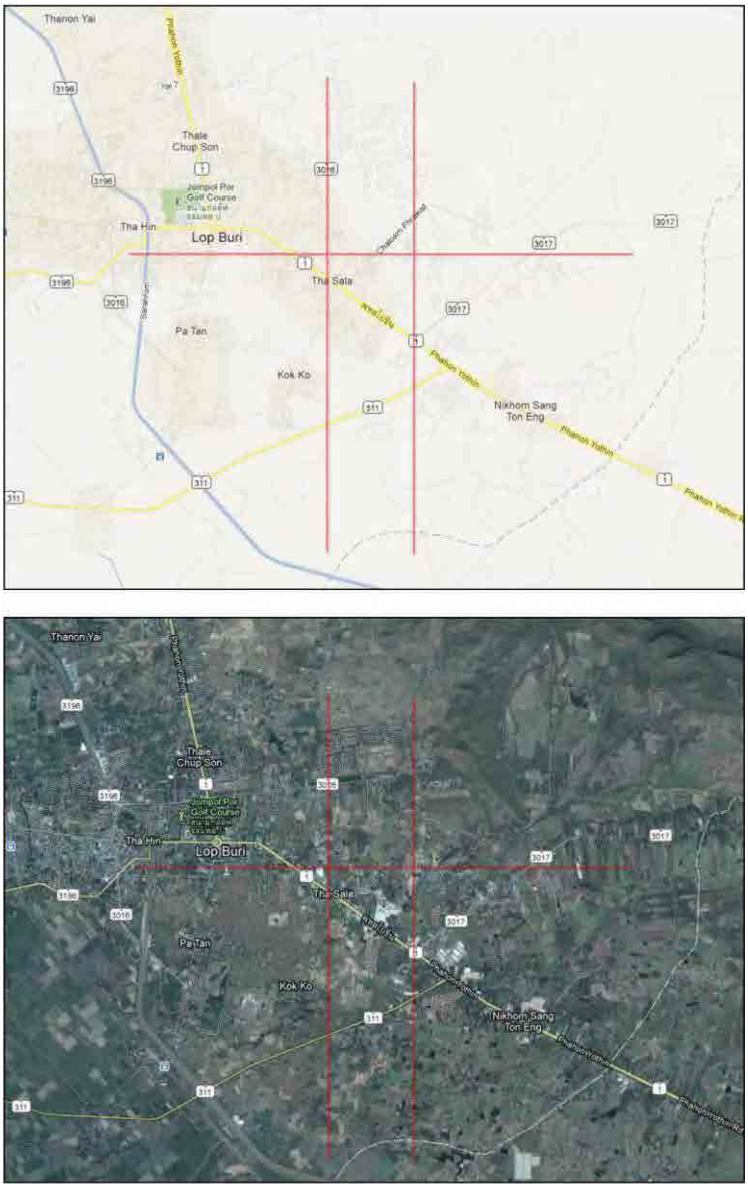


Figure 2.2.19 Calibration Site (VH-WGS)

Table 2.2.13 Measurement Specifications (VH-WGS)

| | |
|---|---|
| Date | March 14, 2012 |
| Calibration Area | Lop Buri |
| Aircraft | VH-WGS |
| System | ALS50 (SN31) |
| Line 1 | Altitude 2,785m |
| Line 2 | Altitude 2,785m |
| Line 3 | Altitude 2,785m |

Based on the result of airborne laser calibration analysis, registry files were created to be used in the 3D measurement data creation process. Of the content of the registry files of each item of the equipment, the portion related to the calibration value has been extracted and described below.

Table 2.2.14 List of Registry Files

| | | | | | |
|---|---|---|---|---|---|
| Systems | Registry Files Name | SN058_Calibrated-101006Hbgg.reg | SN6125_100609_G-OOSI_Salo_MPiA.reg | VH-AZU_ALS50-II_SN087.reg | 120413_SN031_VH-WGS.reg |
| | Aircraft | HS-RSI | OO-MAP | VH-AZU | VH-WGS |
| | System | ALS50-Ⅱ(SN58) | ALS60(SN6125) | ALS50-Ⅱ(SN87) | ALS50 (SN31) |
| Pos offsets | Roll | −0.00287341 rad | 0.00812971 rad | 0.007667894 rad | 0.011570835 rad |
| | Pitch | 0.00615184 rad | −0.00846529 rad | −0.008623409 rad | −0.001774067 rad |
| | Heading | 0.00126656 rad | 0.0019201 rad | 0.001986776 rad | 0.000384623 rad |
| Base Range Corrections | | Bank A / BankB | Bank A / BankB | Bank A / BankB | Bank A / BankB |
| | Renge 1 Correction | 3.332/3.305 | 2.531/2.531 | 2.928/2.928 | 3.150/3.150 |
| | Renge 2 Correction | 3.340/3.344 | 2.503/2.539 | 2.956/2.920 | 3.141/3.152 |
| | Renge 3 Correction | 3.358/3.324 | 2.482/2.582 | 2.977/2.877 | 3.186/3.014 |
| | Renge 4 Correction | 3.300/3.317 | 2.499/2.567 | 2.960/2.892 | 3.096/3.040 |

**Measurement Result**

Airborne laser scanning started on February 29, 2012. A measurement course map, an example of the daily report describing the work status of aircraft and a list of airborne laser scanning results are given below. The laser target area was divided into six blocks from the north for the management of measurement.

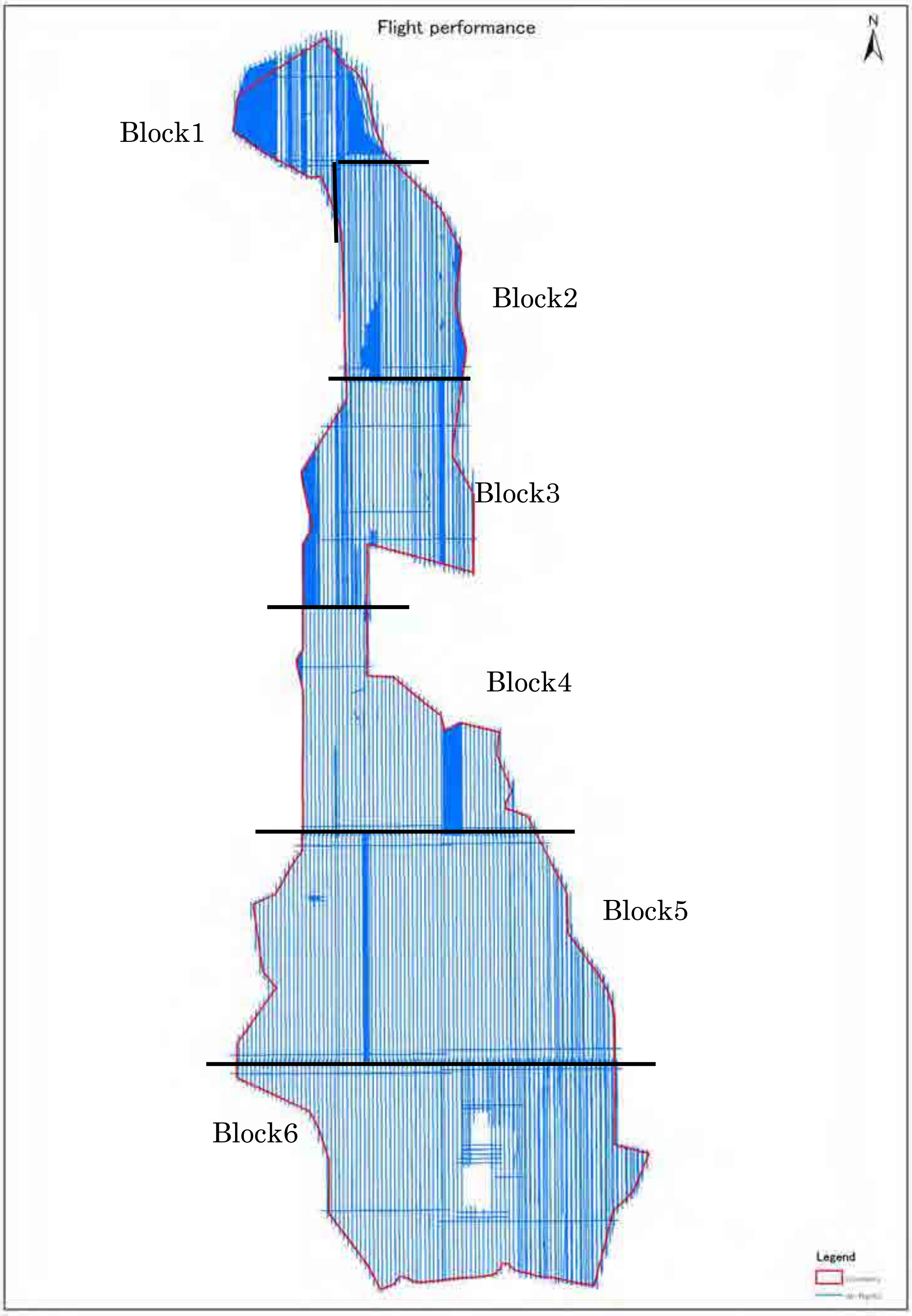


Figure 2.2.20　Measurement Course Map (1,035 courses in total)

## Table 2.2.15 Example of Daily Report

# Daily Report

| | | | | | |
|---|---|---|---|---|---|
| **Date** | 2012.02.29 | | | No. | 005 |
| **Project Name** | The study on a comprehensive flood measurement plan for the Chao Phraya river basin | | | | |
| **Base (Airport)** | VTBD: South / VTPP: North | Don Muang Airport (VTBD) | | Phisanulok Airport (VTPP) | |
| **Time** | | Morning | Afternoon | Morning | Afternoon |
| **Weather** | | Cloudy | Cloudy | Cloudy | Cloudy |
| **Weather Details** | METAR | Attached | | Attached | |
| **Aircraft Information** | | | | | |
| **Aircraft 1** | HS-RSI (Royal Skyways) | Flying | Flying | | |
| **Aircraft 2** | OO-MAP (Aerodata) | ETA: 04 Mar 2012 | | | |
| **Aircraft 3** | VH-AZU (Fuguro) | Preparation of Mobilization (Applying for transit permit based on Thai flight permit) | | | |
| **Aircraft 4** | VH-WGS (Fuguro) | Preparation of Mobilization (Applying for transit permit based on Thai flight permit) | | | |
| **Aircraft 5 (Back-up)** | OH-ONX (FINNMAP) | Stand-by at Finland | | | |
| **Equipment** | | | | | |
| **Equipment 1** | ALS50 Ⅱ (SN58) | Installed (HS-RSI) | | | |
| **Equipment 2** | ALS60 (SN6125) | Stand-by at Royal Skyways Hangar | | | |
| **Equipment 3** | ALS50 Ⅱ (SN87) | Stand-by at Fuguro Australia | | | |
| **Equipment 4** | ALS60 (SN31) | Stand-by at Fuguro Australia | | | |
| **Equipment 5 (Back-up)** | ALS50 Ⅱ (SN68) | PASCO Head Office → PASCO Thailand (ETA: 15 Mar 2012) | | | |
| **Staff Information** | | | | | |
| **Team Leader (Flight)** | Mr. Jyrki Inberg | Airport | | | |
| **Team Leader (GCP)** | Mr. Felix Rohrbach | Airport | | | |
| **Pilot 1 (HS-RSI)** | Mr. Witanyou Oubjiaraphant (Pingin | Flying | | | |
| **Pilot 2 (HS-RSI)** | Mr. Lapus Tantivitayakorn (Sarat) | Flying | | | |
| **Pilot 3 (OO-MAP)** | Mr. Ruben Philipse | ETA: 04 Mar 2012 | | | |
| **Pilot 4 (OO-MAP)** | Mr. Vendenabeele Nicolas | Stand-by at Aerodata (Belgium) | | | |
| **Pilot 5 (VH-AZU)** | Mr. Jamieson Roderick | Stand-by at Fuguro (Australia) | | | |
| **Pilot 6 (VH-WGS)** | Mr. Hunt Andrew | Stand-by at Fuguro (Australia) | | | |
| **Pilot 7 (VH-WGS)** | Mr. Matheson Kim | Stand-by at Fuguro (Australia) | | | |
| **Operator 1** | Mr. Akseli Galkin | Flying | | | |
| **Operator 2** | Mr. Ari Jaaskelainen | Stand-by at FINNMAP (Finland) | | | |
| **Operator 3** | Mr. Ruben Philipse | | | | |
| **Operator 4** | Mr. Kelly Neil (Ned) | Stand-by at Fuguro (Australia) | | | |
| **Operator 5** | Ms. Julie Sherrard | Stand-by at Fuguro (Australia) | | | |
| **Security Officer Information** | | | | | |
| **Security Officer 1 (RTSD A** | HS-RSI (Royal Skyways) | Flying | | | |
| **Security Officer 2 (RTSD B** | HS-RSI (Royal Skyways) | Airport (Ground Security) | | | |
| **Security Officer 3 (RTSD C** | OO-MAP (Aerodata) | | | | |
| **Security Officer 4 (RTSD D** | OO-MAP (Aerodata) | | | | |
| **Security Officer 5 (RTSD E** | VH-AZU (Fuguro) | | | | |
| **Security Officer 6 (RTSD F** | VH-AZU (Fuguro) | | | | |
| **Security Officer 7 (RTSD G** | VH-WGS (Fuguro) | | | | |
| **Security Officer 8 (RTSD H** | VH-WGS (Fuguro) | | | | |
| | | **Description of Work (Comment)** | | | |
| Short report / comment | | Slight haze. 6 lines recorded on area 2-1. | | | |

Table 2.2.16 List of Airborne Laser Scanning Results (February 25 – March 5)

# Flight Operation Report of Aerial Laser Mesurement

No **1**

| | | | |
|---|---|---|---|
| Area Name | Chao Phraya River Circuit Area | Leader | Koichi Honji |
| Base | Don Muang Airport | Marker | Felix Rohrbach |

| No. | Date | Weather | | Aircraft | Contents of Operation | Remark |
|---|---|---|---|---|---|---|
| | | AM | PM | | | |
| 1 | 25-Feb | Cloudy | Cloudy | HS-RSI | Test Flight with equipment (Total System). | OO-MAP, VH-AZU and VH-WGS are ongoing of preparation of mobilization. |
| | | | | OO-MAP | | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | | |
| 2 | 26-Feb | Cloudy | Cloudy | HS-RSI | Test Flight with equipment. | OO-MAP, VH-AZU and VH-WGS are ongoing of preparation of mobilization. |
| | | | | OO-MAP | | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | | |
| 3 | 27-Feb | Cloudy | Cloudy | HS-RSI | No Flight (weather was not suitable for flying). | OO-MAP, VH-AZU and VH-WGS are ongoing of preparation of mobilization. Weather was so bad, Thunderstorm was warned by Thai Meteorologial Department (TMD). |
| | | | | OO-MAP | | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | | |
| 4 | 28-Feb | Cloudy | Cloudy | HS-RSI | Stand-by (weather was not suitable for flying). | OO-MAP started ferry flight from Belgium. VH-AZU and VH-WGS are ongoing of preparation of mobilization. |
| | | | | OO-MAP | Estimated Time of Arrival (ETA) is on 4 Mar 2012 | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | | |
| 5 | 29-Feb | Cloudy | Cloudy | HS-RSI | Flight (6 lines in 500m recorded on Block 2). | Weather was slight haze. VH-AZU and VH-WGS are ongoing of preparation of mobilization. |
| | | | | OO-MAP | ETA is on 4 Mar 2012. | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | | |
| 6 | 1-Mar | Cloudy | Cloudy | HS-RSI | Flight (No data record). | METAR indicated suitable for flying, but clouds over the project areas prevented data capture. VH-AZU and VH-WGS are ongoing of preparation of mobilization. |
| | | | | OO-MAP | ETA is on 4 Mar 2012. | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | | |
| 7 | 2-Mar | Cloudy | Cloudy | HS-RSI | Stand-by (weather was not suitable for flying). | VH-AZU started ferry flight from Australia. VH-WGS is ongoing of preparation of mobilization. |
| | | | | OO-MAP | ETA is on 4 Mar 2012. | |
| | | | | VH-AZU | ETA is on 8 Mar 2012. | |
| | | | | VH-WGS | | |
| 8 | 3-Mar | Cloudy | Cloudy | HS-RSI | Stand-by (weather was not suitable for flying). | VH-WGS is ongoing of preparation of mobilization. |
| | | | | OO-MAP | ETA is on 4 Mar 2012. | |
| | | | | VH-AZU | ETA is on 8 Mar 2012. | |
| | | | | VH-WGS | | |
| 9 | 4-Mar | Sunny | Cloudy | HS-RSI | Flight (4 lines in 2785m recorded on Block 4). | HS-RSI conducted calibration flight. The estimated time of arrival for OO-MAP was changed due to landing approval time in transit country. VH-WGS is ongoing of preparation of mobilization. |
| | | | | OO-MAP | NEW ETA is on 5 Mar 2012. | |
| | | | | VH-AZU | ETA is on 8 Mar 2012. | |
| | | | | VH-WGS | | |
| 10 | 5-Mar | Sunny | Cloudy | HS-RSI | Flight (1.5 lines in 2785m recorded on Block 4) | HS-RSI was flying, but clouds and bad weather was on air, so had to stop operation. VH-WGS is ongoing of preparation of mobilization. |
| | | | | OO-MAP | Arrived in Don Muang Airport | |
| | | | | VH-AZU | ETA is on 8 Mar 2012. | |
| | | | | VH-WGS | | |

Table 2.2.17 List of Airborne Laser Scanning Results (March 30 – May 1)

## Flight Operation Report of Aerial Laser Mesurement

No 5

| | | | |
|---|---|---|---|
| Area Name | Chao Phraya River Circuit Area | Leader | Koichi Honji |
| Base | Don Muang Airport | Marker | Felix Rohrbach |

| No. | Date | Weather | | Aircraft | Contents of Operation | Remark |
|---|---|---|---|---|---|---|
| | | AM | PM | | | |
| 41 | 5-Apr | Rainy | Rainy | HS-RSI | Stand-by (weather was not suitable for flying). | Thunderstorm was warned by Thai Meteorologial Department (TMD) |
| | | | | OO-MAP | Stand-by (weather was not suitable for flying). | |
| | | | | VH-AZU | Stand-by (100hrs maintenance). | |
| | | | | VH-WGS | Stand-by (weather was not suitable for flying). | |
| 42 | 6-Apr | Rainy | Rainy | HS-RSI | Stand-by (weather was not suitable for flying). | Weather was rainy all day in remaining project area. |
| | | | | OO-MAP | Stand-by (weather was not suitable for flying). | |
| | | | | VH-AZU | Stand-by (100hrs maintenance). | |
| | | | | VH-WGS | Stand-by (weather was not suitable for flying). | |
| 43 | 7-Apr | Cloudy | Cloudy | HS-RSI | Stand-by (weather was not suitable for flying). | OO-MAP took off for image acquision flight, but had to return due to technical problem with the aircraft and weather was also very bad condition for LiDAR flight. |
| | | | | OO-MAP | Flight (3 lines in 3300m recorded on Block 6) | |
| | | | | VH-AZU | Stand-by (100hrs maintenance). | |
| | | | | VH-WGS | Stand-by (weather was not suitable for flying). | |
| 44 | 8-Apr | Cloudy | Cloudy | HS-RSI | Flight (7 lines recorded on Block 6) | HS-RSI took off, but returned due to engine problem, then Engine got fixed, took off again to collect some image data. Bascially, weather was very cloudy all areas. |
| | | | | OO-MAP | Stand-by (weather was not suitable for flying). | |
| | | | | VH-AZU | Stand-by (100hrs maintenance). | |
| | | | | VH-WGS | Flight (14 lines in 2785m recorded on Block 6) | |
| 45 | 9-Apr | Cloudy | Rainy - Cloudy | HS-RSI | Flight (12 lines in 3300m recorded on Block 6) | HS-RSI and OO-MAP was flying and collecting image data for uncovered areas. VH-WGS was flying and collecting LiDAR data. |
| | | | | OO-MAP | Flight (24 lines in 2785m recorded on Block 6) | |
| | | | | VH-AZU | Stand-by (100hrs maintenance). | |
| | | | | VH-WGS | Flight (14 lines in 2785m recorded on Block 6) | |
| 46 | 10-Apr | Cloudy | Cloudy | HS-RSI | Stand-by (flight limitation of number of aircraft) | The flying areas only allowed for 2 aircrafts to fly. OO-MAP was flying both LiDAR and image flight in the northern areas. VH-WGS was flying LiDAR lines in the sourthen areas. |
| | | | | OO-MAP | Flight (24 lines recorded on Block 2,3,4,5) | |
| | | | | VH-AZU | Released to Australia | |
| | | | | VH-WGS | Flight (16 lines in 2785m recorded on Block 6) | |
| 47 | 11-Apr | Cloudy | Cloudy | HS-RSI | Flight (6 lines in 3300m recorded on Block 6) | HS-RSI conducted image flight in southern areas. OO-MAP went to the northern area to capture mainly image reflying lines. |
| | | | | OO-MAP | Flight (30 lines recorded on Block 1,2,3) | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | Stand-by (flight limitation of number of aircraft) | |
| 48 | 12-Apr | Cloudy | Cloudy | HS-RSI | Flight (14 lines in 3300m recorded on Block 6) | HS-RSI took 14 image flight lines. OO-MAP took 13 image flight lines and 6 LiDAR lines over military areas. |
| | | | | OO-MAP | Flight (19 lines recorded on Block 2,3) | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | Stand-by (flight limitation of number of aircraft) | |
| 49 | 13-Apr | Cloudy | Cloudy | HS-RSI | Flight (14 lines in 3300m recorded on Block 5,6) | HS-RSI and OO-MAP was flying remaining uncovered image areas. VH-WGS completed all the remaining LiDAR lines over the military areas. |
| | | | | OO-MAP | Flight (14 lines in 3300m recorded on Block 1,2,3) | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | Flight (18 lines in 2785m recorded on Block 4,6) | |
| 50 | 14-Apr | Rainy - Cloudy | Rainy - Cloudy | HS-RSI | Stand-by (weather was not suitable for flying). | Weather condition was very bad due to thunder, rainstorm and heavy clouds. |
| | | | | OO-MAP | Stand-by (50hrs maintenance). | |
| | | | | VH-AZU | | |
| | | | | VH-WGS | Stand-by (weather was not suitable for flying). | |

**Checking for Missing Measurements**

A polygon was created based on the range of laser measurement and superimposed on top of the area to be measured to check if any measurement was missing. Re-measurement was performed for the areas with missing measurements.

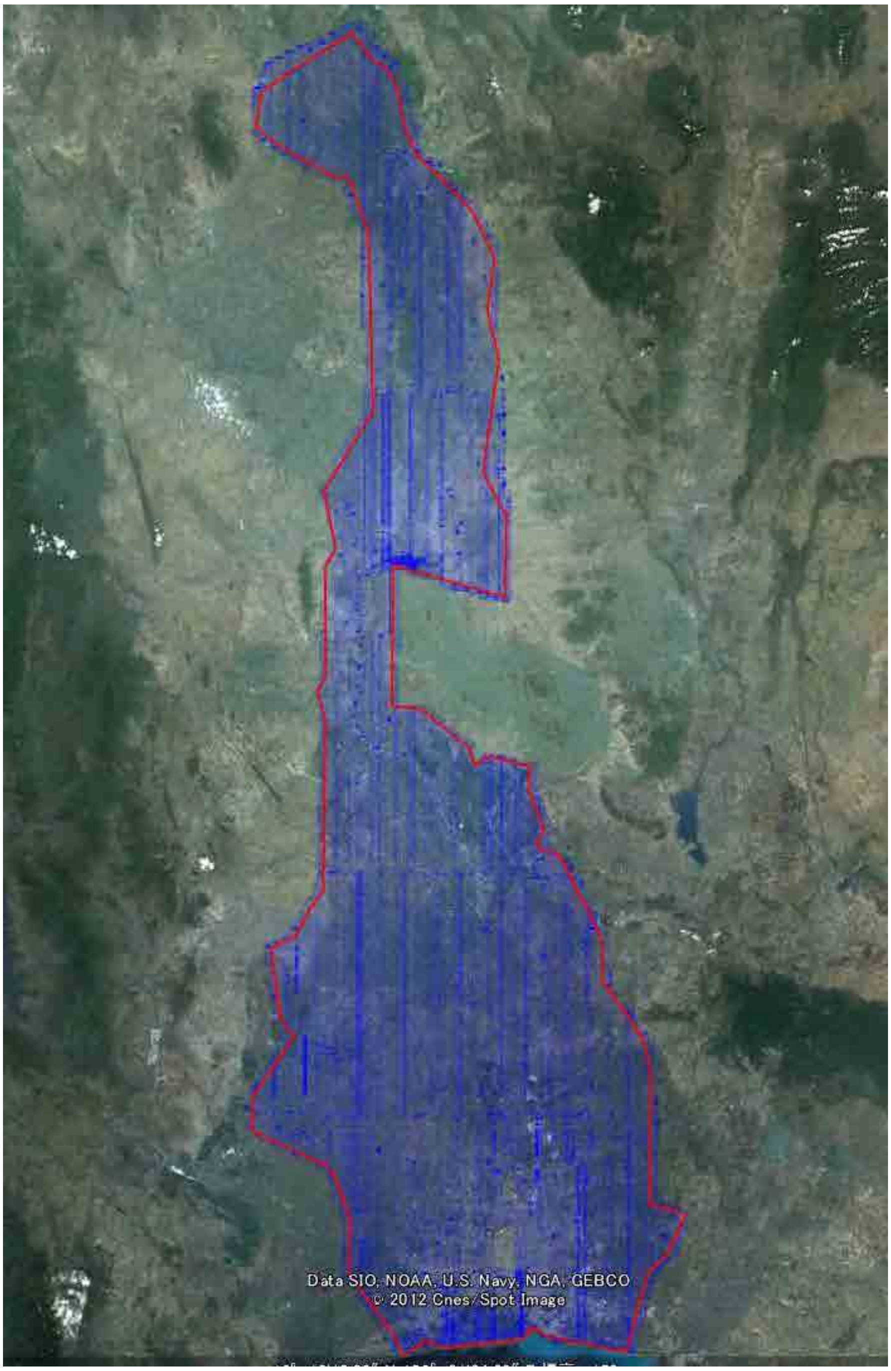


Figure 2.2.21 Map for Checking for Missing Measurements (Red Frame: Area to be Measured, Blue Frame: Measurement Range)

Instructions for checking for missing measurements and re-measurement were given by the RID project office.

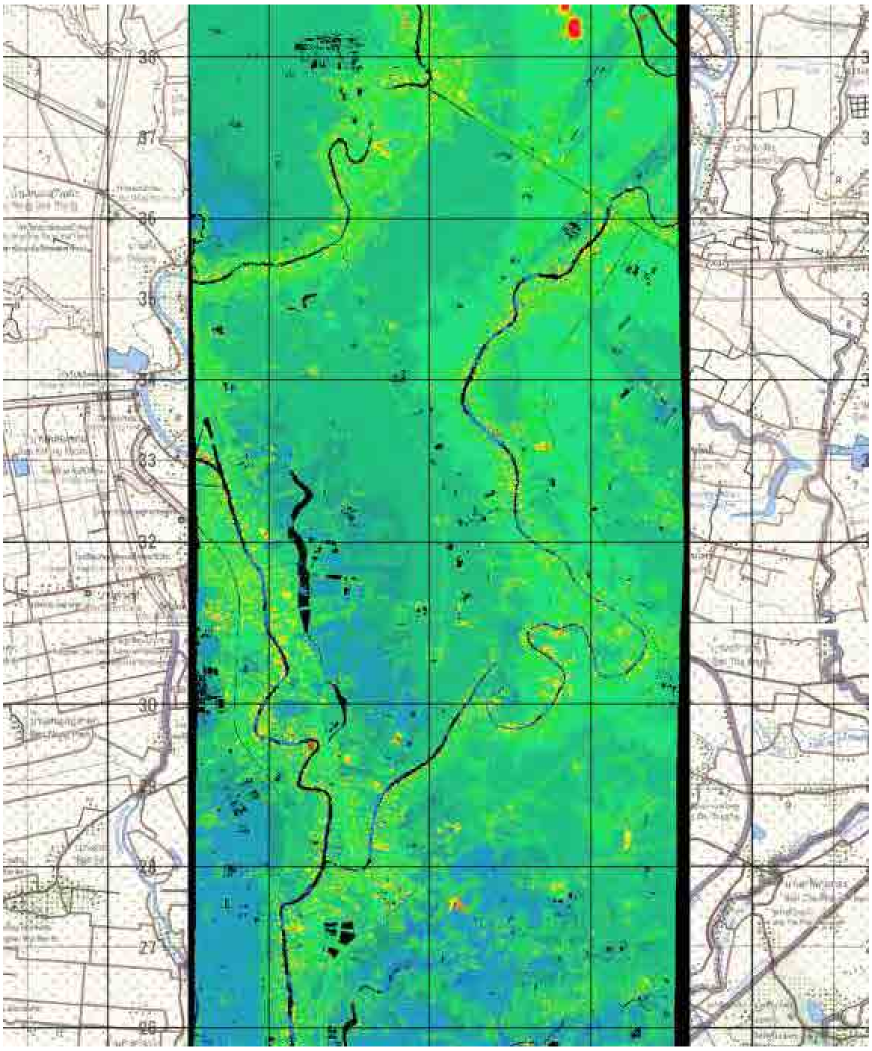


Figure 2.2.22 Checking for Missing Measurements

The figure above is expressed in the gradation of blue (low elevation) to red (high elevation) with black parts representing the areas where the data is missing. Since the airborne laser is a light, it tends to dissipate on water surfaces. Hence, the data on the water surfaces is missing. The data on black roofs and asphalt surfaces also tends to be missing.

As this missing data cannot be obtained by re-measurement, it was not counted as missing measurements. As a result, no measurement was found to be missing.

### Checking of Cloud Coverage

The laser intensity image was checked for the presence of clouds within the measurement courses. Re-measurement was performed for the areas where measurement was obstructed by clouds.

Figure 2.2.23 Example of Checking of Cloud Coverage Based on Laser Intensity Image (Clouds exist within the red frame.)

### 2-2-8 Creation of 3D Measurement Data

Airborne laser measurement data was created by means of integration analysis for comparative checking with the control points for correction. It should be confirmed that the standard deviation for the checked results is within 25cm or the average value is within ±25cm. Abnormal values due to diffused reflection or other causes should be removed as noise data.

Locations to be checked should be selected on the areas between courses that are duplicated, and comparative checking of the elevation values for each course should be performed. Four locations should be designated for checking that are located at equidistant locations on the duplicated areas. Flat locations that can be clearly distinguished should be selected for checking, with the averaged values for measurement data in a circle with the same radius as the grid width or a square for which the side length is approximately two times the grid width being adopted. However, the number of points to be checked may be reduced in mountainous and other areas that are influenced by terrain conditions. It should be confirmed that the average difference in the elevation values of the checked results is within ±30cm.

The ground coordinate value unit for the 3D measurement data to be created should be 1cm.

Furthermore, the proportion of measurement loss (proportion of the areas with missing measurements in target area) used to judge whether or not the measured results pass should be within 10%. In the event that the proportion of measurement loss is 10% or more, if this is due to the influence of water surfaces and black colored objects (roofs, etc.), the data should be judged as passing.

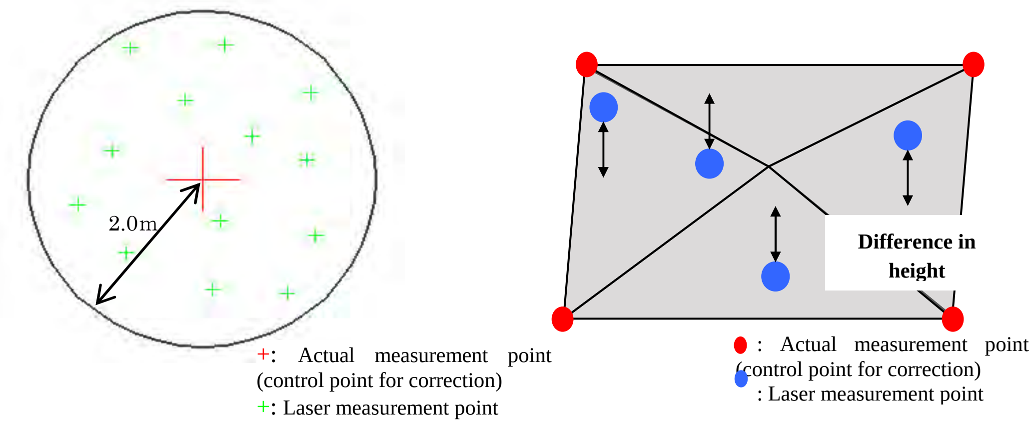


Figure 2.2.24 Conceptual Diagram for Checking of Control Points for Correction

The procedures for creation of 3D measurement data are outlined in the following diagram.

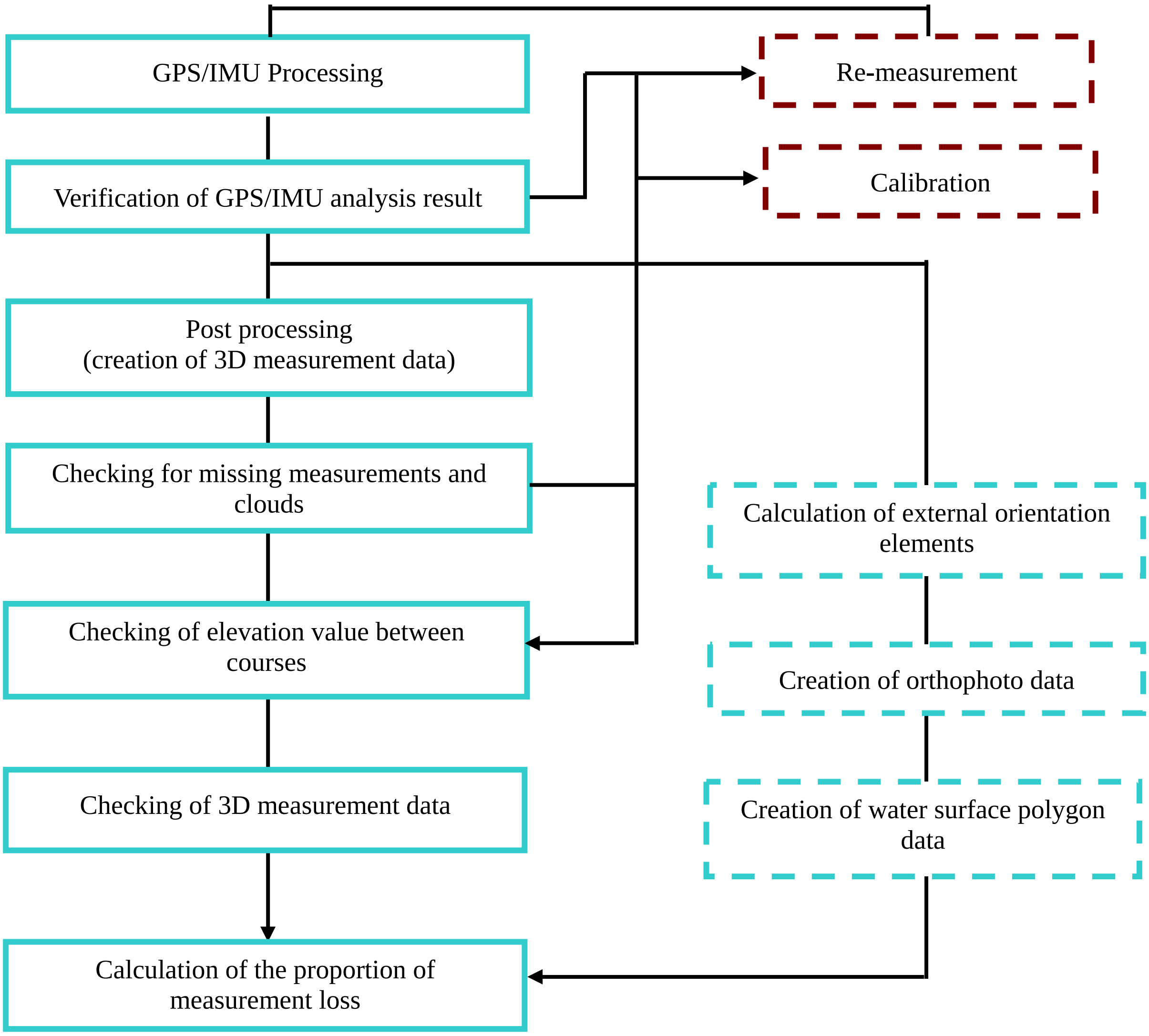


Figure 2.2.25 Outline of 3D Measurement Data Creation Procedures (Items within broken lines are those handled in other sections.)

In airborne laser scanning, based on the acquired airborne data (GPS/IMU data) and ground GCP observation data, aircraft position and posture (direct georeferencing data) at the time of laser irradiation are determined. Furthermore, combining the laser telemeter data (scan angle and distance from ground), measurement point group data is created for each course. This data also includes laser points created by the reflection of birds, airborne dust and other objects, which should be removed as noise. The details of the procedures for the creation of 3D measurement data are described below.

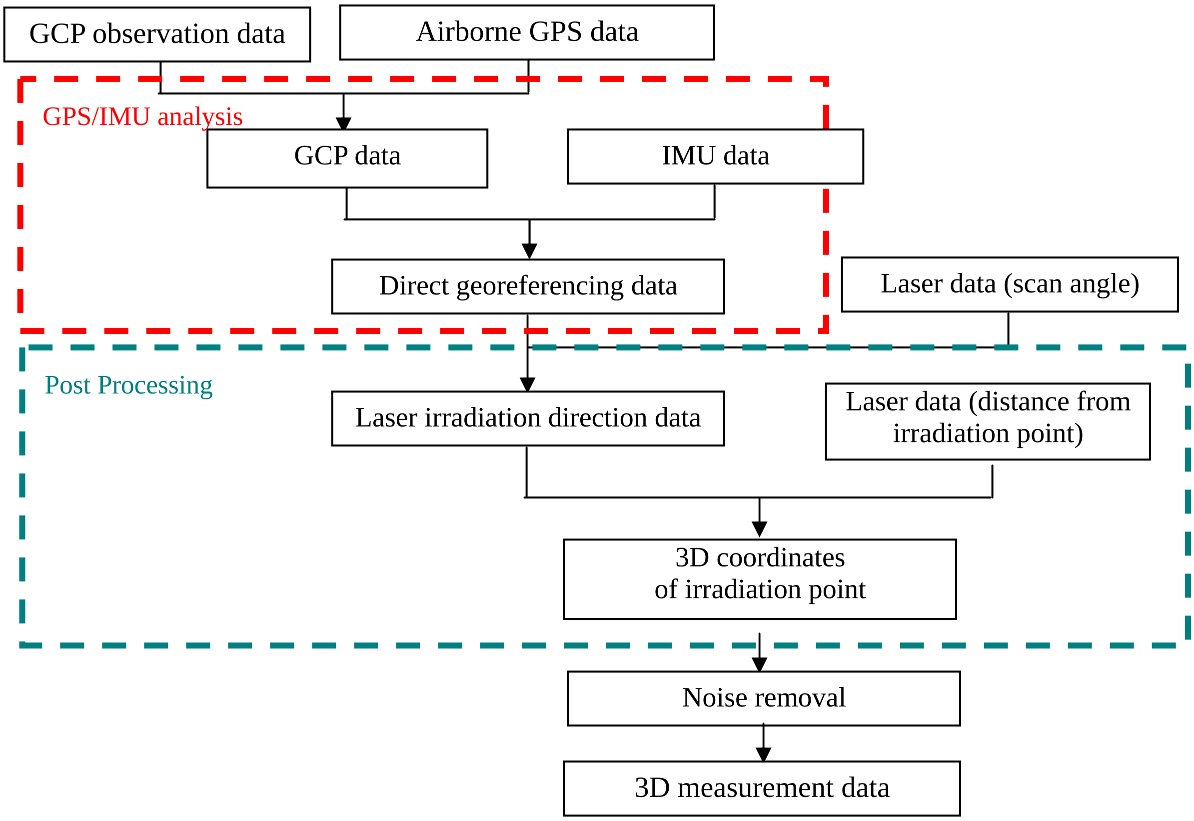


Figure 2.2.26 Details of 3D Measurement Data Creation Procedures

### GPS/IMU Analysis/Verification

By means of baseline analysis of the data from airborne GPS and GPS installed at ground control points, the flight path of an aircraft during scanning was obtained. Figures 2.2.27 to 2.2.29 describe the examples of analysis results.

Aircraft position and posture were determined by analyzing the flight path combined with the IMU (inertia measurement unit) data to create solution files needed for the creation of 3D measurement data and external orientation element files needed for the creation of orthophotos.

Measurement courses that provided no fixed solution from the baseline analysis were subject to re-calculation using course adjustment software called TerraMatch (made by TerraSolid), and results within the accuracy tolerance limits were obtained. (Figure 2.2.30.)

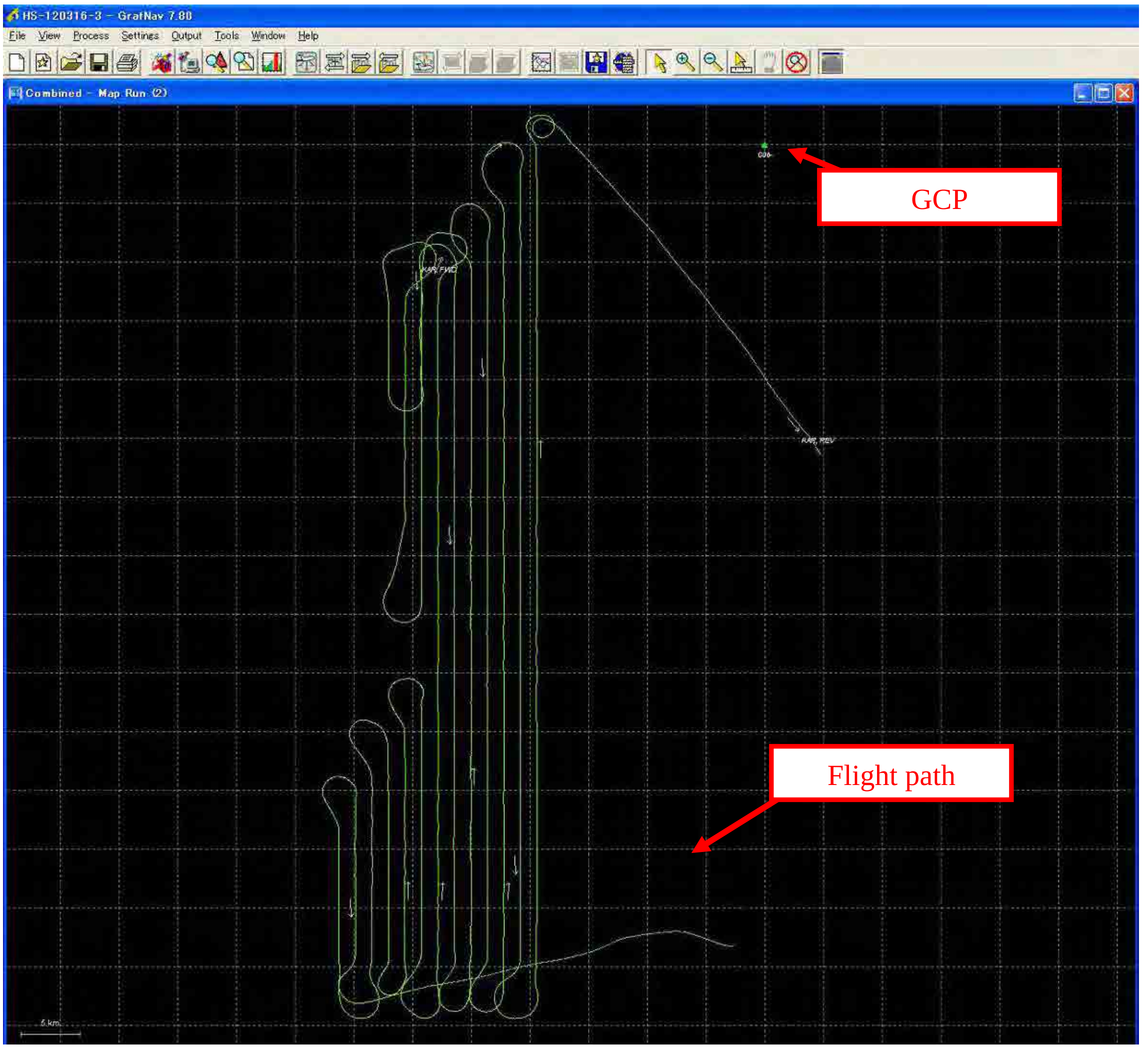


Figure 2.2.27 Example of GPS/IMU Analysis

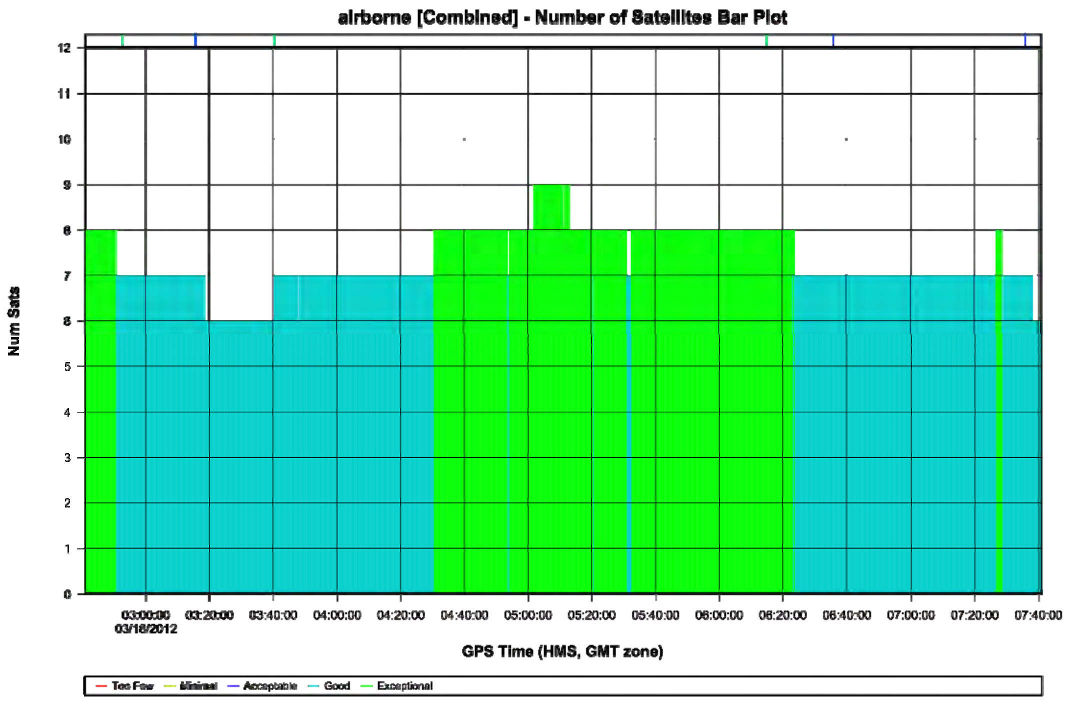


Figure 2.2.28 Example of Number of Satellites

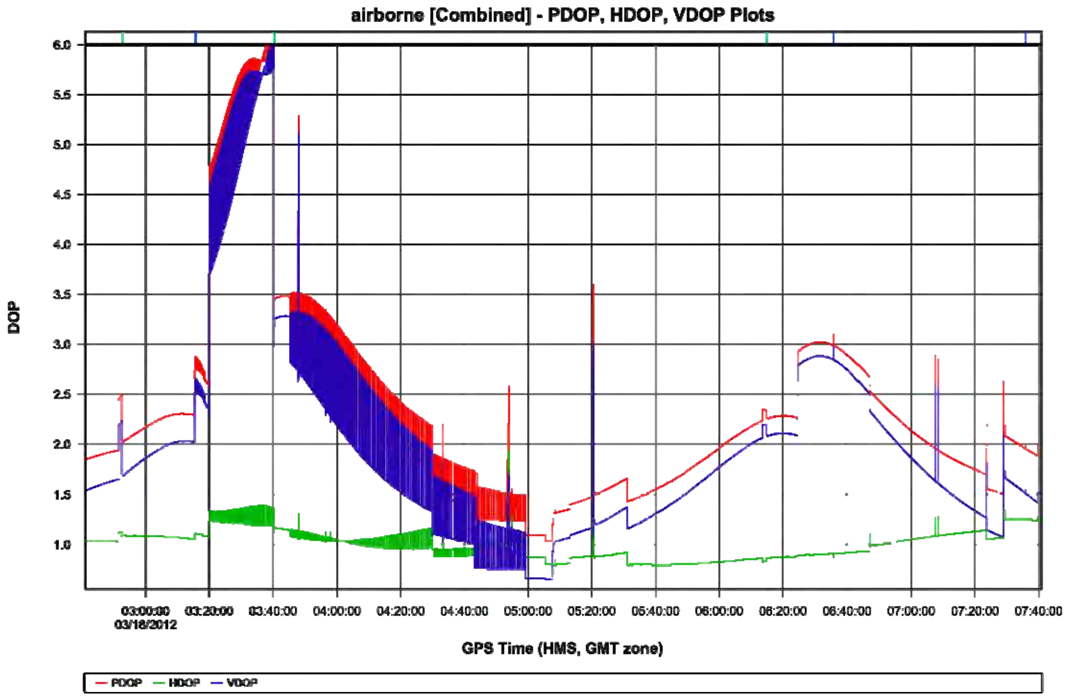


Figure 2.2.29 Example of PDOP

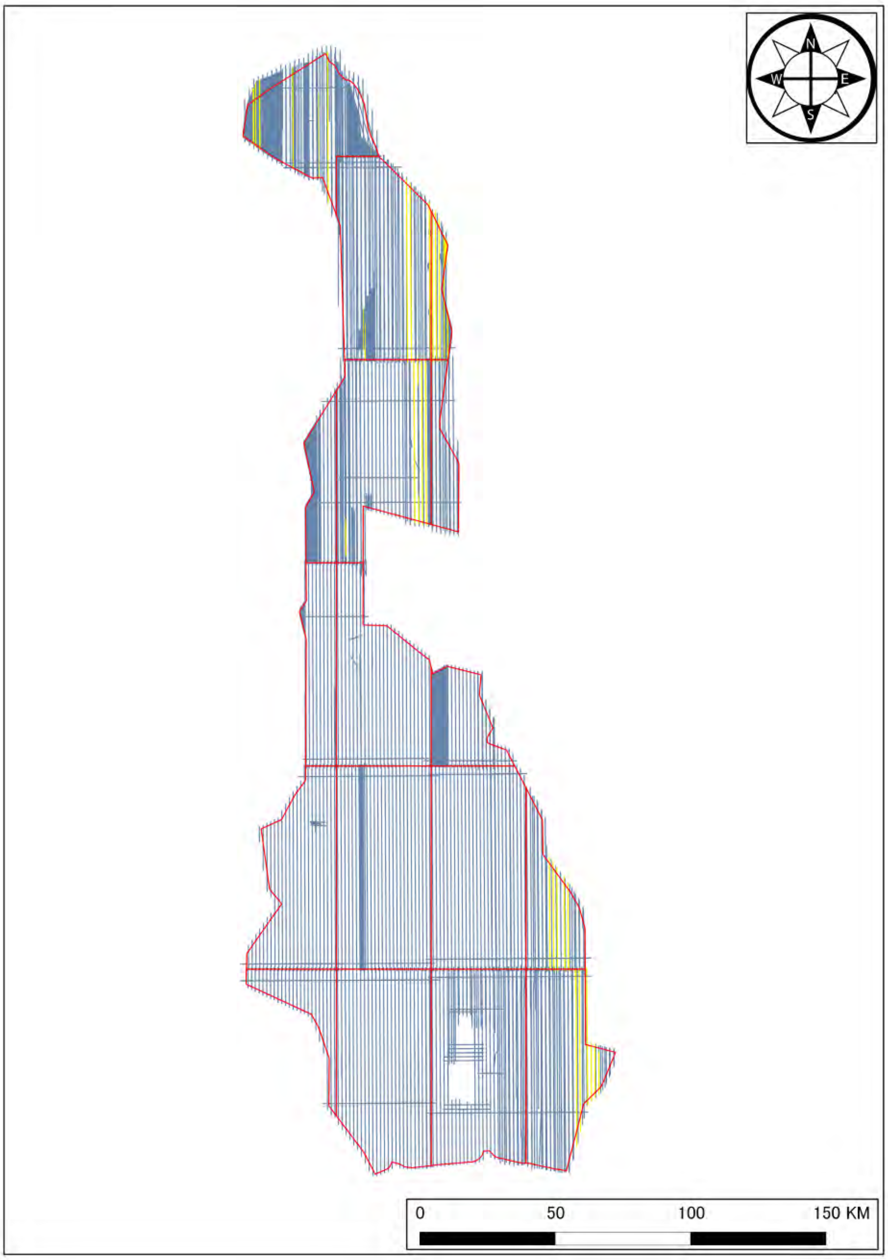
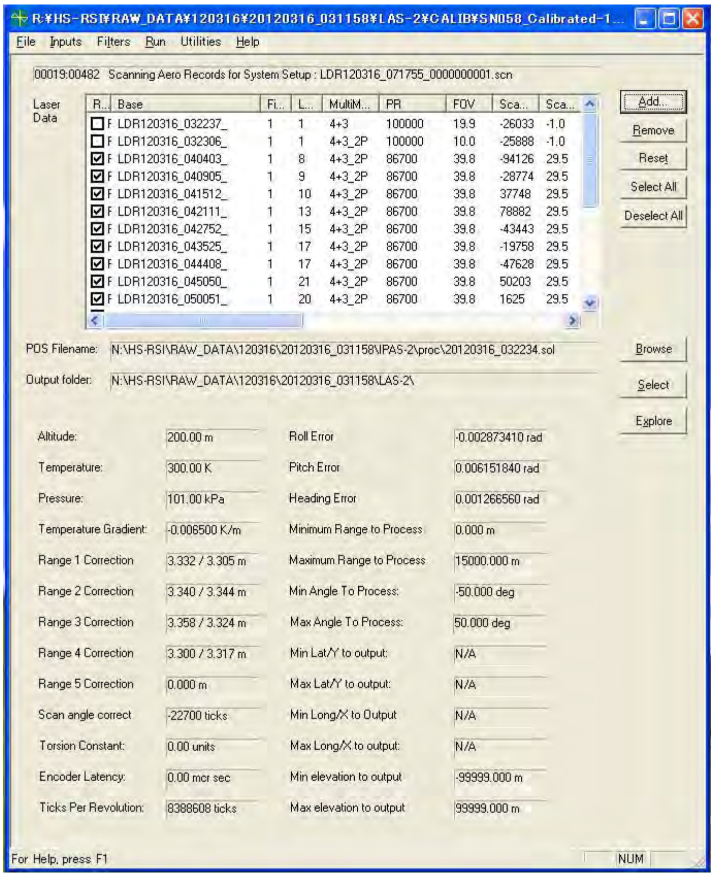


Figure 2.2.30 Flight paths subject to Re-Calculation Using TerraMatch (indicated in yellow, 43 courses in total)

## Post Processing (Creation of 3D Measurement Data)

3D measurement data was calculated based on the solution files obtained through the GPS/IMU analysis. ALS Post Processor (Release 2.71 BUILD #15) was used for calculation. With respect to the output data, the elevation value was obtained by using UTM 47 system, WGS84 for the ellipsoid of revolution and EGM2008 for the geoid. The details of the settings for ALS Post Processor, which varied according to the measurement equipment, are given in Tables 2.2.18 to 2.2.22.



00019:00482 Scanning Aero Records for System Setup : LDR120316_071755_0000000001.scn

Laser Data

| R... | Base | Fi... | L... | MultiM... | PR | FOV | Sca... | Sca... |
|---|---|---|---|---|---|---|---|---|
| ☐ F | LDR120316_032237_ | 1 | 1 | 4+3 | 100000 | 19.9 | -26033 | -1.0 |
| ☐ F | LDR120316_032306_ | 1 | 1 | 4+3_2P | 100000 | 10.0 | -25888 | -1.0 |
| ☑ F | LDR120316_040403_ | 1 | 8 | 4+3_2P | 86700 | 39.8 | -94126 | 29.5 |
| ☑ F | LDR120316_040905_ | 1 | 9 | 4+3_2P | 86700 | 39.8 | -28774 | 29.5 |
| ☑ F | LDR120316_041512_ | 1 | 10 | 4+3_2P | 86700 | 39.8 | 37748 | 29.5 |
| ☑ F | LDR120316_042111_ | 1 | 13 | 4+3_2P | 86700 | 39.8 | 78882 | 29.5 |
| ☑ F | LDR120316_042752_ | 1 | 15 | 4+3_2P | 86700 | 39.8 | -43443 | 29.5 |
| ☑ F | LDR120316_043525_ | 1 | 17 | 4+3_2P | 86700 | 39.8 | -19758 | 29.5 |
| ☑ F | LDR120316_044408_ | 1 | 17 | 4+3_2P | 86700 | 39.8 | -47628 | 29.5 |
| ☑ F | LDR120316_045050_ | 1 | 21 | 4+3_2P | 86700 | 39.8 | 50203 | 29.5 |
| ☑ F | LDR120316_050051_ | 1 | 20 | 4+3_2P | 86700 | 39.8 | 1625 | 29.5 |

POS Filename: N:\HS-RSI\RAW_DATA\120316\20120316_031158\IPAS-2\proc\20120316_032234.sol

Output folder: N:\HS-RSI\RAW_DATA\120316\20120316_031158\LAS-2\

| | | | |
|---|---|---|---|
| Altitude: | 200.00 m | Roll Error | -0.002873410 rad |
| Temperature: | 300.00 K | Pitch Error | 0.006151840 rad |
| Pressure: | 101.00 kPa | Heading Error | 0.001266560 rad |
| Temperature Gradient: | -0.006500 K/m | Minimum Range to Process | 0.000 m |
| Range 1 Correction | 3.332 / 3.305 m | Maximum Range to Process | 15000.000 m |
| Range 2 Correction | 3.340 / 3.344 m | Min Angle To Process: | -50.000 deg |
| Range 3 Correction | 3.358 / 3.324 m | Max Angle To Process: | 50.000 deg |
| Range 4 Correction | 3.300 / 3.317 m | Min Lat/Y to output: | N/A |
| Range 5 Correction | 0.000 m | Max Lat/Y to output: | N/A |
| Scan angle correct | -22700 ticks | Min Long/X to Output | N/A |
| Torsion Constant: | 0.00 units | Max Long/X to output: | N/A |
| Encoder Latency: | 0.00 mcr sec | Min elevation to output | -99999.000 m |
| Ticks Per Revolution: | 8388608 ticks | Max elevation to output | 99999.000 m |

For Help, press F1

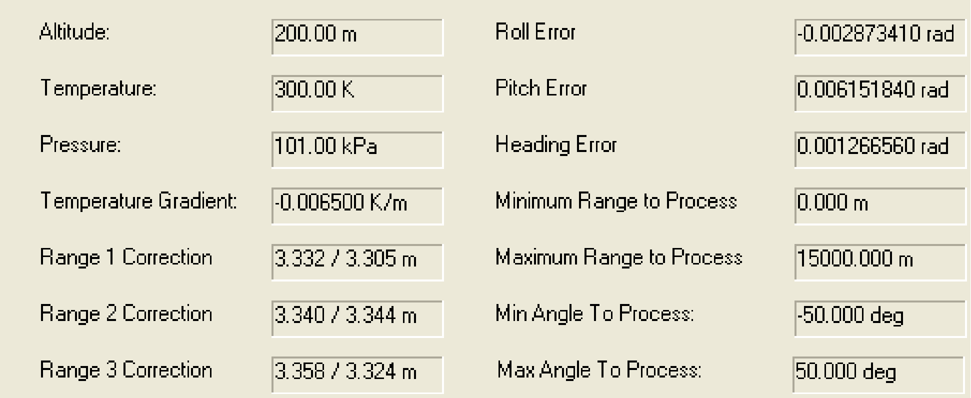
NUM

Figure 2.2.31 Example of Post Processing

Table 2.2.18 Setting for Post Processing

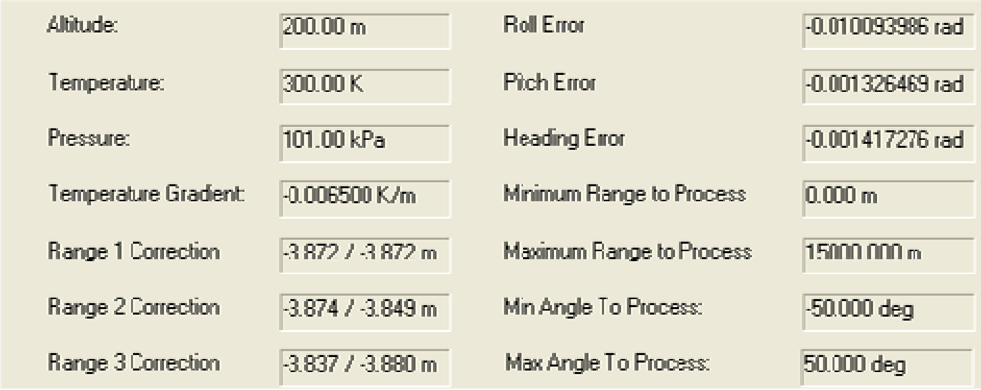
| | |
|---|---|
| System | UYM |
| Zone | 47N 96E to 102E |
| Horizontal Datum | WGS84 |
| Horizontal Units | Meters |
| Vertical Datum | EGM2008 |
| Vertical Units | Maters |

Table 2.2.19 Settings for HS-RSI Leica ALS50-II (SN58)



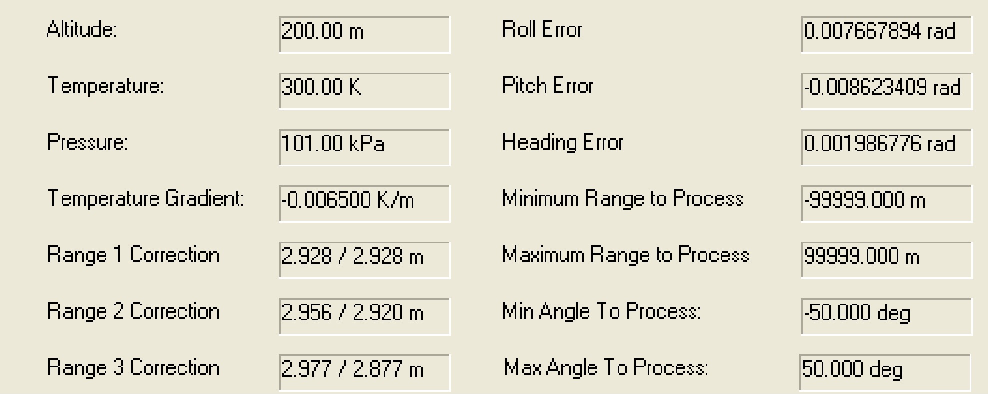
| | | | |
|---|---|---|---|
| Altitude: | 200.00 m | Roll Error | -0.002873410 rad |
| Temperature: | 300.00 K | Pitch Error | 0.006151840 rad |
| Pressure: | 101.00 kPa | Heading Error | 0.001266560 rad |
| Temperature Gradient: | -0.006500 K/m | Minimum Range to Process | 0.000 m |
| Range 1 Correction | 3.332 / 3.305 m | Maximum Range to Process | 15000.000 m |
| Range 2 Correction | 3.340 / 3.344 m | Min Angle To Process: | -50.000 deg |
| Range 3 Correction | 3.358 / 3.324 m | Max Angle To Process: | 50.000 deg |

Table 2.2.20 Settings for OO-MAP Leica ALS60 (SN6125)



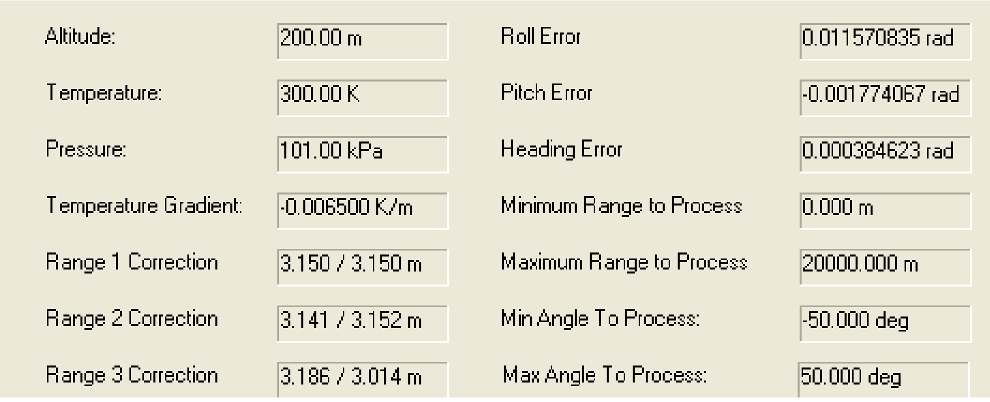
| | | | |
|---|---|---|---|
| Altitude: | 200.00 m | Roll Error | -0.010093986 rad |
| Temperature: | 300.00 K | Pitch Error | -0.001326469 rad |
| Pressure: | 101.00 kPa | Heading Error | -0.001417276 rad |
| Temperature Gradient: | -0.006500 K/m | Minimum Range to Process | 0.000 m |
| Range 1 Correction | -3.872 / -3.872 m | Maximum Range to Process | 15000.000 m |
| Range 2 Correction | -3.874 / -3.849 m | Min Angle To Process: | -50.000 deg |
| Range 3 Correction | -3.837 / -3.880 m | Max Angle To Process: | 50.000 deg |

Table 2.2.21 Settings for VH-AZU Leica ALS50-II (SN87)



| | | | |
|---|---|---|---|
| Altitude: | 200.00 m | Roll Error | 0.007667894 rad |
| Temperature: | 300.00 K | Pitch Error | -0.008623409 rad |
| Pressure: | 101.00 kPa | Heading Error | 0.001986776 rad |
| Temperature Gradient: | -0.006500 K/m | Minimum Range to Process | -99999.000 m |
| Range 1 Correction | 2.928 / 2.928 m | Maximum Range to Process | 99999.000 m |
| Range 2 Correction | 2.956 / 2.920 m | Min Angle To Process: | -50.000 deg |
| Range 3 Correction | 2.977 / 2.877 m | Max Angle To Process: | 50.000 deg |

Table 2.2.22 Settings for VH-WGS Leica ALS50 (SN31)



| | | | |
|---|---|---|---|
| Altitude: | 200.00 m | Roll Error | 0.011570835 rad |
| Temperature: | 300.00 K | Pitch Error | -0.001774067 rad |
| Pressure: | 101.00 kPa | Heading Error | 0.000384623 rad |
| Temperature Gradient: | -0.006500 K/m | Minimum Range to Process | 0.000 m |
| Range 1 Correction | 3.150 / 3.150 m | Maximum Range to Process | 20000.000 m |
| Range 2 Correction | 3.141 / 3.152 m | Min Angle To Process: | -50.000 deg |
| Range 3 Correction | 3.186 / 3.014 m | Max Angle To Process: | 50.000 deg |

### Checking of 3D Measurement Data

Centering on the control points for correction, laser scanning data within a circle with a radius of 2m, which is the grid width, or within a square with one side equivalent to about twice the grid width was extracted and the elevation differences between the control points for correction and each item of the extracted laser scanning data was calculated for comparative checking.

Error measurement points caused by diffuse reflection or other factors should be identified by checking the display of aerial view for areas of strange TIN shape and the display of cross section for point groups with abnormal elevation values and removed as noise data.

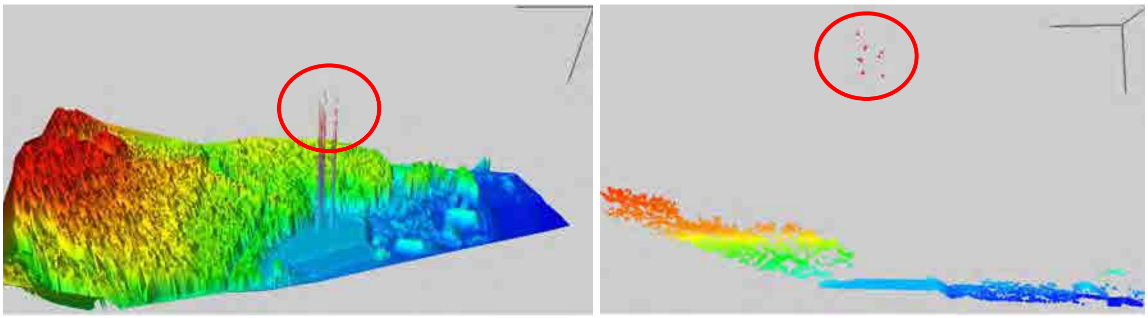


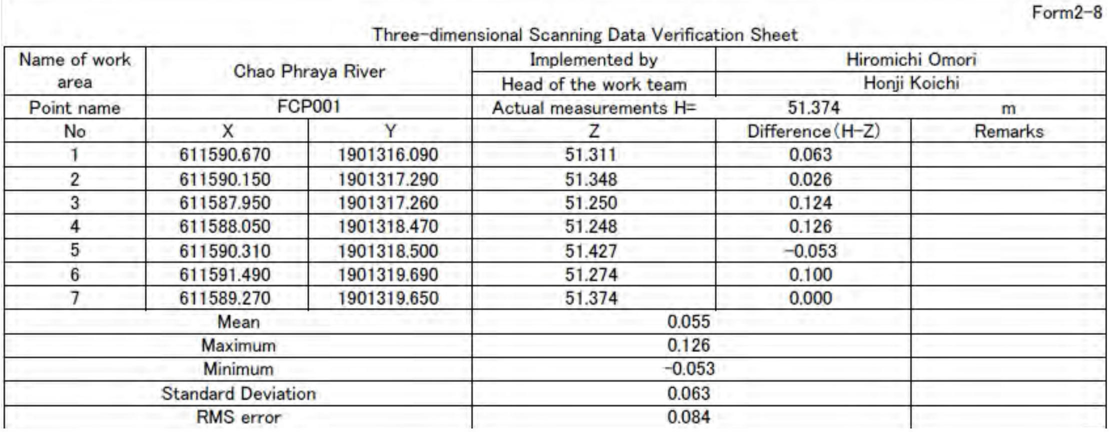
Figure 2.2.32 Images of Noise Data to be Removed in the Display of Aerial View (Left) and the Display of Cross Section (Right)

*: Only one point has been extracted, because a car was parked near FCP867 when laser scanning was performed, which has been included in the result of checking.

The 3D measurement data was checked in accordance with the control points for correction distributed in the area to be measured (Figure 2.2.33). If the result of checking revealed that the standard deviation was no less than 25cm or the mean was no less than ±25cm, re-calculation or re-measurement was performed after studying the cause. The result of checking was organized into

“3D Measurement Data Checking Table” and “Control Points for Correction Survey Sheet”.

Table 2.2.23 Form 2-8 3D Measurement Data Checking Table



Form2-8

Three-dimensional Scanning Data Verification Sheet

| | | | | | |
|---|---|---|---|---|---|
| Name of work area | Chao Phraya River | | Implemented by | Hiromichi Omori | |
| | | | Head of the work team | Honji Koichi | |
| Point name | FCP001 | | Actual measurements H= | 51.374 | m |
| No | X | Y | Z | Difference(H-Z) | Remarks |
| 1 | 611590.670 | 1901316.090 | 51.311 | 0.063 | |
| 2 | 611590.150 | 1901317.290 | 51.348 | 0.026 | |
| 3 | 611587.950 | 1901317.260 | 51.250 | 0.124 | |
| 4 | 611588.050 | 1901318.470 | 51.248 | 0.126 | |
| 5 | 611590.310 | 1901318.500 | 51.427 | -0.053 | |
| 6 | 611591.490 | 1901319.690 | 51.274 | 0.100 | |
| 7 | 611589.270 | 1901319.650 | 51.374 | 0.000 | |
| Mean | | | 0.055 | | |
| Maximum | | | 0.126 | | |
| Minimum | | | -0.053 | | |
| Standard Deviation | | | 0.063 | | |
| RMS error | | | 0.084 | | |

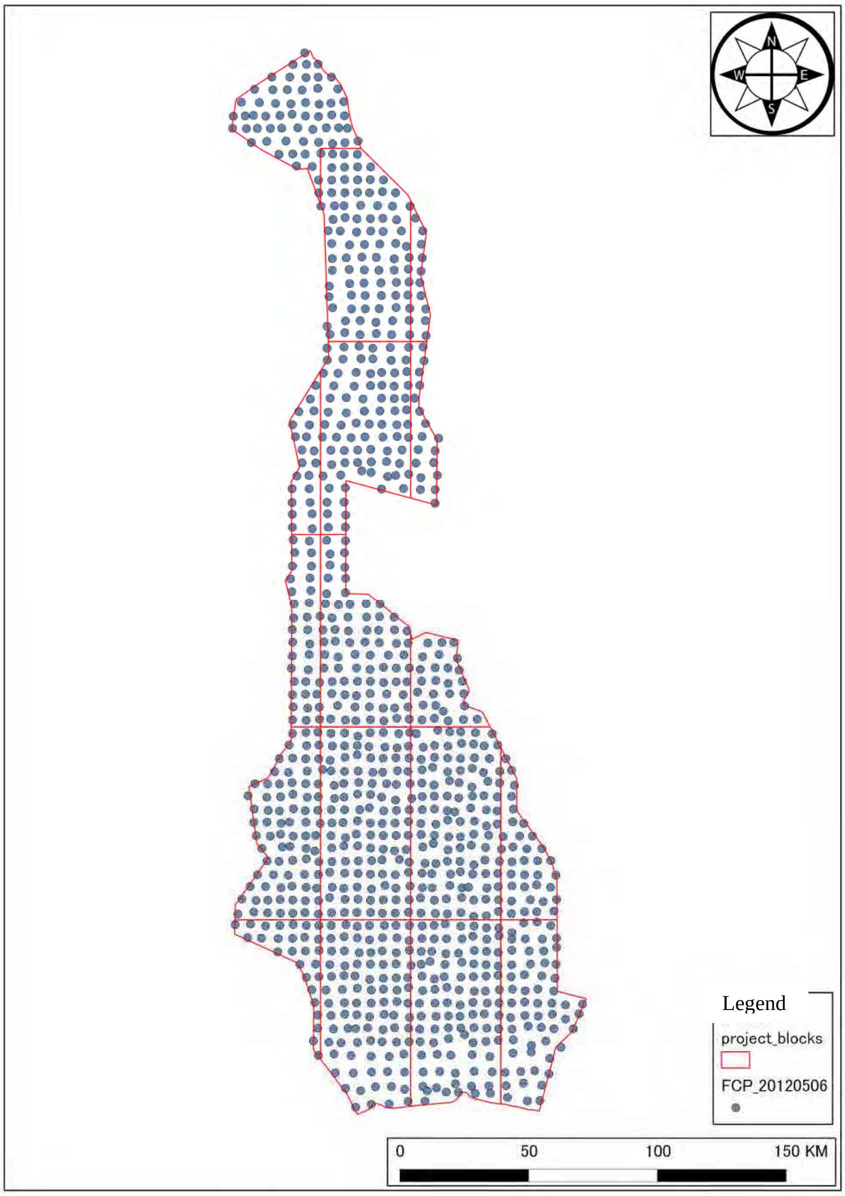


Figure 2.2.33 Distribution of Control Points for Verification (993 points in total)

Table 2.2.24 Example of Control Points for Correction Survey Sheet

## Control Point for Correction Survey Sheet

| Name of work area | | Chao Phraya River | | | | | Implemented by | Kiyofumi Tamari | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Head of the work team | Koichi Honji | |
| No | Point name | Leveling result | Output of laser scanning | Difference from the result of leveling | No | Point name | Leveling result | Output of laser scanning | Difference from the result of leveling |
| 1 | FCP401 | 9.593 | 9.701 | −0.108 | 41 | FCP441 | 18.807 | 18.637 | 0.170 |
| 2 | FCP402 | 8.680 | 8.828 | −0.148 | 42 | FCP442 | 28.541 | 28.482 | 0.059 |
| 3 | FCP403 | 10.339 | 10.244 | 0.095 | 43 | FCP443 | 20.399 | 20.224 | 0.175 |
| 4 | FCP404 | 11.797 | 11.765 | 0.032 | 44 | FCP444 | 16.236 | 16.164 | 0.072 |
| 5 | FCP405 | 9.721 | 9.787 | −0.066 | 45 | FCP445 | 11.751 | 11.705 | 0.046 |
| 6 | FCP406 | 8.275 | 8.330 | −0.055 | 46 | FCP446 | 7.679 | 7.458 | 0.221 |
| 7 | FCP407 | 9.056 | 9.242 | −0.186 | 47 | FCP447 | 7.691 | 7.727 | −0.036 |
| 8 | FCP408 | 12.920 | 12.960 | −0.040 | 48 | FCP448 | 8.334 | 8.306 | 0.028 |
| 9 | FCP409 | 25.714 | 25.715 | −0.001 | 49 | FCP449 | 8.311 | 8.306 | 0.005 |
| 10 | FCP410 | 14.961 | 14.903 | 0.058 | 50 | FCP450 | 8.991 | 8.874 | 0.117 |
| 11 | FCP411 | 10.387 | 10.195 | 0.192 | 51 | FCP451 | 7.653 | 7.661 | −0.008 |
| 12 | FCP412 | 8.427 | 8.270 | 0.157 | 52 | FCP452 | 6.919 | 6.910 | 0.009 |
| 13 | FCP413 | 10.769 | 10.786 | −0.017 | 53 | FCP453 | 9.093 | 9.156 | −0.063 |
| 14 | FCP414 | 11.602 | 11.653 | −0.051 | 54 | FCP454 | 8.816 | 8.954 | −0.138 |
| 15 | FCP415 | 10.192 | 10.163 | 0.029 | 55 | FCP455 | 6.665 | 6.599 | 0.066 |
| 16 | FCP416 | 9.846 | 9.850 | −0.004 | 56 | FCP456 | 6.265 | 6.172 | 0.093 |
| 17 | FCP417 | 9.143 | 9.169 | −0.026 | 57 | FCP457 | 6.930 | 6.889 | 0.041 |
| 18 | FCP418 | 10.283 | 10.178 | 0.105 | 58 | FCP458 | 6.412 | 6.362 | 0.050 |
| 19 | FCP419 | 9.093 | 9.232 | −0.139 | 59 | FCP459 | 8.076 | 8.099 | −0.023 |
| 20 | FCP420 | 10.201 | 10.427 | −0.226 | 60 | FCP460 | 23.038 | 22.970 | 0.068 |
| 21 | FCP421 | 9.131 | 9.187 | −0.056 | 61 | FCP461 | 20.700 | 20.763 | −0.063 |
| 22 | FCP422 | 9.588 | 9.467 | 0.121 | 62 | FCP462 | 14.919 | 14.905 | 0.014 |
| 23 | FCP423 | 9.230 | 9.083 | 0.147 | 63 | FCP463 | 9.043 | 9.005 | 0.038 |
| 24 | FCP424 | 15.422 | 15.417 | 0.005 | 64 | FCP464 | 8.105 | 8.174 | −0.069 |
| 25 | FCP425 | 30.706 | 30.550 | 0.156 | 65 | FCP465 | 6.656 | 6.679 | −0.023 |
| 26 | FCP426 | 16.110 | 16.123 | −0.013 | 66 | FCP466 | 7.434 | 7.402 | 0.032 |
| 27 | FCP427 | 10.279 | 10.157 | 0.122 | 67 | FCP467 | 6.955 | 6.901 | 0.054 |
| 28 | FCP428 | 10.230 | 10.104 | 0.126 | 68 | FCP468 | 7.745 | 7.622 | 0.123 |
| 29 | FCP429 | 9.220 | 9.150 | 0.070 | 69 | FCP469 | 7.039 | 6.956 | 0.083 |
| 30 | FCP430 | 9.422 | 9.439 | −0.017 | 70 | FCP470 | 7.289 | 7.303 | −0.014 |
| 31 | FCP431 | 9.451 | 9.544 | −0.093 | 71 | FCP471 | 7.394 | 7.343 | 0.051 |
| 32 | FCP432 | 10.003 | 9.958 | 0.045 | 72 | FCP472 | 7.759 | 7.999 | −0.240 |
| 33 | FCP433 | 7.513 | 7.558 | −0.045 | 73 | FCP473 | 6.635 | 6.612 | 0.023 |
| 34 | FCP434 | 8.832 | 8.913 | −0.081 | 74 | FCP474 | 6.628 | 6.532 | 0.096 |
| 35 | FCP435 | 8.454 | 8.467 | −0.013 | 75 | FCP475 | 7.263 | 7.168 | 0.095 |
| 36 | FCP436 | 8.005 | 8.247 | −0.242 | 76 | FCP476 | 5.964 | 6.089 | −0.125 |
| 37 | FCP437 | 8.875 | 8.779 | 0.096 | 77 | FCP477 | 6.923 | 6.701 | 0.222 |
| 38 | FCP438 | 5.656 | 5.528 | 0.128 | 78 | FCP478 | 9.233 | 9.114 | 0.119 |
| 39 | FCP439 | 8.097 | 7.946 | 0.151 | 79 | FCP479 | 18.981 | 18.947 | 0.034 |
| 40 | FCP440 | 13.416 | 13.491 | −0.075 | 80 | FCP480 | 27.006 | 27.216 | −0.210 |

| | Mean (m) | Standard deviation (m) | RMS error (m) | Maximum (m) | Minimum (m) | Maximum – Minimum | Number of data |
|---|---|---|---|---|---|---|---|
| Difference from the result of leveling for the entire scan area | -0.001 | 0.134 | 0.134 | 0.447 | -0.464 | -0.911 | 976 |

**Survey for Checking Between Courses**

Duplicated areas between adjacent courses were selected for comparative checking of the elevation values for each course. For each course, a maximum of four locations, which were located at equal intervals, were designated for checking.

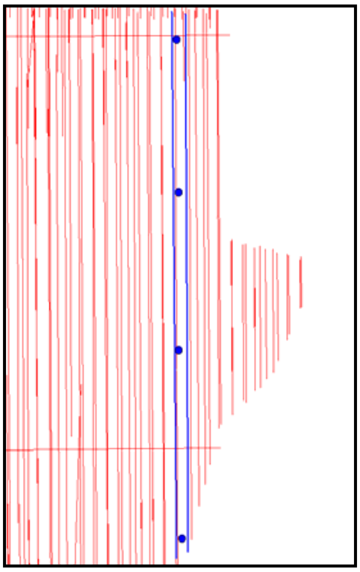


Figure 2.2.34 Example of locations for verification between flight paths

To designate the locations for checking, flat areas were selected in the overlapping range (yellow range) based on the laser intensity image.

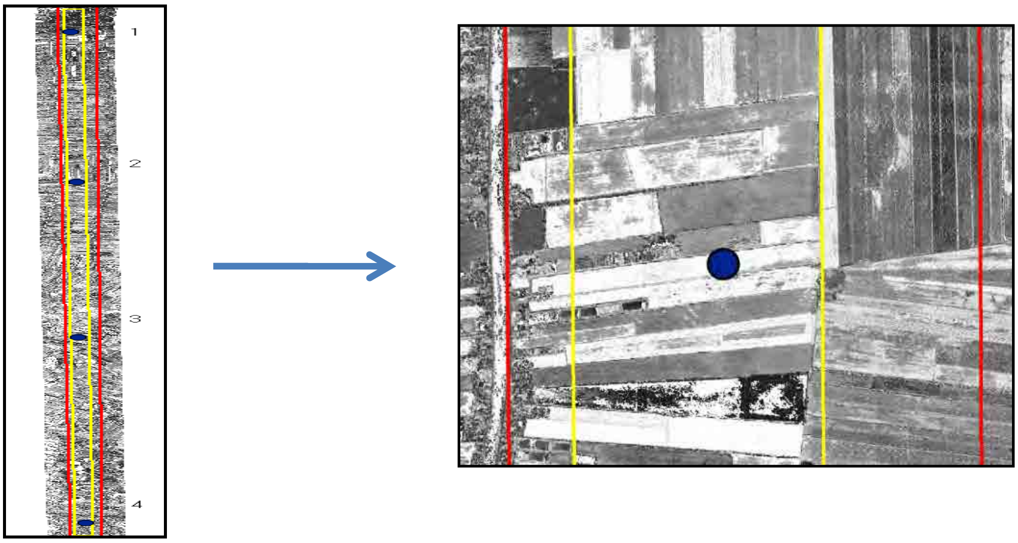


Figure 2.2.35 Example of Selected Location

In checking, 3D measurement data of the $4m^2$ range centered on the location for checking was averaged for comparison.

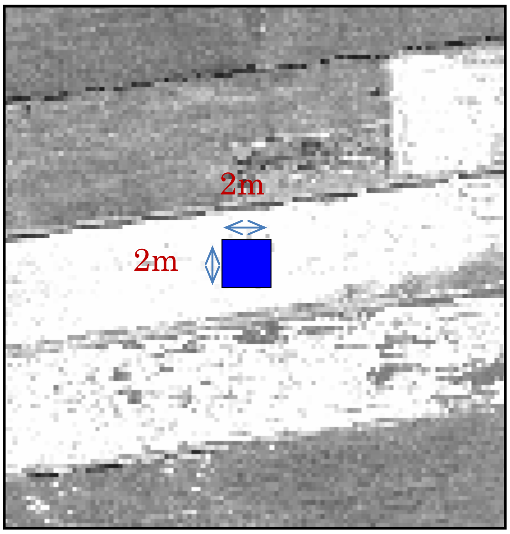
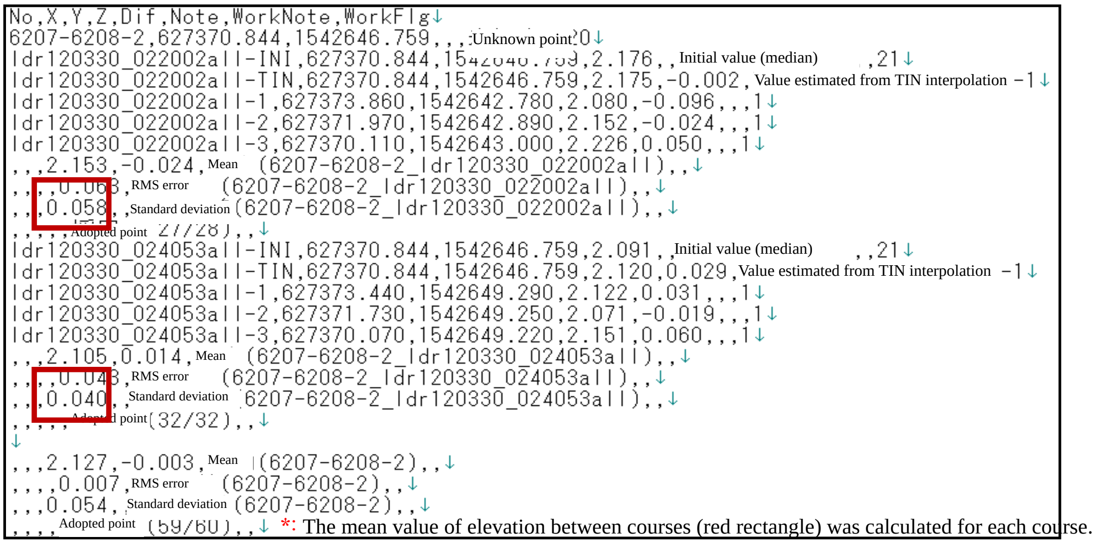


Figure 2.2.36　Example of Checking Range

It was confirmed that the elevation difference between courses was within ±30cm. In the event that the result of checking exceeded the limits, re-establishment of the location for checking or revision of the calibration value was performed.

Table 2.2.25　Example of Checking Result Table

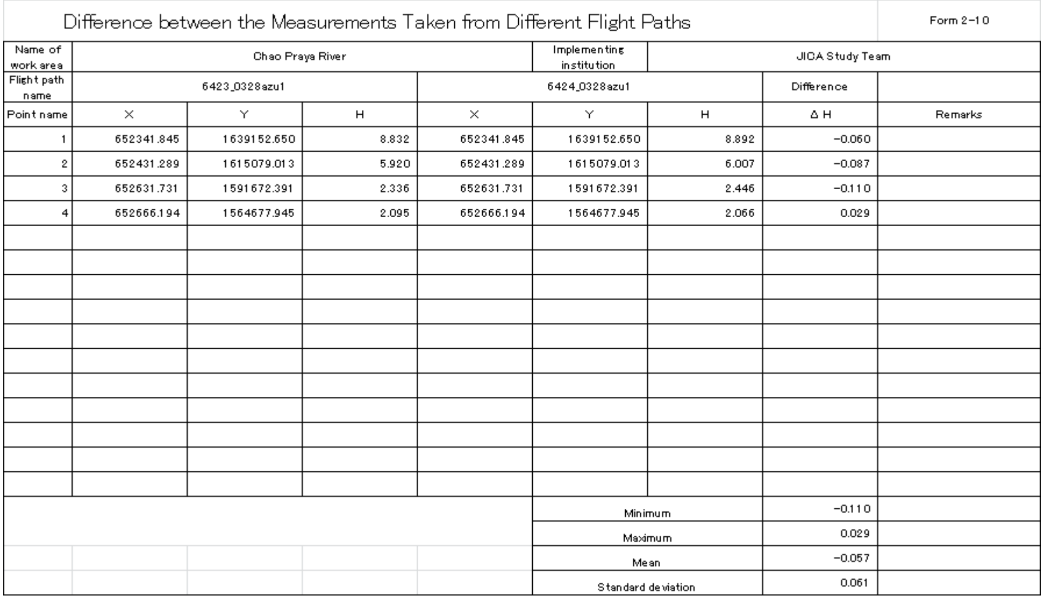


```
No,X,Y,Z,Dif,Note,WorkNote,WorkFlg↓
6207-6208-2,627370.844,1542646.759,,,Unknown point,0↓
ldr120330_022002all-INI,627370.844,1542646.759,2.176,,Initial value (median)      ,,21↓
ldr120330_022002all-TIN,627370.844,1542646.759,2.175,-0.002,Value estimated from TIN interpolation -1↓
ldr120330_022002all-1,627373.860,1542642.780,2.080,-0.096,,,1↓
ldr120330_022002all-2,627371.970,1542642.890,2.152,-0.024,,,1↓
ldr120330_022002all-3,627370.110,1542643.000,2.226,0.050,,,1↓
,,,2.153,-0.024,Mean  (6207-6208-2_ldr120330_022002all),,↓
,,,,0.063,RMS error   (6207-6208-2_ldr120330_022002all),,↓
,,,0.058,,Standard deviation (6207-6208-2_ldr120330_022002all),,↓
,,,,,Adopted point 27/28),,↓
ldr120330_024053all-INI,627370.844,1542646.759,2.091,,Initial value (median)      ,,21↓
ldr120330_024053all-TIN,627370.844,1542646.759,2.120,0.029,Value estimated from TIN interpolation -1↓
ldr120330_024053all-1,627373.440,1542649.290,2.122,0.031,,,1↓
ldr120330_024053all-2,627371.730,1542649.250,2.071,-0.019,,,1↓
ldr120330_024053all-3,627370.070,1542649.220,2.151,0.060,,,1↓
,,,2.105,0.014,Mean  (6207-6208-2_ldr120330_024053all),,↓
,,,,0.043,RMS error   (6207-6208-2_ldr120330_024053all),,↓
,,,0.040,,Standard deviation 6207-6208-2_ldr120330_024053all),,↓
,,,,,Adopted point(32/32),,↓
↓
,,,2.127,-0.003,Mean  (6207-6208-2),,↓
,,,,0.007,RMS error   (6207-6208-2),,↓
,,,0.054,,Standard deviation (6207-6208-2),,↓
,,,,Adopted point (59/60),,↓
```

*: The mean value of elevation between courses (red rectangle) was calculated for each course.

The results of checking were tabulated as “Differences at Locations for Checking between Courses” and a distribution map was prepared as “Distribution Map of Locations for Checking Between Courses”.

Table 2.2.26 Form 2-10 Differences at Locations for Checking Between Courses



Difference between the Measurements Taken from Different Flight Paths

Form 2-10

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name of work area | Chao Praya River | | | | Implementing institution | JICA Study Team | | |
| Flight path name | 6423_0328azu1 | | | 6424_0328azu1 | | | Difference | |
| Point name | X | Y | H | X | Y | H | Δ H | Remarks |
| 1 | 652341.845 | 1639152.650 | 8.832 | 652341.845 | 1639152.650 | 8.892 | -0.060 | |
| 2 | 652431.289 | 1615079.013 | 5.920 | 652431.289 | 1615079.013 | 6.007 | -0.087 | |
| 3 | 652631.731 | 1591672.391 | 2.336 | 652631.731 | 1591672.391 | 2.446 | -0.110 | |
| 4 | 652666.194 | 1564677.945 | 2.095 | 652666.194 | 1564677.945 | 2.066 | 0.029 | |
| | | | | | | | | |
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| | | | | | | | | |
| | | | | | Minimum | | -0.110 | |
| | | | | | Maximum | | 0.029 | |
| | | | | | Mean | | -0.057 | |
| | | | | | Standard deviation | | 0.061 | |

As a resulting of checking all the differences between courses, it was confirmed that the measurements were within the limits.

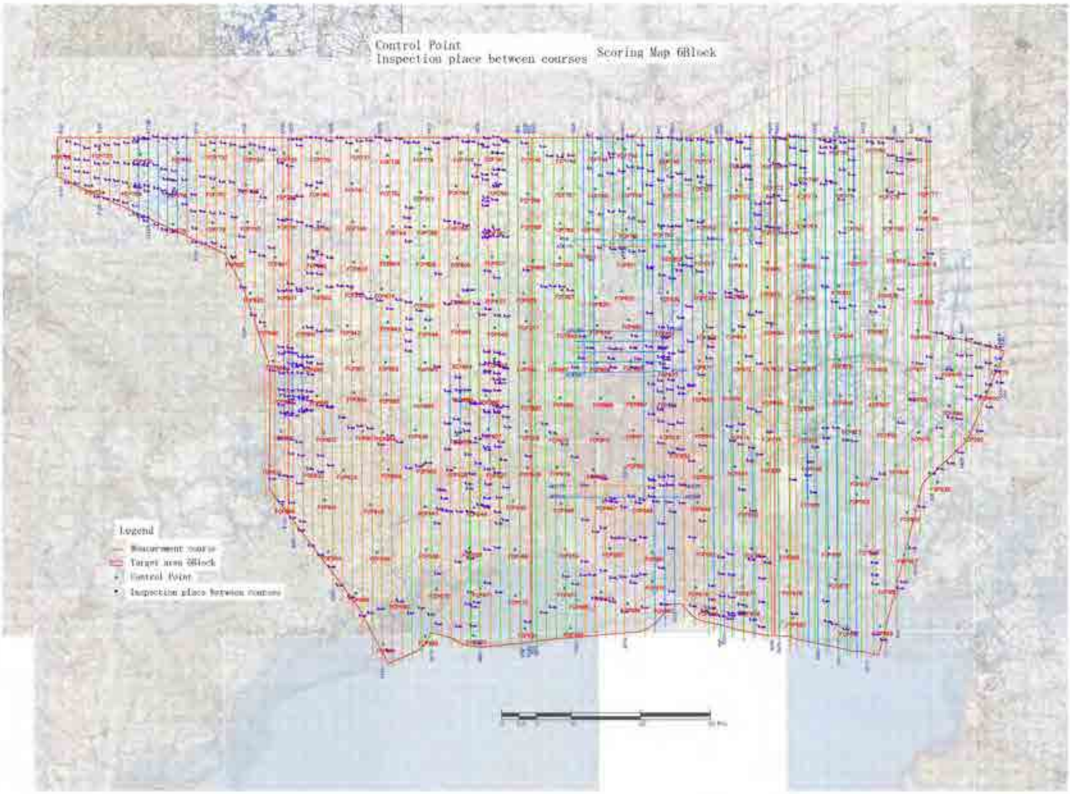


Figure 2.2.37 Distribution Map of Locations for Checking Between Courses

The distribution map of locations for checking between courses was prepared for each block. The names of the tie points were simplified for the convenience of indication.

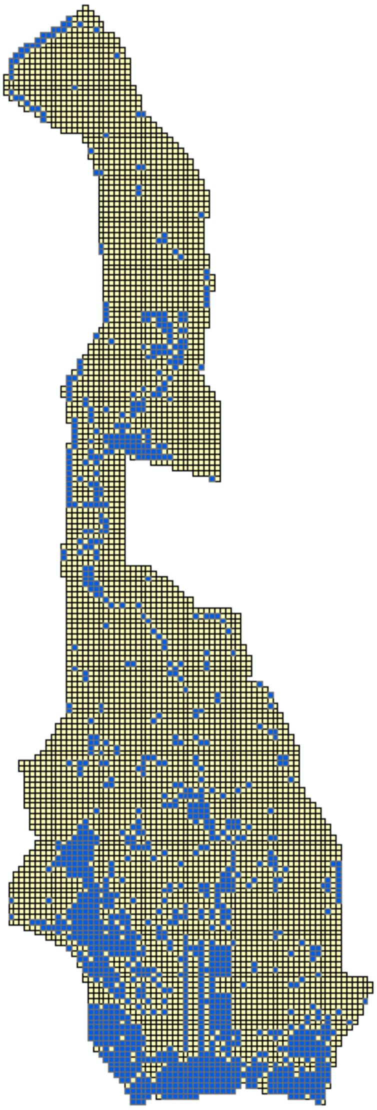
### Checking of Proportion of Measurement Loss

To determine the measurement loss in the measurement result, proportion of measurement loss (proportion of areas with missing measurements in the target area) was calculated.

As the grid interval is 2m in this project, the limit shall be less than 10%.

The proportion of measurement loss indicates the proportion of missing measurements in the target area and it was obtained with the following formula stipulated in the rule.

Proportion of measurement loss = (Number of missing grids/Number of grids)×100



Areas in blue: 10% or more

Figure 2.2.38 Calculation Result of the Proportion of Measurement Loss

Table 2.2.27　Result of Checking the Proportion of Measurement Loss

| Total number of map sheets | Less than 10% | 10% or more |
|---|---|---|
| 6666 | 5,416 | 1,250 |

If the proportion of measurement loss was less than 10%, the measured results should pass. In the event 10% or more of the area is missing, if this is due to the influence of water surface and black colored planimetric features (roofs, etc.), the data was judged as passing.

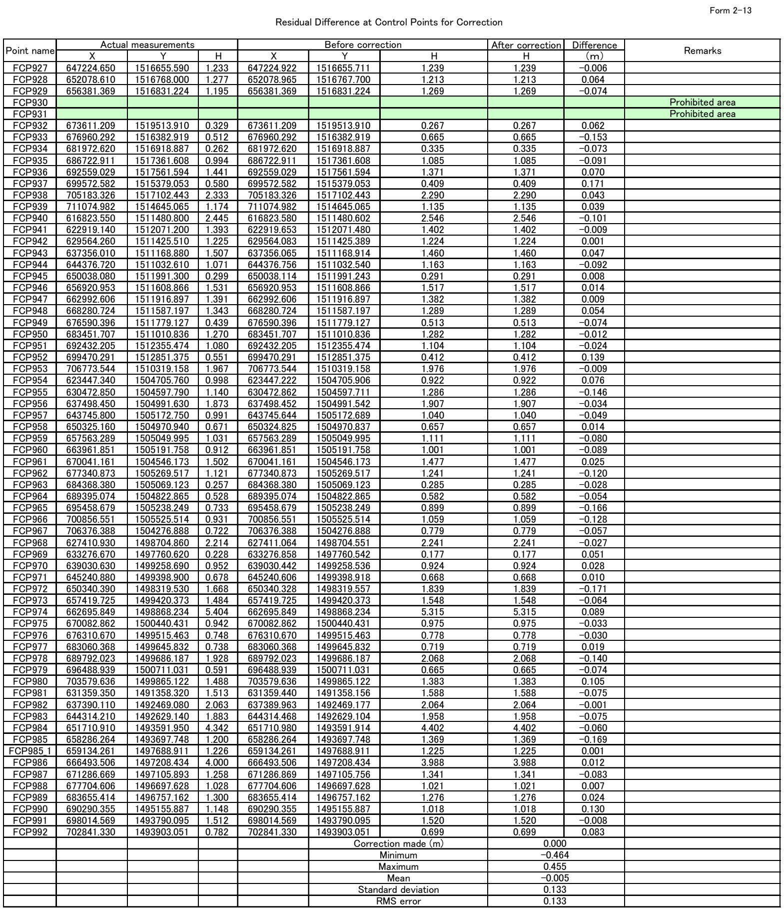
When the proportion of measurement loss was confirmed as exceeding the limit (10%), water surface polygons were created based on the ortho image that had been created.

### Survey of Control Points for Correction

The elevation value of the control points for correction and that of the original data after correction were compared for verification.

As the RMS error was within the prescribed value of 25cm for all the control points for correction, the elevation accuracy of the laser scanning data after correction (correction value: 0.00m) was satisfactory.

Table 2.2.28　Form 2-13 Residual error at Control Points for Correction



Form 2−13

Residual Difference at Control Points for Correction

| Point name | Actual measurements | | | Before correction | | | After correction | Difference | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | X | Y | H | X | Y | H | H | (m) | |
| FCP927 | 647224.650 | 1516655.590 | 1.233 | 647224.922 | 1516655.711 | 1.239 | 1.239 | −0.006 | |
| FCP928 | 652078.610 | 1516768.000 | 1.277 | 652078.965 | 1516767.700 | 1.213 | 1.213 | 0.064 | |
| FCP929 | 656381.369 | 1516831.224 | 1.195 | 656381.369 | 1516831.224 | 1.269 | 1.269 | −0.074 | |
| FCP930 | | | | | | | | | Prohibited area |
| FCP931 | | | | | | | | | Prohibited area |
| FCP932 | 673611.209 | 1519513.910 | 0.329 | 673611.209 | 1519513.910 | 0.267 | 0.267 | 0.062 | |
| FCP933 | 676960.292 | 1516382.919 | 0.512 | 676960.292 | 1516382.919 | 0.665 | 0.665 | −0.153 | |
| FCP934 | 681972.620 | 1516918.887 | 0.262 | 681972.620 | 1516918.887 | 0.335 | 0.335 | −0.073 | |
| FCP935 | 686722.911 | 1517361.608 | 0.994 | 686722.911 | 1517361.608 | 1.085 | 1.085 | −0.091 | |
| FCP936 | 692559.029 | 1517561.594 | 1.441 | 692559.029 | 1517561.594 | 1.371 | 1.371 | 0.070 | |
| FCP937 | 699572.582 | 1515379.053 | 0.580 | 699572.582 | 1515379.053 | 0.409 | 0.409 | 0.171 | |
| FCP938 | 705183.326 | 1517102.443 | 2.333 | 705183.326 | 1517102.443 | 2.290 | 2.290 | 0.043 | |
| FCP939 | 711074.982 | 1514645.065 | 1.174 | 711074.982 | 1514645.065 | 1.135 | 1.135 | 0.039 | |
| FCP940 | 616823.550 | 1511480.800 | 2.445 | 616823.580 | 1511480.602 | 2.546 | 2.546 | −0.101 | |
| FCP941 | 622919.140 | 1512071.200 | 1.393 | 622919.653 | 1512071.480 | 1.402 | 1.402 | −0.009 | |
| FCP942 | 629564.260 | 1511425.510 | 1.225 | 629564.083 | 1511425.389 | 1.224 | 1.224 | 0.001 | |
| FCP943 | 637356.010 | 1511168.880 | 1.507 | 637356.065 | 1511168.914 | 1.460 | 1.460 | 0.047 | |
| FCP944 | 644376.720 | 1511032.610 | 1.071 | 644376.756 | 1511032.540 | 1.163 | 1.163 | −0.092 | |
| FCP945 | 650038.080 | 1511991.300 | 0.299 | 650038.114 | 1511991.243 | 0.291 | 0.291 | 0.008 | |
| FCP946 | 656920.953 | 1511608.866 | 1.531 | 656920.953 | 1511608.866 | 1.517 | 1.517 | 0.014 | |
| FCP947 | 662992.606 | 1511916.897 | 1.391 | 662992.606 | 1511916.897 | 1.382 | 1.382 | 0.009 | |
| FCP948 | 668280.724 | 1511587.197 | 1.343 | 668280.724 | 1511587.197 | 1.289 | 1.289 | 0.054 | |
| FCP949 | 676590.396 | 1511779.127 | 0.439 | 676590.396 | 1511779.127 | 0.513 | 0.513 | −0.074 | |
| FCP950 | 683451.707 | 1511010.836 | 1.270 | 683451.707 | 1511010.836 | 1.282 | 1.282 | −0.012 | |
| FCP951 | 692432.205 | 1512355.474 | 1.080 | 692432.205 | 1512355.474 | 1.104 | 1.104 | −0.024 | |
| FCP952 | 699470.291 | 1512851.375 | 0.551 | 699470.291 | 1512851.375 | 0.412 | 0.412 | 0.139 | |
| FCP953 | 706773.544 | 1510319.158 | 1.967 | 706773.544 | 1510319.158 | 1.976 | 1.976 | −0.009 | |
| FCP954 | 623447.340 | 1504705.760 | 0.998 | 623447.222 | 1504705.906 | 0.922 | 0.922 | 0.076 | |
| FCP955 | 630472.850 | 1504597.790 | 1.140 | 630472.862 | 1504597.711 | 1.286 | 1.286 | −0.146 | |
| FCP956 | 637498.450 | 1504991.630 | 1.873 | 637498.452 | 1504991.542 | 1.907 | 1.907 | −0.034 | |
| FCP957 | 643745.800 | 1505172.750 | 0.991 | 643745.644 | 1505172.689 | 1.040 | 1.040 | −0.049 | |
| FCP958 | 650325.160 | 1504970.940 | 0.671 | 650324.825 | 1504970.837 | 0.657 | 0.657 | 0.014 | |
| FCP959 | 657563.289 | 1505049.995 | 1.031 | 657563.289 | 1505049.995 | 1.111 | 1.111 | −0.080 | |
| FCP960 | 663961.851 | 1505191.758 | 0.912 | 663961.851 | 1505191.758 | 1.001 | 1.001 | −0.089 | |
| FCP961 | 670041.161 | 1504546.173 | 1.502 | 670041.161 | 1504546.173 | 1.477 | 1.477 | 0.025 | |
| FCP962 | 677340.873 | 1505269.517 | 1.121 | 677340.873 | 1505269.517 | 1.241 | 1.241 | −0.120 | |
| FCP963 | 684368.380 | 1505069.123 | 0.257 | 684368.380 | 1505069.123 | 0.285 | 0.285 | −0.028 | |
| FCP964 | 689395.074 | 1504822.865 | 0.528 | 689395.074 | 1504822.865 | 0.582 | 0.582 | −0.054 | |
| FCP965 | 695458.679 | 1505238.249 | 0.733 | 695458.679 | 1505238.249 | 0.899 | 0.899 | −0.166 | |
| FCP966 | 700856.551 | 1505525.514 | 0.931 | 700856.551 | 1505525.514 | 1.059 | 1.059 | −0.128 | |
| FCP967 | 706376.388 | 1504276.888 | 0.722 | 706376.388 | 1504276.888 | 0.779 | 0.779 | −0.057 | |
| FCP968 | 627410.930 | 1498704.860 | 2.214 | 627411.064 | 1498704.551 | 2.241 | 2.241 | −0.027 | |
| FCP969 | 633276.670 | 1497760.620 | 0.228 | 633276.858 | 1497760.542 | 0.177 | 0.177 | 0.051 | |
| FCP970 | 639030.630 | 1499258.690 | 0.952 | 639030.442 | 1499258.536 | 0.924 | 0.924 | 0.028 | |
| FCP971 | 645240.880 | 1499398.900 | 0.678 | 645240.606 | 1499398.918 | 0.668 | 0.668 | 0.010 | |
| FCP972 | 650340.390 | 1498319.530 | 1.668 | 650340.328 | 1498319.557 | 1.839 | 1.839 | −0.171 | |
| FCP973 | 657419.725 | 1499420.373 | 1.484 | 657419.725 | 1499420.373 | 1.548 | 1.548 | −0.064 | |
| FCP974 | 662695.849 | 1498868.234 | 5.404 | 662695.849 | 1498868.234 | 5.315 | 5.315 | 0.089 | |
| FCP975 | 670082.862 | 1500440.431 | 0.942 | 670082.862 | 1500440.431 | 0.975 | 0.975 | −0.033 | |
| FCP976 | 676310.670 | 1499515.463 | 0.748 | 676310.670 | 1499515.463 | 0.778 | 0.778 | −0.030 | |
| FCP977 | 683060.368 | 1499645.832 | 0.738 | 683060.368 | 1499645.832 | 0.719 | 0.719 | 0.019 | |
| FCP978 | 689792.023 | 1499686.187 | 1.928 | 689792.023 | 1499686.187 | 2.068 | 2.068 | −0.140 | |
| FCP979 | 696488.939 | 1500711.031 | 0.591 | 696488.939 | 1500711.031 | 0.665 | 0.665 | −0.074 | |
| FCP980 | 703579.636 | 1499865.122 | 1.488 | 703579.636 | 1499865.122 | 1.383 | 1.383 | 0.105 | |
| FCP981 | 631359.350 | 1491358.320 | 1.513 | 631359.440 | 1491358.156 | 1.588 | 1.588 | −0.075 | |
| FCP982 | 637390.110 | 1492469.080 | 2.063 | 637389.963 | 1492469.177 | 2.064 | 2.064 | −0.001 | |
| FCP983 | 644314.210 | 1492629.140 | 1.883 | 644314.468 | 1492629.104 | 1.958 | 1.958 | −0.075 | |
| FCP984 | 651710.910 | 1493591.950 | 4.342 | 651710.980 | 1493591.914 | 4.402 | 4.402 | −0.060 | |
| FCP985 | 658286.264 | 1493697.748 | 1.200 | 658286.264 | 1493697.748 | 1.369 | 1.369 | −0.169 | |
| FCP985_1 | 659134.261 | 1497688.911 | 1.226 | 659134.261 | 1497688.911 | 1.225 | 1.225 | 0.001 | |
| FCP986 | 666493.506 | 1497208.434 | 4.000 | 666493.506 | 1497208.434 | 3.988 | 3.988 | 0.012 | |
| FCP987 | 671286.669 | 1497105.893 | 1.258 | 671286.869 | 1497105.756 | 1.341 | 1.341 | −0.083 | |
| FCP988 | 677704.606 | 1496697.628 | 1.028 | 677704.606 | 1496697.628 | 1.021 | 1.021 | 0.007 | |
| FCP989 | 683655.414 | 1496757.162 | 1.300 | 683655.414 | 1496757.162 | 1.276 | 1.276 | 0.024 | |
| FCP990 | 690290.355 | 1495155.887 | 1.148 | 690290.355 | 1495155.887 | 1.018 | 1.018 | 0.130 | |
| FCP991 | 698014.569 | 1493790.095 | 1.512 | 698014.569 | 1493790.095 | 1.520 | 1.520 | −0.008 | |
| FCP992 | 702841.330 | 1493903.051 | 0.782 | 702841.330 | 1493903.051 | 0.699 | 0.699 | 0.083 | |
| | | | | | Correction made (m) | | 0.000 | | |
| | | | | | Minimum | | −0.464 | | |
| | | | | | Maximum | | 0.455 | | |
| | | | | | Mean | | −0.005 | | |
| | | | | | Standard deviation | | 0.133 | | |
| | | | | | RMS error | | 0.133 | | |

### 2-2-9 Creation of Original Data

In creating 3D data, when the difference from the control points for correction and the result of checking between courses exceeded the limit, or when the result of checking the control points for correction with the 3D data exceeded the limit, the elevation values were corrected by means of parallel movement to offset (shift) them vertically by a uniform amount.

Due to the influence of DOP during scanning and the long course distances, the courses have accumulated IMU errors. Since this resulted in a displacement that would never occur normally, edge smoothing, revision of calibration and correction of minute displacement of the course data were performed in addition to shifting the data vertically by a uniform amount, which is normally performed independently.

Table 2.2.29 Correction for Each Course

| Item | Number of courses | Remarks |
|---|---|---|
| Without correction | 96 | Courses without correction |
| With correction | 542 | Courses for which uniform shifting and edge smoothing of the data were performed |
| Re-calculation | 205 | Courses for which calibration and re-calculation were performed |
| Rejection | 192 | Pass courses, high altitude (3,300ft) courses, etc. |
| Total | 1035 | Measurement courses |

#### Vertical Uniform Shifting

Vertical uniform shifting means to shift an amount of error to equalize the data when the whole course has a certain amount of error, as shown in the diagram below.

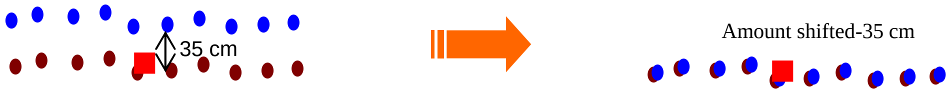


Figure 2.2.39 Conceptual Diagram of Vertical Uniform Shifting

#### Edge Smoothing

Edge smoothing is a method to remove the difference by removing the lap of each course, as shown in the diagram below.

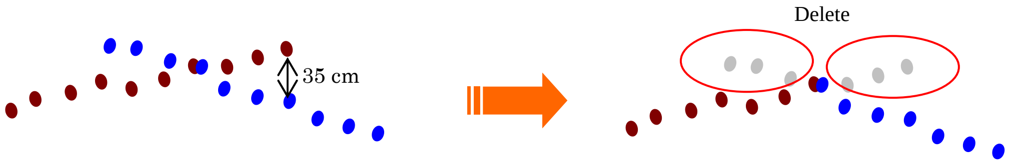


Figure 2.2.40 Conceptual Diagram of Edge Smoothing

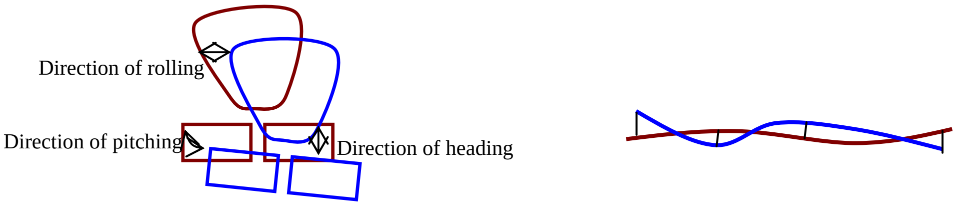
### Re-Calibration

Re-calibration is a method to re-correct the displacement (in three axes) caused by the influence of machine errors.

Figure 2.2.41 Conceptual Diagram of Calibration

### Displacement Correction for Each Course

This method uses the fluctuation correction function of TerraScan and TerraMatch to extract the displacement in the height direction of each point for correction, when the displacement in the height direction, which exists in addition to the displacement in three axes, is not uniform but fluctuating.



Displacement in the direction of three axes Displacement in the height direction

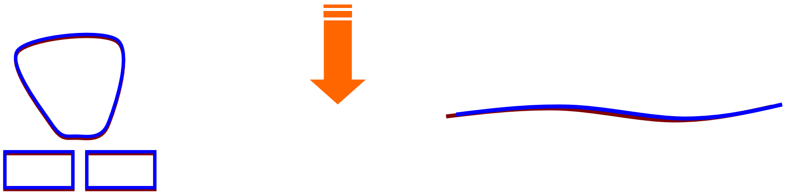
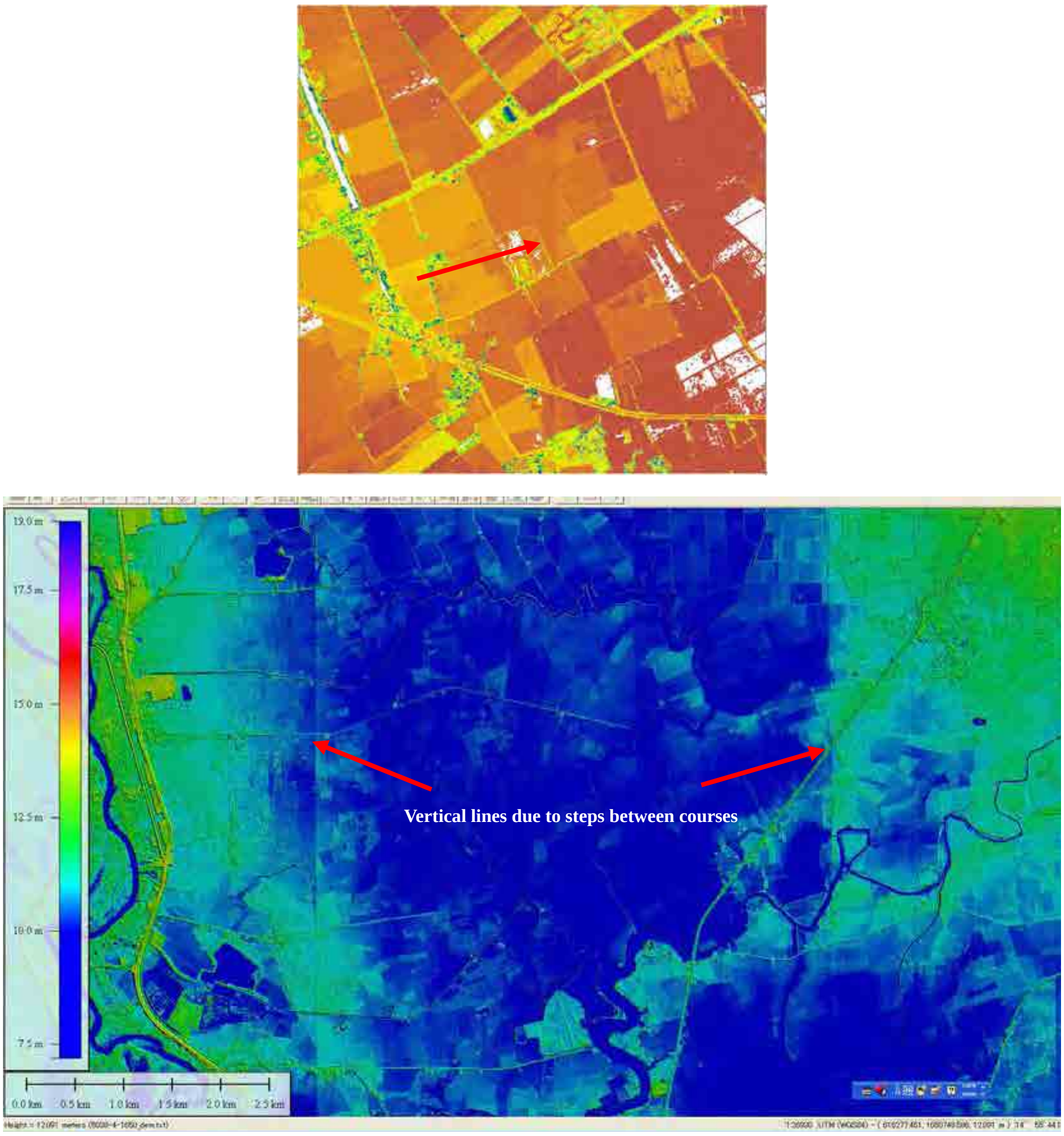


Figure 2.2.42 Conceptual Diagram of Displacement Correction for Each Course

The original data thus created contains differences of about 30cm at a maximum between courses. Therefore, a layer tint map created based on the elevation data shows vertical lines stretching from north to south in some areas. Although this is within the accuracy tolerance limit of airborne laser scanning, care should be taken in using such data.



Vertical lines due to steps between courses

Figure 2.2.43 Layer Tint Map (Visualization of Steps)

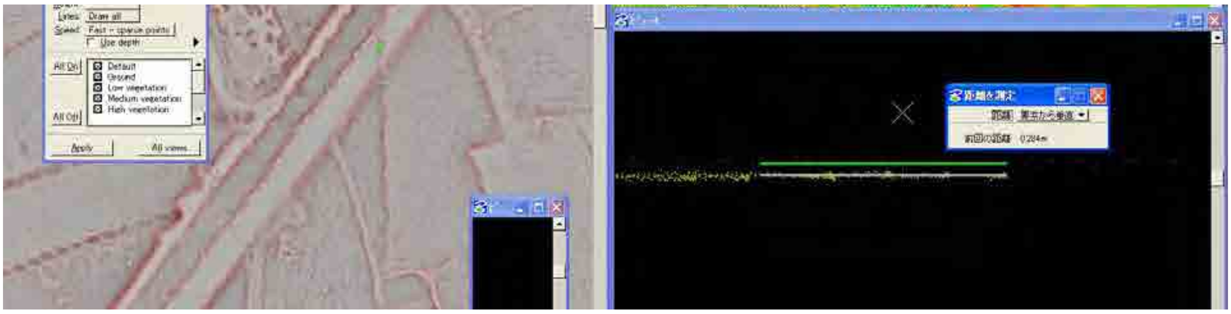


Figure 2.2.44 Confirmation of Step Profile

It should be noted that the step is within 30cm, which is the standard value.

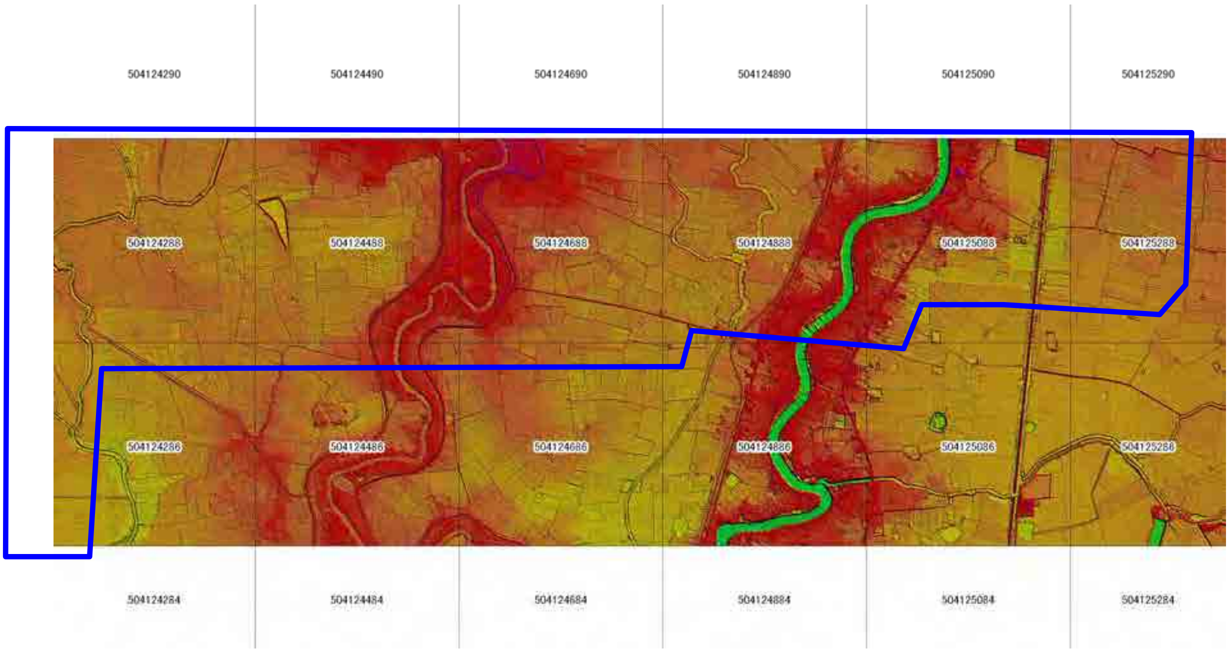


Figure 2.2.45 Confirmation of Step Profile

In particular, there is a difference in elevation between the blocks. Because above maps (7 maps) have been found some step, when it is necessary to use to be caution.

The data was created in text files in accordance with Form 2-18.

File name : 5136IV7438**_org.txt**

Id1, x1, y1, z1, p1 Id : Unique serial number within the file
id2, x2, y2, z2, p2 X1,Y1 : Measured coordinate value (in meters, up to the second decimal place)
: : : : : Z1 : Elevation value (in meters, up to the second decimal place)
idn, xn, yn, zn, pn px : x is a pulse number.

### 2-2-10 Creation of Ground Data

The ground data is the portion of the original data that indicates the ground elevation. It is created by filtering the original data. With respect to the filtering items, original specifications of Thailand (Figure 2.2.46-Figure 2.2.49) were created based on Japanese standards.

Table 2.2.30 Filtering Items

| | | |
|---|---|---|
| Transport facilities | Road facilities, etc. | Road bridges (5m or more long), viaducts, pedestrian bridge lights, signal lights, road signs, etc. |
| | Railroad facilities | Railroad bridges (5m or more long), viaducts (including B.T.S. elevated bridges), over bridges, platforms, platform roofs, line support poles, signal light poles |
| | Mobile items | Vehicles, railroad cars, vessels |
| Buildings, etc. | Buildings, ancillary facilities, etc. | Ordinary housing, factories, warehouses, public facilities, stations, structures without walls (hot houses, green houses), stadium grandstands, gates, pools (including foundation), fences |
| Small objects | | Memorial statues, water tanks, fertilizer tanks, water towers, cranes, smokestacks, towers, broadcast towers, lighthouses, light beacons, transport pipe (on ground, in air), power transmission lines |
| Water surface | Structures related to water surface | Pontoons, water level observation facilities, river signs |
| Vegetation | | Trees *1, bamboo forests *1, hedges *1 |
| Other | Other | Areas with large-scale construction *2, areas with excavation work for subways, materials in open-air storage |
| Remarks | *1: Items that can be judged as ground level shall be adopted as much as possible.<br>*2: Items that can be nearly judged as permanent ground level shall be adopted. | |

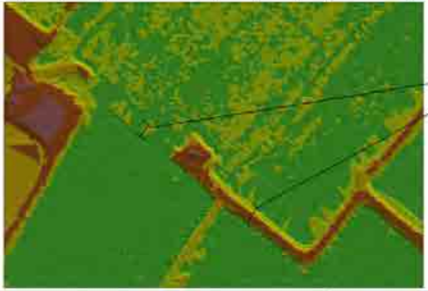
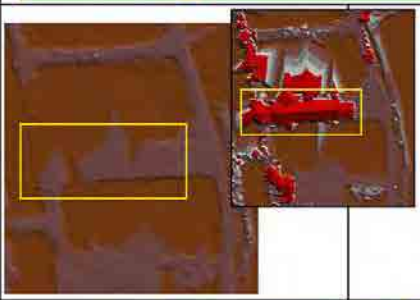
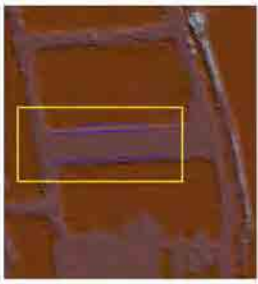
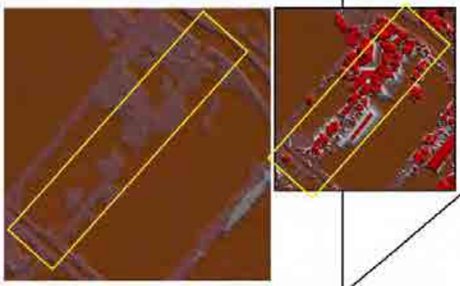
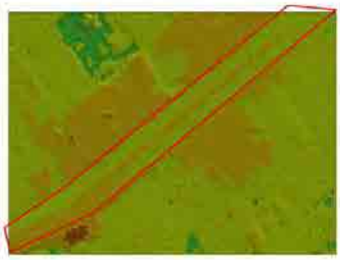
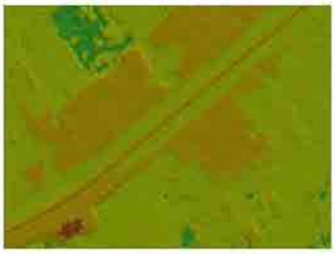
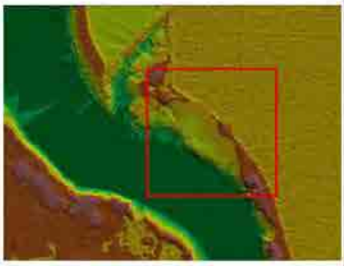
|  | Automatic filtering | Manual filtering | Description |
|---|---|---|---|
| Road |  |  | Adoption of footpath<br>(Footpaths of 7.5m or more in width shall always be adopted.) |
|  |  | Road width shall be measured from the topographic rise |  |
| Road |  |  | <br> <br>When a road is partly covered by a building of 50m or less in length and there is no point on the ground, the road shall be interpolated at the break points. |
| Road |  |  | When a footpath does not have a ground point as it is covered by trees and buildings (the elevation of the break point cannot be determined because the elevation of the footpath is missing)<br>No correction |
| Road |  |  | Topographic swelling of a median strip<br>Adopted |
| River |  |  | Topographic deformation along the river due to buildings<br>No correction |

Figure 2.2.46 Filtering Specifications

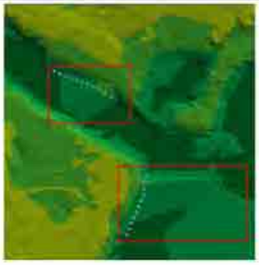
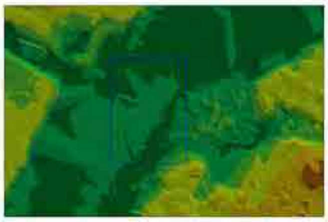
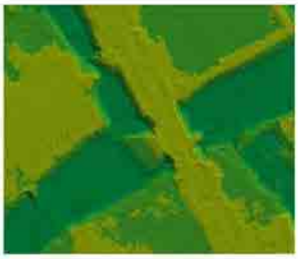
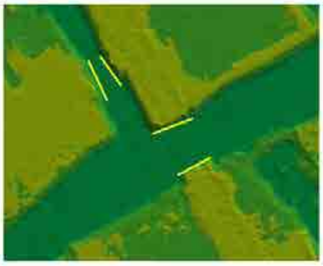
|  | Automatic filtering | Manual filtering | Description |
|---|---|---|---|
| River |  |  | Adoption of dykes and river banks<br>(shall be interpolated at break points) |
| River |  |  | Stretching from the land to the river<br>No correction<br>* However, if both shores are connected at the same level as the land, a breakpoint shall be inserted. |
| River |  |  | River<br>No correction due to no TIN stretching from land |
| River |  |  | Elevation difference in areas with running water shall not be corrected. |
| River |  |  | River width is less than 7.5m<br>TIN stretching of both shores<br>No correction |
| River |  |  | <br>Bridges over rivers of 7.5m or more in width shall be removed. |

Figure 2.2.47 Filtering Specifications

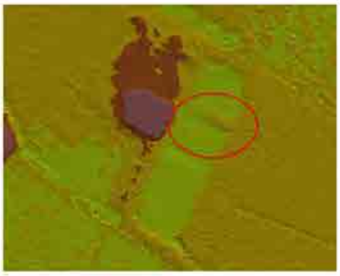
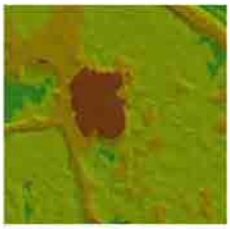
|  | Automatic filtering | Manual filtering | Description |
|---|---|---|---|
| River |  |  |  <br>River mouths shall be adopted. |
| River |  |  | Water plants in waterways<br>No correction |
| Pond |  |  | Pond<br>TIN stretching from the land to the pond<br>No correction |
| Rice field |  |  | Rice field<br>TIN stretching from the land to the rice field<br>No correction |
| Topography |  |  | Topographic swelling<br>Adopted |
| Buildings |  |  | Removal of buildings |

Figure 2.2.48 Filtering Specifications

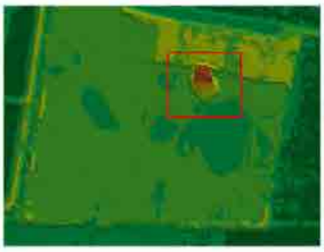
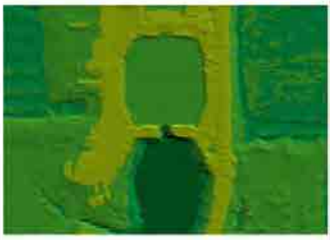
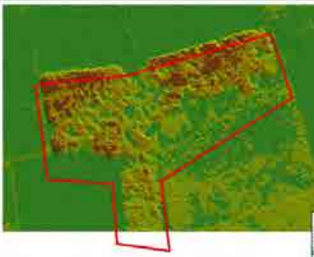
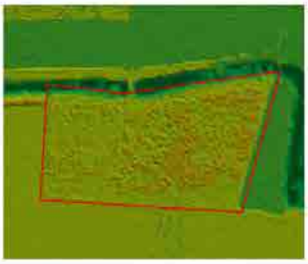
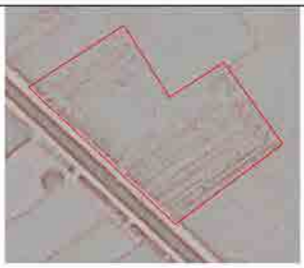
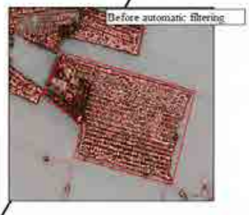
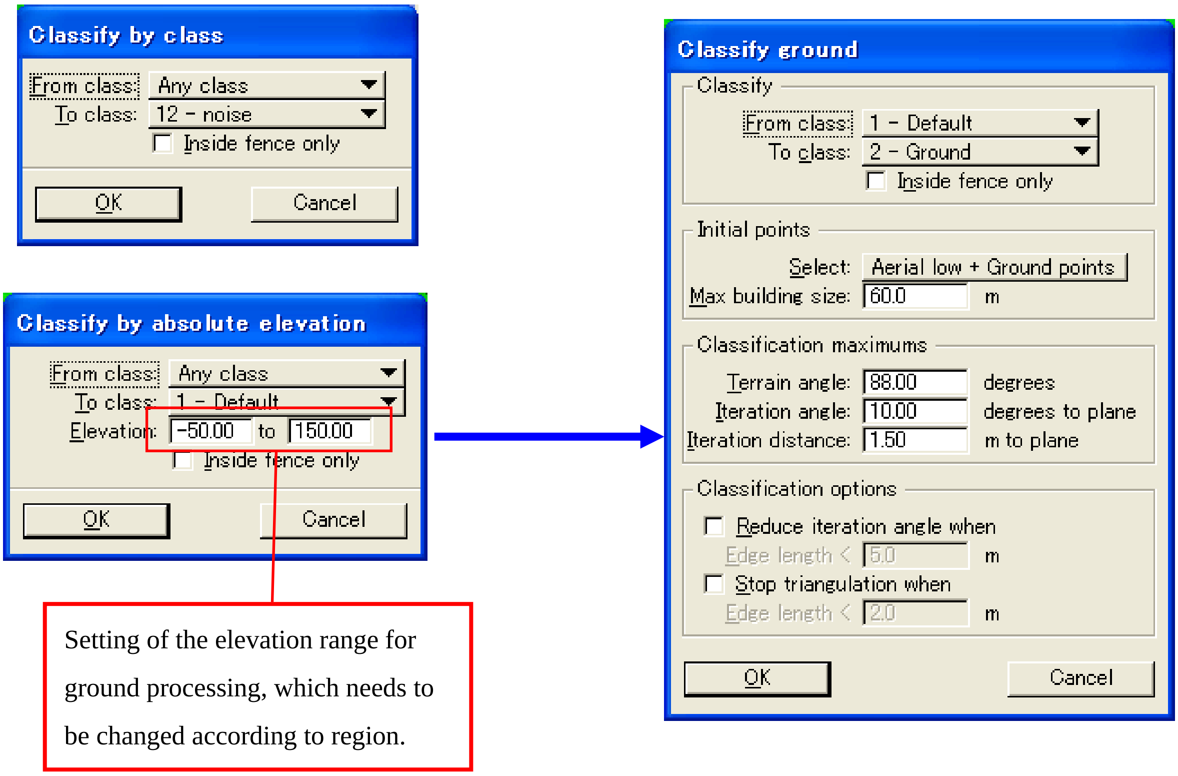
|  | Automatic filtering | Manual filtering | Description |
|---|---|---|---|
| Building |  |  | Removal of buildings on a farm |
| Dam |  |  | Dam restoration |
| Plants |  | <br> | A field like a sugar cane field<br>Elevation difference from the ground: 1-3m<br>Removal of plants<br>Rejected |
| Plants |  |  | Undergrowth<br>No correction (as automatically filtered) |
| Plant |  | <br>Before automatic filtering | Rice and other crops<br>No correction (as automatically filtered) |
| Plants |  | <br>Before automatic filtering |  |

Figure 2.2.49 Filtering Specifications

Filtering was performed automatically by using TerraScan (made by TerraSolid). Parameters used for the filtering process are described in the following figure.



**Classify by class**

From class: Any class
To class: 12 - noise
☐ Inside fence only

**Classify by absolute elevation**

From class: Any class
To class: 1 - Default
Elevation: -50.00 to 150.00
☐ Inside fence only

**Classify ground**

Classify
From class: 1 - Default
To class: 2 - Ground
☐ Inside fence only

Initial points
Select: Aerial low + Ground points
Max building size: 60.0 m

Classification maximums
Terrain angle: 88.00 degrees
Iteration angle: 10.00 degrees to plane
Iteration distance: 1.50 m to plane

Classification options
☐ Reduce iteration angle when
Edge length < 5.0 m
☐ Stop triangulation when
Edge length < 2.0 m

Setting of the elevation range for ground processing, which needs to be changed according to region.

Figure 2.2.50 Setting of Automatic Filtering Parameters

Visual checking was performed on the data that had been automatically processed, and unsuitable locations were edited with Arc GIS (made by ESRI), which is interactive software for manual processing. In addition, when checking was performed, data of topographic maps, such as slope classification maps, for which the topography could have been interpreted, were used to correct problem locations. Furthermore, after overall checking, sampling inspection was carried out within the project office by drawing a sample representing 2% of the total volume, to ensure that there was no failure.

Figure 2.2.51 Example of Slope Classification Map

As described in Figure 2.2.52, the ground data should ultimately be point data that represents only the ground surface, excluding planimetric features, such as buildings and trees. The data was created in text files in accordance with a format stipulated in Form 2-18.

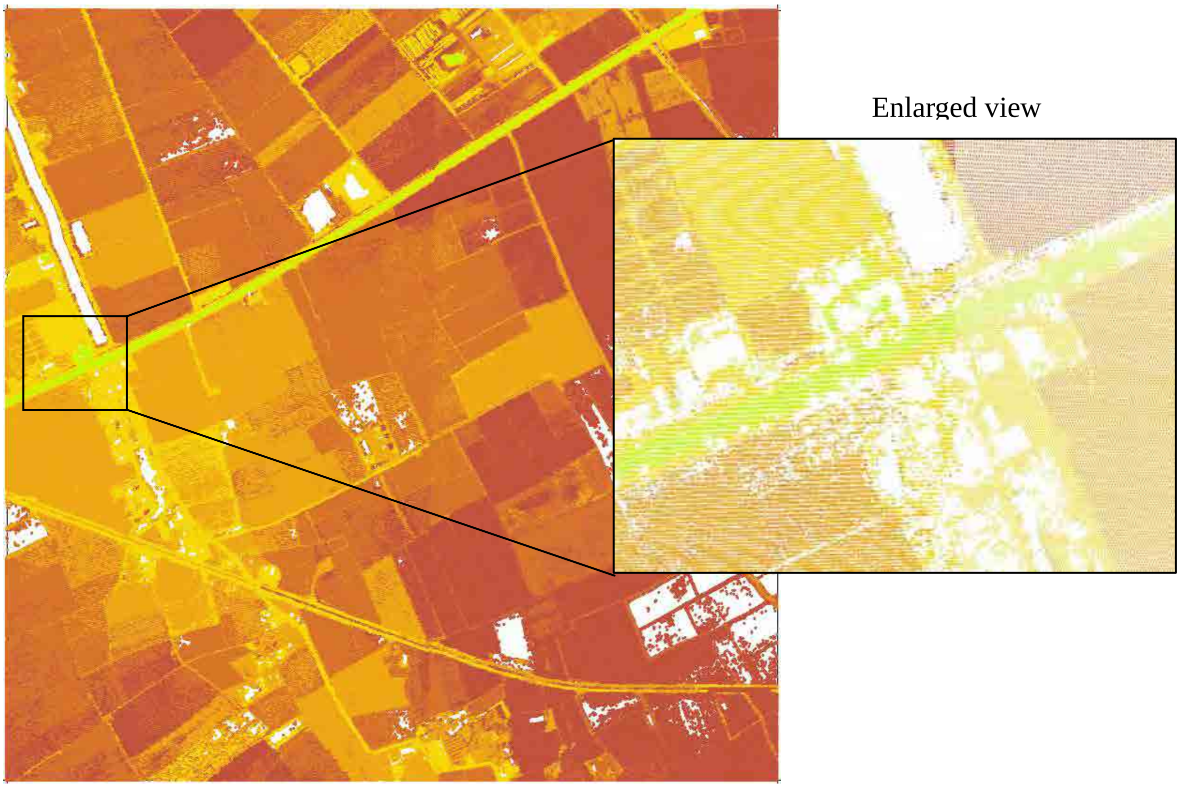


Figure 2.2.52 Ground Data

File name : 5136IV7438**_grd.txt**

Id1, x1, y1, z1

id2, x2, y2, z2

: : : :

idn, xn, yn, zn

Id : Unique serial number within the file

X1,Y1 : Measured coordinate value (in meters, up to the second decimal place)

Z1 : Elevation value (in meters, up to the second decimal place)

### 2-2-11 Creation of Grid Data

Grid data at 2m intervals was created from the ground data by means of interpolation. The TIN method was used to enable the elevation values of the ground data to be extracted during the interpolation process.

Furthermore, data of the slope classifications map was used to check the topography in checking the grid data. As mentioned in the section on original data, due to the influence of the differences between courses, lines may be shown. However, since this is within the accuracy tolerance limit, it is determined that the data has a favorable quality. The data was created in text files in accordance with a format stipulated in Form 2-18.

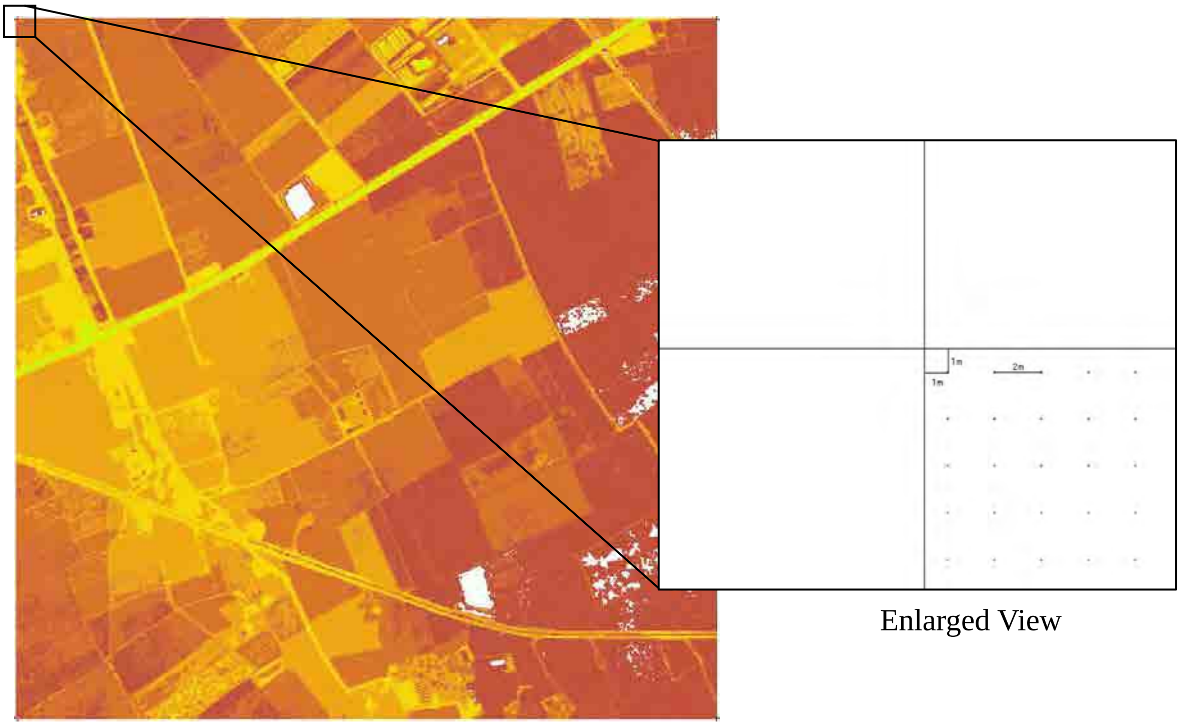


Figure 2.2.53 Example of Grid Data

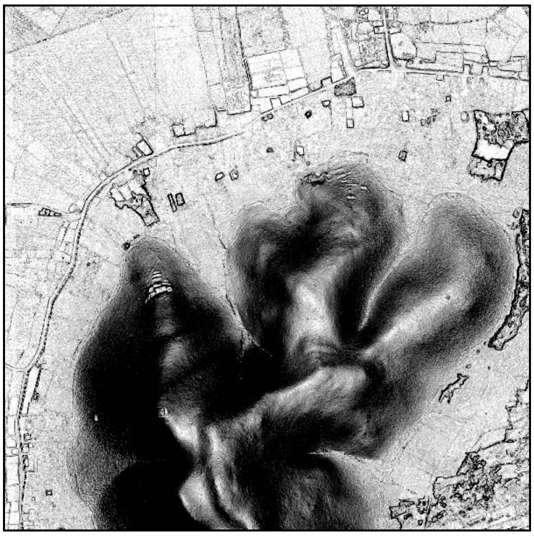


Figure 2.2.54 Example of Slope Classification Map

### 2-2-12 Creation of Contour Line Data

Contour lines at 1m intervals were automatically extracted from the grid data by calculating proximity statistics with 3×3 cells as average in order to conduct leveling. It was initially planned to create contour lines at 2m intervals. However, since contour lines at 2m intervals are unable to express footpaths, as is obvious from Figure 2.2.55, contour lines were created at 1m intervals. Intervals of 0.5m were also taken into consideration, but it was determined that 1m intervals were adequate, as 0.5m interval would result in the creation of detailed contour lines in areas such as in rice fields, making the data difficult to use.

The index contour lines should be 5m, and the intermediate contour lines 1m, with the data file format as Shape file.

Contour Line Data at 2m Intervals Contour Line Data at 1m Intervals

Figure 2.2.55 Comparison of Contour Line Data

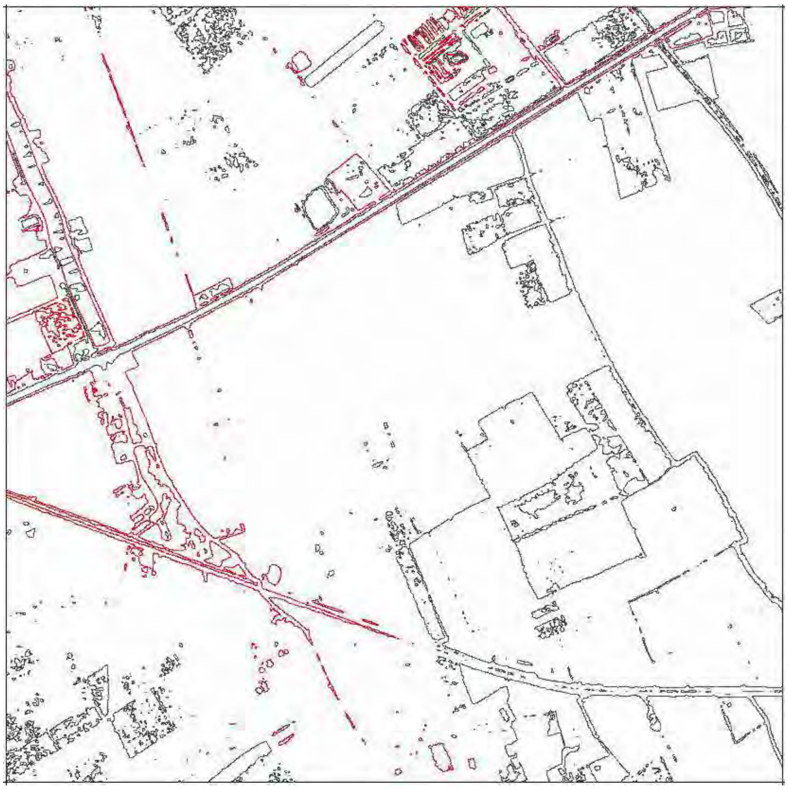


Figure 2.2.56 Contour Line Data (Red Line: Index, Black Line: Intermediate)

### 2-2-13 Digital Aerial Photography

Ground level image data shall be acquired with the CCD camera outlined below at the same time as airborne laser scanning. Photography shall be performed with the digital camera installed at the same time with the airborne laser scanning system on the aircraft. There shall be no limits on the amount of clouds since the main objective is to obtain a grasp of elevation data in the target area.

【Measurement CDD Camera (RCD105) Specifications】

- Lens focal point distance: 59.694mm
- Image size (perpendicular to flight): 7162 pixels
- Image size (flight direction): 5389 pixels
- Pixel size: 6.8μm
- Image resolution on ground: Approx. 35cm

RCD105

ProSilica

Table 2.2.31 Equipment Input

| | Aircraft No. | Model | Airborne Laser Scanning Equipment | Digital Camera |
|---|---|---|---|---|
| 1 | HS-RSI | Piper PA-31-350 | Leica ALS50-II (SN58) | Leica RCD105 |
| 2 | OO-MAP | Cessna 404 | Leica ALS60 (SN6125) | Leica RCD105 |
| 3 | VH-WGS | Cessna 404 | Leica ALS50 (SN31) | ––– |
| 4 | VH-AZU | Cessna 404 | Leica ALS50-II (SN87) | ProSilica |

Since VH-WGS does not have a camera installed, it mainly took flights over the areas where photography is prohibited (about 600 km$^2$), while other aircraft took flights over the ordinary areas to ensure that the images would exhaustively cover the target area.

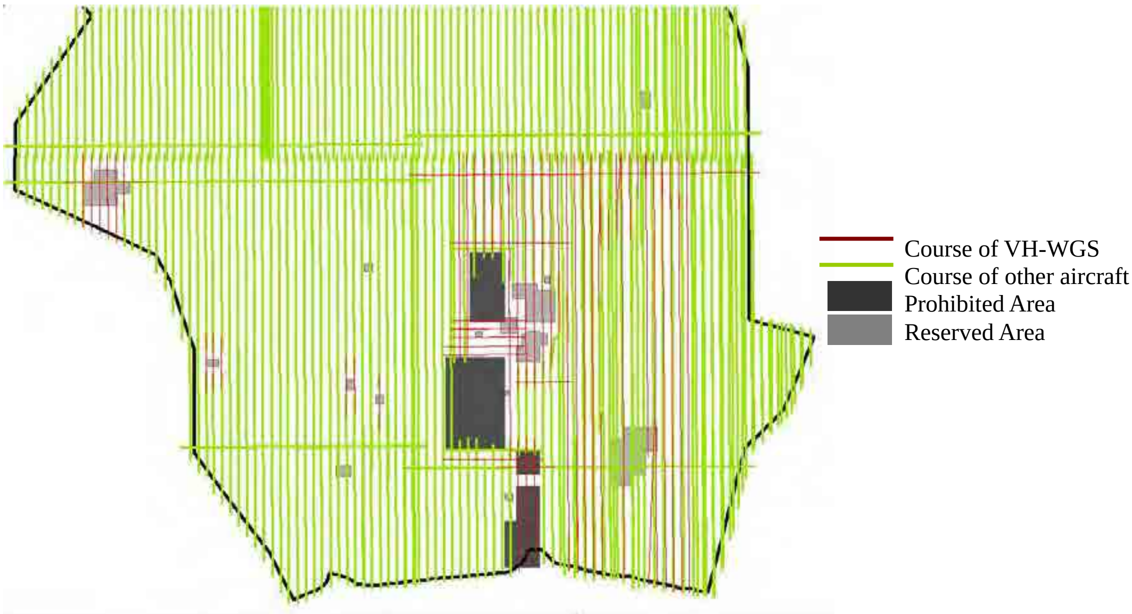


Figure 2.2.57 Flight paths of VH-WGS

### 2-2-14 Creation of Orthophoto Data

Digital orthophoto data was created based on the photographed ground level image data and external orientation elements (positional information of photos) after being corrected for camera inclination and distortion due to the elevation difference. The ground resolution of the orthophoto data to be created should be 0.5m.

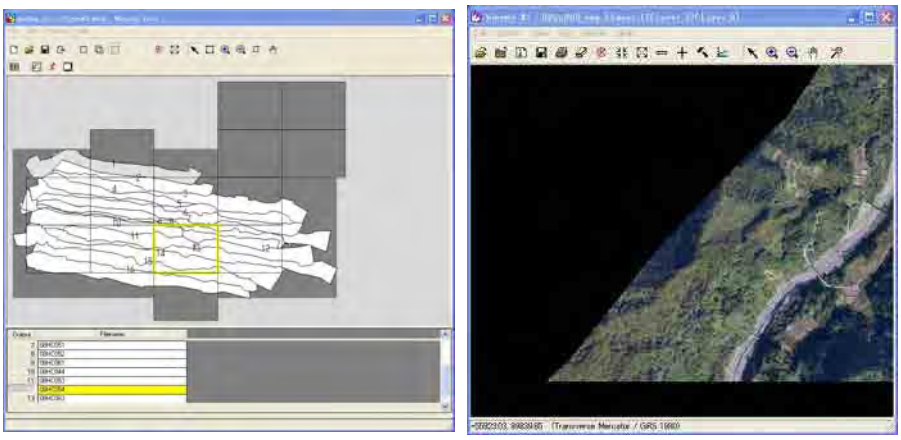


Figure 2.2.58 Creation of Orthophoto (Example of Erdas Imagine)

Without the inclusion of clouds With the inclusion of clouds

Figure 2.2.59 Example of Orthophoto

When the proportion of measurement loss verified in 2-2-9 exceeded the limit (10%), water surface polygons were created based on the ortho images that have been created for rivers of 7.5m in width or wider and ponds, etc. of 7.5m x 7.5m or larger.

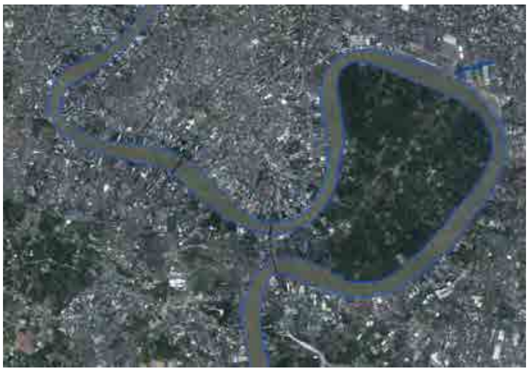


Figure 2.2.60 Water Surface Polygon

### 2-2-15 Data Verification

During data verification, the results obtained from the work in Japan were confirmed and verified in accordance with the details described in the table below. When there were remaining issues to be verified, instructions to perform re-measurement or re-creation of data should be promptly issued. Items that have not been described up to the previous section are described in the table below and the following sections.

Table 2.2.32 Details for Data Verification

| **Verification Items** | **Details for Checking** |
|---|---|
| Censorship of images and data | Confirmation and reflection of censoring of images and data |
| Checking of 3D measurement data | Whether it is within limit value (0.25m) or not |
| Checking of areas between courses | Whether it is within limit value (0.30m) or not |
| Checking of proportion of measurement loss | Whether it is within limit value (10%) or not |
| Examination of control points for correction | Whether correction is necessary or not |
| In-house checking of 3D topographic maps | Confirmation of topographic expressions |
| Ground data creation accuracy control table | Confirmation of accuracy control results |
| Elevation data creation accuracy control table | Confirmation of accuracy control results |
| Digital data creation accuracy control table | Confirmation of accuracy control results |
| Checking of contour line data | Confirmation of topographic expressions |
| Checking of orthophoto data | Confirmation of topographic expressions |
| Checking of water surface polygons | Confirmation of water surface area |
| Checking of cloud polygons | Confirmation of cloud area |

#### 1) Censorship of Images and Data

Censorship was carried out by the RTSD on the measured data to delete military secrets and other data in this project. Areas that were required to be censored were determined through preliminary discussions with the RTSD. The classifications and location map of these areas are given below.

Prohibited Area: Areas where flights for measurement are prohibited

Reserved Area: This includes areas under military restrictions (Military Secured Area) and areas regulated by the Department of Civil Aviation (Civil Aviation Secured Area). Permissions were obtained separately to perform measurement in these areas. Since these areas cannot be open to general public, some of the data was deleted. The deleted data is called Level 1 data, while undeleted data is called Level 0 data. Only the organizations within the Thai government that obtained permission for using the data can access Level 0 data.

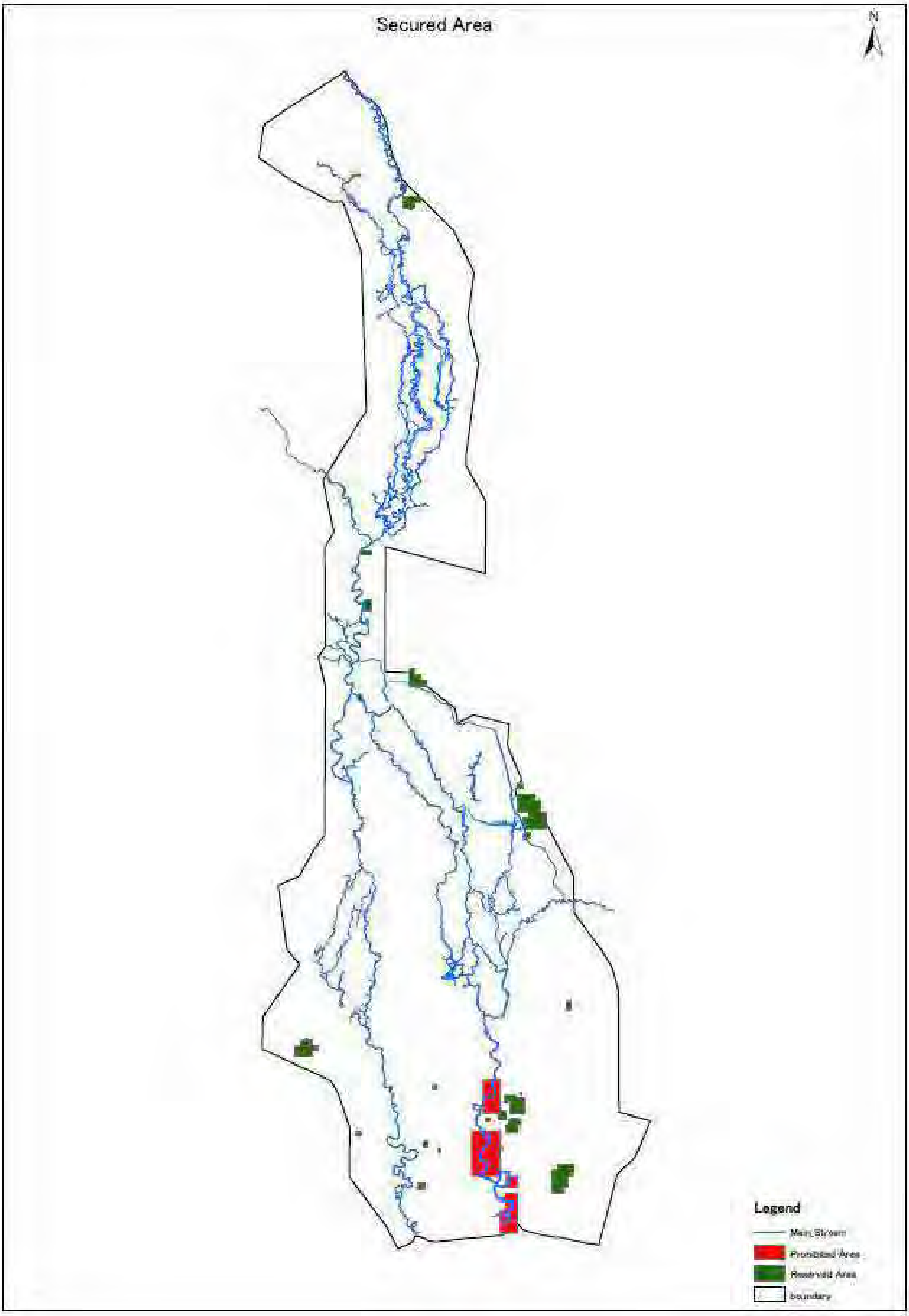


Figure 2.2.61 Areas Under Regulation

**Data Masking for Restricted Areas**

Since the target area of this airborne laser scanning work included restricted areas as indicated in Figure 2.2.61, only for the measurement courses crossing the restricted areas, measured data for the restricted areas was removed to finalize the survey result. Table 2.2.34 shows the cut out point of measured data.

Table 2.2.33 Example of Control Points for Correction Examination Sheet

| Date | Aircraft | LINE ID | LINE NUMBER | File Rename | File Output | |
|---|---|---|---|---|---|---|
| | | | | | First File Number | Last File Number |
| 23-Mar | HS-RSI | 120323_051153 | 6305 | LDR120323_051153_0_I0_1+35cm | 1 | 32 |
| | | | | LDR120323_051153_0_I0_2+35cm | 38 | 59 |
| 11-Apr | HS-RSI | 120411_042500 | 609 | LDR120411_042500_0_I0_1 | 2 | 12 |
| 31-Mar | OO-MAP | 120331_023514 | 6312 | LDR120331_023514_0_I0_1+39cm | 1 | 2 |
| | | | | LDR120331_023514_0_I0_2+39cm | 7 | 18 |
| 10-Apr | VH-WGS | 120410_024101 | ADD_8R | LDR120410_024101_0_I0_1 | 1 | 8 |
| | | | | LDR120410_024101_0_I0_2 | 12 | 13 |
| | | 120410_024639 | P16R | LDR120410_024639_0_I0_1 | 1 | 4 |
| | | | | LDR120410_024639_0_I0_2 | 8 | 11 |
| | | 120410_025508 | 6318R | LDR120410_025508_0_I0_1 | 1 | 3 |
| | | | | LDR120410_025508_0_I0_2 | 7 | 18 |
| | | | | LDR120410_025508_0_I0_3 | 25 | 27 |
| | | 120410_030326 | 6315R | LDR120410_030326_0_I0_1 | 1 | 8 |
| | | | | LDR120410_030326_0_I0_2 | 13 | 16 |
| | | | | LDR120410_030326_0_I0_3 | 21 | 23 |
| | | 120410_030955 | 6314R | LDR120410_030955_0_I0_1 | 1 | 4 |
| | | | | LDR120410_030955_0_I0_2 | 8 | 12 |
| | | | | LDR120410_030955_0_I0_3 | 16 | 19 |
| | | | | LDR120410_030955_0_I0_4 | 26 | 27 |

Censorship during the implementation of the work was carried out as described below.

(1) Censorship during measurement (on board): Monitoring by security officers who were on board the aircraft for measurement to check if any measurement was carried out in the flight prohibited areas.

(2) Data censorship after measurement (airport): Censorship by security officers on image data downloaded after measurement to ensure that data measured of restricted areas, if any, is deleted or stored so that such data will not be sent to post processing.

(3) Data censorship after primary processing (project office): Censorship by security officers to check if images after primary processing and processed data before dispatch to Japan include restricted areas.

(4) Censorship after data creation (each workshop in Japan): Censorship by security officers to ensure that restricted areas have been deleted after the creation of Level 0 and Level 1 data.

(5) Final result censorship (project office): Censorship by security officers to ensure that restricted areas have been deleted from the final results created as Level 0 and Level 1 data.

### 2) In-House Checking of 3D Topographic Maps

Visual checking was performed for locations with inadequate filtering, focusing on the following checkpoints.

- Whether or not filtering has been carried out appropriately shall be checked.
- Causes for outstanding locations, such as locations with large angles of slope, shall be investigated.

Figure 2.2.62 Ortho Image

When the original data is shown on the slope classification map, DSM is indicated. Locations with large angles of slope are expressed as in the following figure.

Figure 2.2.63 Original

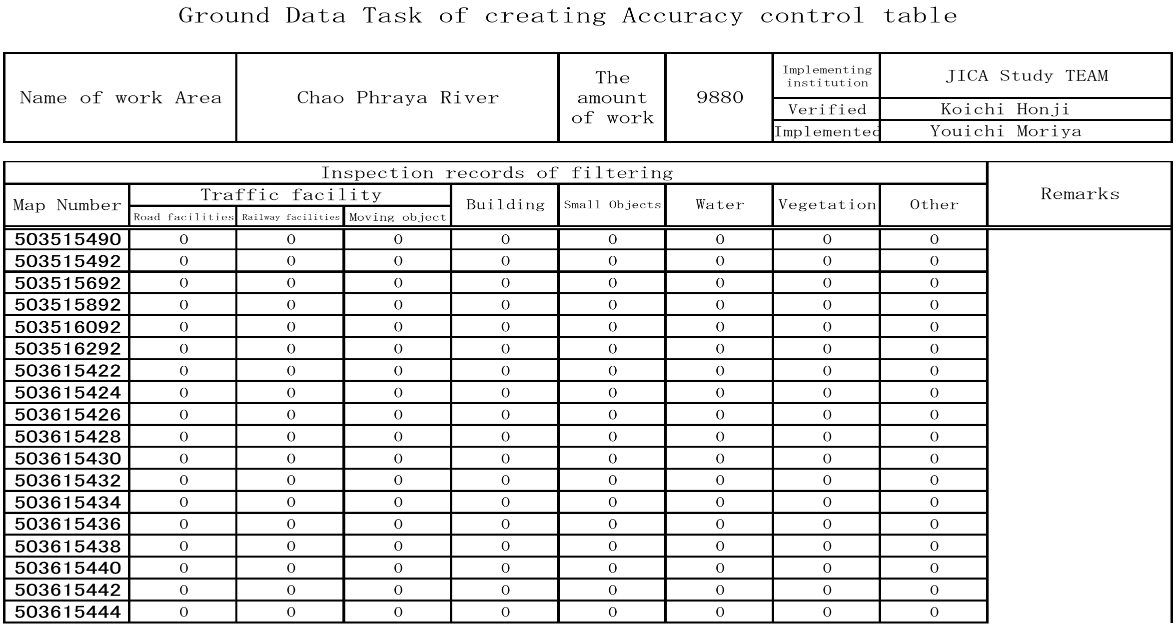
When the ground data is shown on the slope classification map, DTM is indicated. Locations with a small angle of slope represent the total as in the following figure.

Figure 2.2.64 Ground Data Slope Classification Map

### 3) Ground Data Creation accuracy control table

The results of checking the ground data for each of the 1:4000 map sheets were summarized into an accuracy control table.

Table 2.2.34 Ground Data Creation accuracy control table



Ground Data Task of creating Accuracy control table

| | | | | | |
|---|---|---|---|---|---|
| Name of work Area | Chao Phraya River | The amount of work | 9880 | Implementing institution | JICA Study TEAM |
| | | | | Verified | Koichi Honji |
| | | | | Implemented | Youichi Moriya |

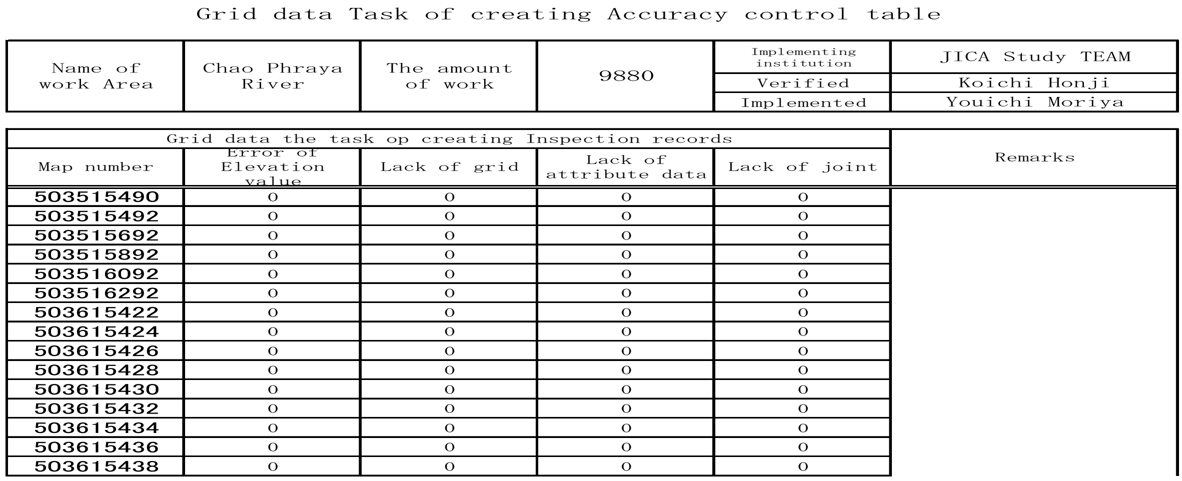
| Map Number | Inspection records of filtering | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Traffic facility | | | Building | Small Objects | Water | Vegetation | Other | |
| | Road facilities | Railway facilities | Moving object | | | | | | |
| 503515490 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503515492 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503515692 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503515892 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503516092 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503516292 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615422 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615424 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615426 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615428 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615430 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615432 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615434 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615436 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615438 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615440 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615442 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615444 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

Since the result of final inspection is entered, the inspection result should be “0”.

### 4) Grid Data Creation accuracy control table

The results of checking the created grid data for each of the 1:4000 map sheets were summarized into an accuracy control table.

Table 2.2.35 Grid Data Creation accuracy control table



Grid data Task of creating Accuracy control table

| | | | | | |
|---|---|---|---|---|---|
| Name of work Area | Chao Phraya River | The amount of work | 9880 | Implementing institution | JICA Study TEAM |
| | | | | Verified | Koichi Honji |
| | | | | Implemented | Youichi Moriya |

| Grid data the task op creating Inspection records | | | | | Remarks |
|---|---|---|---|---|---|
| Map number | Error of Elevation value | Lack of grid | Lack of attribute data | Lack of joint | |
| 503515490 | 0 | 0 | 0 | 0 | |
| 503515492 | 0 | 0 | 0 | 0 | |
| 503515692 | 0 | 0 | 0 | 0 | |
| 503515892 | 0 | 0 | 0 | 0 | |
| 503516092 | 0 | 0 | 0 | 0 | |
| 503516292 | 0 | 0 | 0 | 0 | |
| 503615422 | 0 | 0 | 0 | 0 | |
| 503615424 | 0 | 0 | 0 | 0 | |
| 503615426 | 0 | 0 | 0 | 0 | |
| 503615428 | 0 | 0 | 0 | 0 | |
| 503615430 | 0 | 0 | 0 | 0 | |
| 503615432 | 0 | 0 | 0 | 0 | |
| 503615434 | 0 | 0 | 0 | 0 | |
| 503615436 | 0 | 0 | 0 | 0 | |
| 503615438 | 0 | 0 | 0 | 0 | |

Since the result of final inspection is entered, the inspection result should be “0”.

### 5) Digital Data File Creation accuracy control table

The results of checking the created grid data for each of the 1:4000 map sheets were summarized into an accuracy control table. A diagonal line has been entered for the grids that do not require the creation of water surface polygons.

Table 2.2.36 Digital Topographic Map Data File Creation accuracy control table

Figure terrain data file task of creating accuracy control table

| | | | | | |
|---|---|---|---|---|---|
| Name of work Area | Chao Phraya River | The amount of work | 9880 | Implementing institution | JICA Study TEAM |
| | | | | Verified | Koichi Honji |
| | | | | Implemented | Youichi Moriya |

| Figure terrain data file task of creating Inspection records | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| Map Number | Original data | | Ground data | | Grid data | | Water Polygon | |
| | Graphic quality of the file structure point | Quality of the file structure attribute point | Graphic quality of the file structure point | Quality of the file structure attribute point | Quality of the header format | Quality of the text format | Quality of the polygon file structure | |
| 503515490 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503515492 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503515692 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503515892 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503516092 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503516292 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615422 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615424 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615426 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615428 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615430 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615432 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615434 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615436 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615438 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615440 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615442 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 503615444 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 503615446 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

Since the result of final inspection is entered, the inspection result should be “0”.

### 6) Checking of Contour Line Data

To check the created contour line data, contour lines were created from the grid data and visual checking was performed for locations with unnatural terrain shapes, using GIS software.

Checking was carried out for the following three points.

- If the contour line interval was 1m
- Errors and omissions of the contour line data
- Shape of the contour line data

The location of the contour lines was checked by indicating the intermediate contour lines in blue and index contour lines in black.

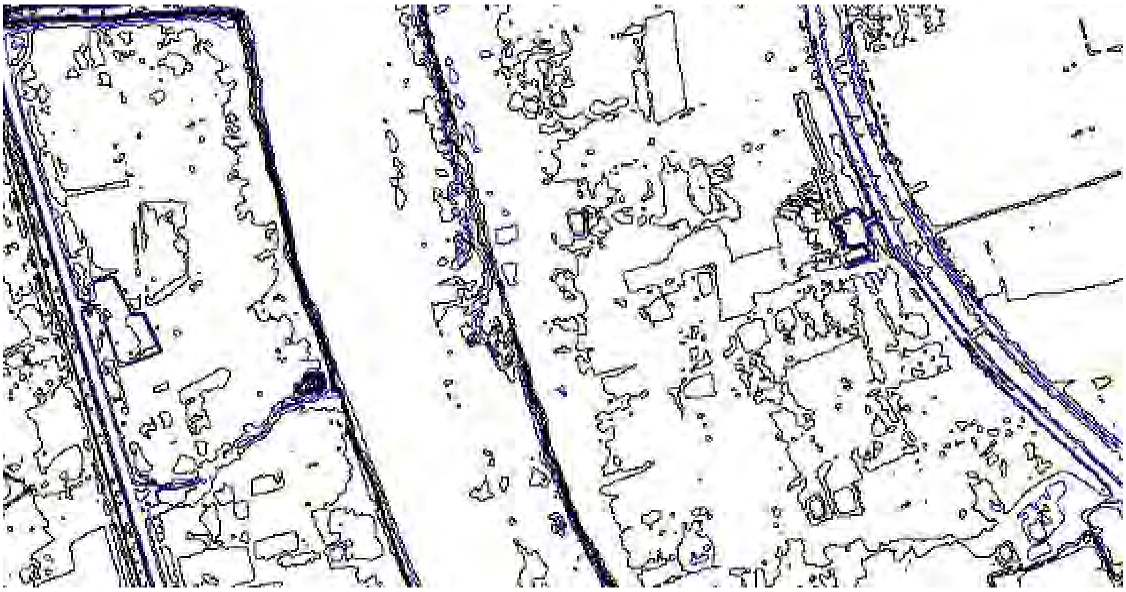


Figure 2.2.65　Contour Line Data

To check the location, ortho images were superimposed on top of the contour lines.

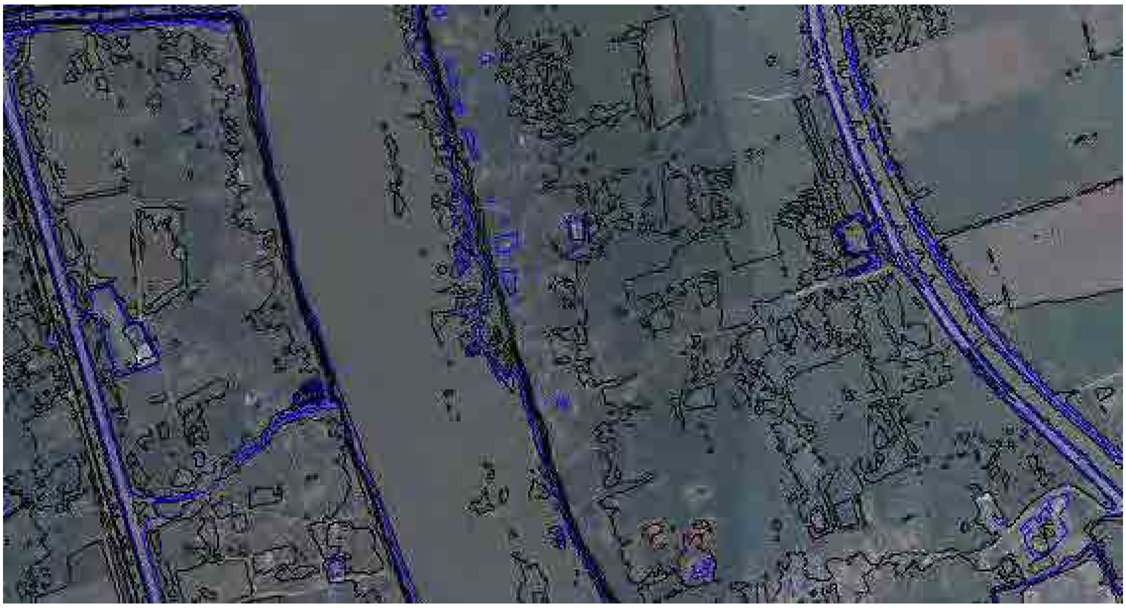


Figure 2.2.66　Ortho Image Superimposed on Contour Lines

Elevation value attributes were indicated to visually check the errors and omissions in the entry of attributes.

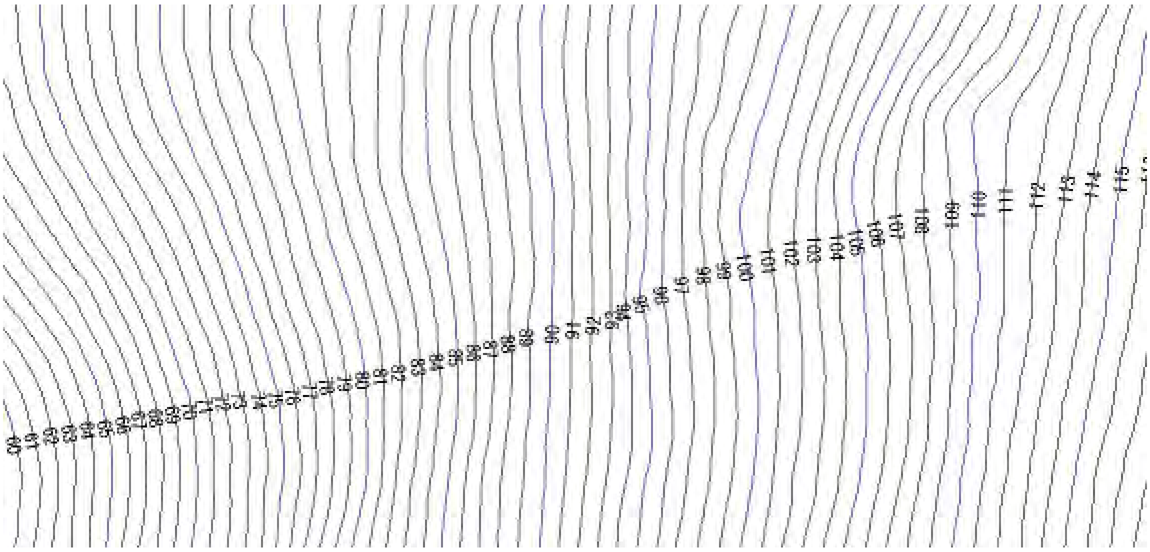


Figure 2.2.67 Indication of Elevation Value Attributes

The shape was checked for abnormality.

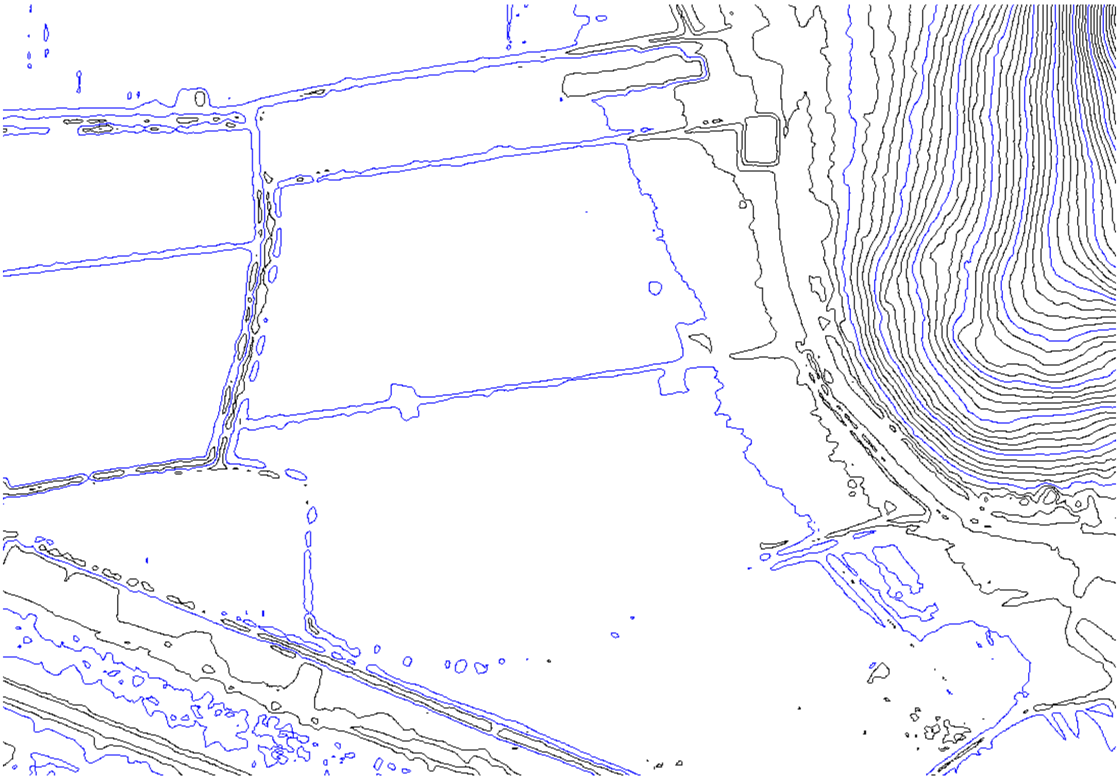


Figure 2.2.68 Checking of Contour Line Shape

### 7) Checking of Orthophoto Data

Orthophoto data was used to investigate the causes of the proportion of measurement loss in 3D measurement data being 10% or higher and to interpret planimetric features in performing filtering. Therefore, with respect to the target area of filtering, causes of areas that appeared blank in ortho creation and locations for ortho creation, were visually identified by using GIS software.

Blank areas were found in the following areas and their major causes are as follows:

- Sidelap breakage between courses
- Areas where flight is prohibited

Figure 2.2.69 Example of Broken Sidelap

Defects of the images used for ortho creation may cause displacement of the data as indicated in the following figure. Causes of such defects were investigated and corrected.

Figure 2.2.70 Example of Location to be Checked for Errors in Ortho Creation

### 8) Checking of Water Surface Polygon

With respect to the map sheets that the proportion of measurement loss exceeded the limit value (10%), water surface polygons were created based on the ortho images for rivers of 7.5m or more in width and ponds and others of 7.5m×7.5m or larger.

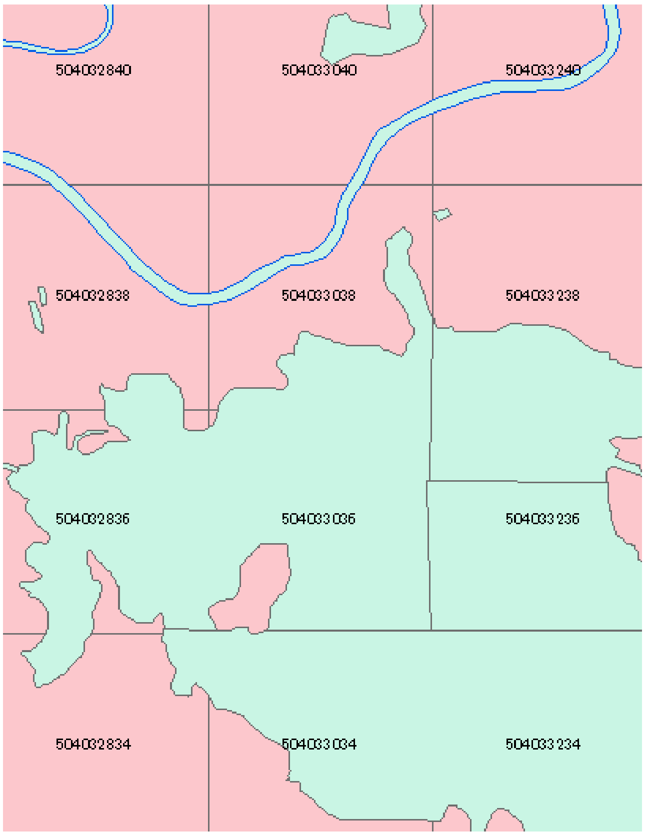


Figure 2.2.71 Checking of Water Surface (The light blue areas are water surfaces.)

### 9) Checking of Cloud Polygon

After the completion of measurement of the area to be surveyed (24,700km$^2$, 6666 map sheets in total), collected data was inspected to check if any data were missing (about 43 km$^2$). As a result, it was confirmed that some data was missing and most omissions were due to clouds. The survey team created cloud polygon data in Shape files to make up for the missing data.

Laser data and orthophotos were used for data acquisition. Areas where data acquisition was possible from either of them due to the availability of duplicated data (overlap or sidelap) despite the presence of clouds were excluded.

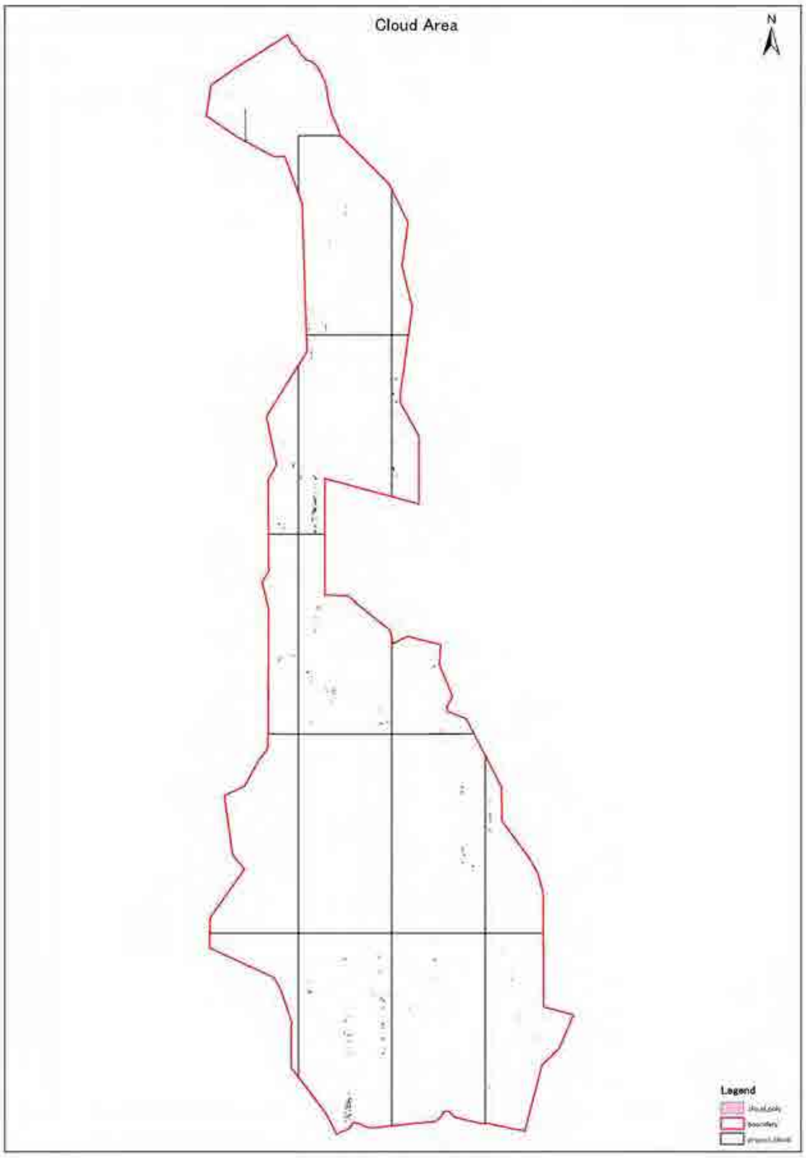


Figure 2.2.72　Result of Cloud Confirmation (Terrain Clearance: 500m, 2,785m)

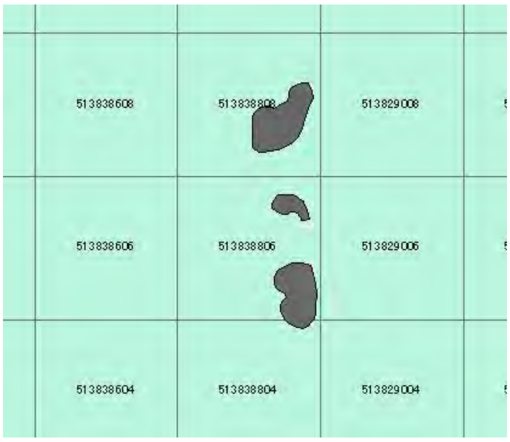


Figure 2.2.73　Enlarged View of Areas with Clouds (The gray portions in the figure are clouds.)

### 2-2-16 Discussion for Effective Use of Map Data / Explanation of Results (Technology Transfer)

Since the objective of this Work is to collect topographic data that is required to implement the Chao Phraya River Basin Flood Control Project, technology to create topographic maps shall not be transferred, but instruction was provided regarding the effective use of map data.

(1) Utilization of Data

Since the created data is point group data, the large volume of the data makes it extremely difficult to handle. Therefore, instruction was provided on using GIS software or CAD software to perform the required data conversion.

(2) Utilization as Topographic Maps

In addition, since this is 3D data, the detailed topography in the Chao Phraya River Basin area can be expressed in three dimensions. Therefore, expression methods used for ordinary 3D maps were introduced, and technology on operation methods was transferred to facilitate future use of the data as topographic maps.

(3) Airborne laser scanning survey training

| | |
|---|---|
| Implemented on March 26 | Laser scanning training<br>Observation of aircraft and laser scanning equipment to be used |
| Implemented on March 29 | Laser scanning training<br>Study session within the RID “Airborne Laser Scanning” |
| Implemented on March 30 | On-site control point survey training<br>Uthai Thani Province, Chainat Province |
| Implemented on March 31 | On-site control point survey training<br>Nakhon Sawan Province, Phichit Province |
| Implemented on May 1 | On-site control point survey training<br>Ayutthaya Province, Saraburi Province |
| Implemented on May 2 | On-site control point survey training<br>Suphan Buri Province |
| Implemented on May 22 | On-site control point survey training<br>Samut Prakan Province |
| Implemented on June 12 | Training in data creation and verification (for RID)<br>Airborne laser data verification, data creation, explanation of result data (lecture training)<br>Data verification, data creation (hands-on training) |
| Implemented on June 13 | Training in data creation and verification (for RTSD) |

| | |
|---|---|
| | Airborne laser data verification, data creation, explanation of result data (lecture training) |
| Implemented on July 6 | Training in data creation and verification (for GISTDA)<br>Airborne laser data verification, data creation, explanation of result data (lecture training) |

### 2-2-17 Summary of Results (including preparation of reports, etc.)

The results of this Work were summarized in a survey report, taking the content of explanation to parties concerned and mutual discussion into consideration.

1) Final report

The final report describes the overall results of the work and results of technology transfer.

2) Recommendations

This work has so far been carried out by applying relevant Japanese work regulation rules. To apply the rules to the future work in Thailand, however, the Consultants would like to make the following recommendations regarding the items to be revised and developed in a draft set of work regulation rules for airborne laser scanning survey in Thailand "Work Regulation Rules and Operation Standards for Creation of Elevation Data by Airborne Laser Scanning Survey (Draft)". (See Appendix-3).

It would be a great pleasure for the Consultants if this could be utilized in the future work of airborne laser scanning survey.

i) Control points for correction

989 points, that is, one point in every 25km$^2$, were installed in this Work. However, considering the fact that there is almost no elevation difference on the flat land stretching to the northern region, the density of point distribution may be reduced. Therefore, we would recommend distributing the points at a rate of one point in every 10km×10km (100km$^2$).

ii) Installation of MCP (master control point)

RTSD owns reference points and benchmarks (BM). However, if the target area is wide as in this Work, control points for correction in every 100km$^2$ cannot be directly observed with the existing reference points and benchmarks alone. Therefore, the Consultants would recommend organizing a primary control point (MCP) network for the project with the baseline length as about 30km.

iii) Extension distance between courses

Since Japanese work regulation rules do not include a rule on the extension distance of a course, the extension distance was set to be fairly long in this Work, with the longest being 80km, partly for the purpose of increasing the measurement timings. However, as it turned out that the accumulation of IMU errors significantly affected the accuracy because of the long distance, the Consultants would recommend that the extension distance should be 50km at the longest.

iv) Verification between courses

A maximum of four points were verified between courses, but since the course extension distance was long, four points are a little too few. The Consultants would recommend verifying one location for every 10km of the course extension distance.

v) Checking of filtering

Japanese work regulation rules stipulate two kinds of maps, namely, a “superimposition map of ortho image data and contour line data” and a “superimposition map of ortho image, original data and water surface polygon”. However, a “slope classification map”, a “shading map”, a “layer tint map”, etc., which were also used in this Work, are effective in grasping the topographic condition of a flat land. Therefore, the Consultants would recommend using these maps.

vi) Quantity to be inspected

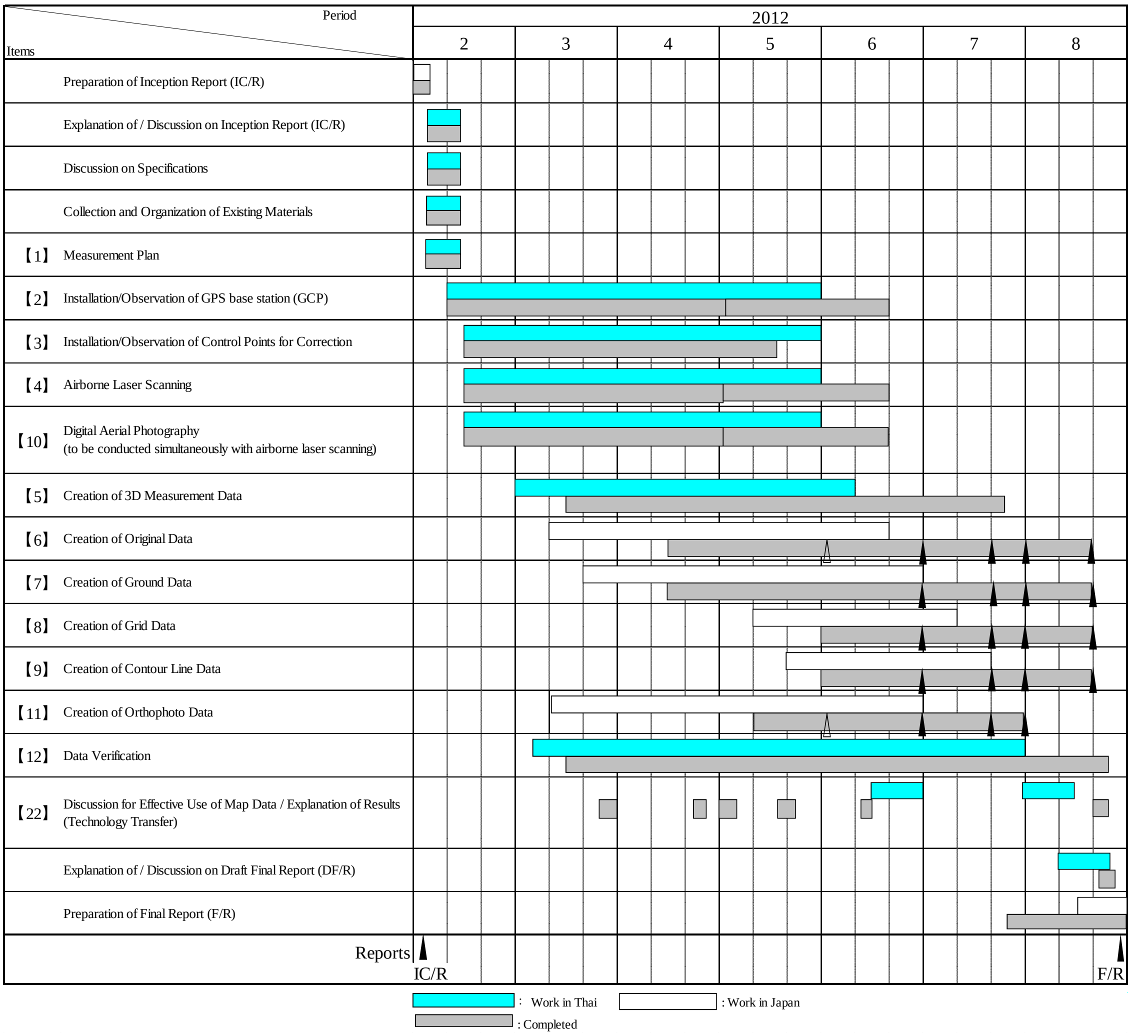
As a method of appropriate accuracy control to ensure the accuracy of survey, Japanese work regulation rules stipulate that 2% of the data should be inspected for topographic survey and photogrammetry.

Since airborne laser scanning survey falls in the same category, the Consultants would recommend that 2% of the data should be inspected.

## 2.3 Work Schedule and Record

The initial work schedule and the result of implementation are described in the table below.

Form-2 Work Plan



## 2.4 Personnel Plan and Record

Personnel plan and the record in this Work are as follows:

**Personnel involved**

| | Work Items | Name | Company | Rank | 2012 (months 1–9) | Man/Month Total Thai | Man/Month Total Japan | Man/Month Total Study Team's expense |
|---|---|---|---|---|---|---|---|---|
| Work in Thailand | Team Leader / Airborne Laser Scanning 1 | HONJI Koichi | PASCO Corporation | 3 | 2/5 4/8, 4/21 5/17, 5/19 6/19, 6/25 7/12, 7/29 8/30, 8/31 9/1 | 5.80 | | 0.07 |
| | Team Sub-Leader | MORI Hisashi | PASCO Corporation | 3 | 2/8 2/22, 4/18 4/28 | 0.87 | | |
| | Photography Plan | NAKAO Motohiko | PASCO Corporation | 3 | 2/5 3/10, 5/7 5/16, 6/7 6/16, 8/23 9/1 | 2.17 | | |
| | Airborne Laser Scanning 2 | NAKANO Yasutaka | PASCO Corporation | 4 | 2/5 4/16, 4/22 4/24, 4/25 5/3 | 2.50 | | 0.30 |
| | Airborne Laser Scanning 3 | INOUE Takeshi | Air Asia Survey Co., Ltd. | 4 | 3/4 6/1 | 3.00 | | |
| | Airborne Laser Scanning 4 | KANEDA Shinichi | Air Asia Survey Co., Ltd. | 4 | 3/4 6/1 | 3.00 | | |
| | Airborne Laser Scanning 5 | ITO Fumihiko | Air Asia Survey Co., Ltd. | 5 | Cancellation of dispatch | | | - |
| | Setup of GPS Base Station / Control Points for Correction 1 | SHIMODA Shozo | Kokusai Kogyo Co., Ltd.<br>( Toa-Tech Co., Ltd. ) | 4 | 2/16 4/15 | 2.00 | | |
| | Setup of GPS Base Station / Control Points for Correction 2 | KIRA Susumu | Air Asia Survey Co., Ltd. | 4 | 2/16 4/15 | 2.00 | | |
| | Setup of GPS Base Station / Control Points for Correction 3 | TSUKADA Masayuki | Kokusai Kogyo Co., Ltd. | 4 | 4/4 6/2 | 2.00 | | |
| | Setup of GPS Base Station / Control Points for Correction 4 | FUKUTOMI Seiichi | Air Asia Survey Co., Ltd.<br>(DMS Co., Ltd.) | 4 | 4/4 6/2 | 2.00 | | |
| | Data Verification 1 | IDA Kengo | Kokusai Kogyo Co., Ltd. | 6 | 3/4 6/2 | 3.03 | | |
| | Data Verification 1 | SHIMANO Sota | Kokusai Kogyo Co., Ltd. | 6 | Change in personnel; 5/29 6/2, 6/3 7/31, 8/1 8/1 | 1.97 | | 0.20 |
| | Data Verification 2 | TAMARI Kiyohumi | Air Asia Survey Co., Ltd.<br>(DMS Co., Ltd.) | 4 | 3/4 7/31 | 5.00 | | |
| | Data Verification 3 | OMORI Hiromichi | PASCO Corporation<br>(GIS Kansai) | 4 | 3/4 7/31, 8/1 8/1, 8/15 8/31 | 5.00 | | 0.60 |
| | Data Verification 4 | YOTSUMATA Toru | PASCO Corporation | 4 | 4/3 6/24 | 2.77 | | |
| | Data Verification 4 | SHIMAGO Takafumi | PASCO Corporation | 4 | Change in personnel; 6/21 6/24, 6/25 8/20, 8/21 8/31 | 1.90 | | 0.50 |
| | Work Coordination/ Photography Plan Assistance | TSUDA Kaoru | PASCO Corporation | 4 | 2/1 2/15, 2/16 2/25, 3/29 4/10, 4/17 4/18, 8/23 9/1 | 1.33 | | 0.33 |
| | | | | | | 46.34 | | 2.00 |
| Work in Japan | Team Leader / Airborne Laser Scanning 1 | HONJI Koichi | PASCO Corporation | 3 | 2/1 2/4, 4/9 4/14, 7/13 7/27 | | 0.83 | |
| | Team Sub-Leader | MORI Hisashi | PASCO Corporation | 3 | 2/1 2/4, 4/9 4/14 | | 0.33 | |
| | Photography Plan | NAKAO Motohiko | PASCO Corporation | 3 | 7/27 8/10 | | 0.50 | |
| | | | | | | | 1.66 | |
| | Reports, etc. | | | | △ IC/R (1), △ F/R (8) | | | |

| Thai | Japan | Study Team's expense |
|---|---|---|
| 46.34 | 1.66 | 2.00 |
| Total 48.00 | | |

Legend: ■ Work in Thai □ Work in Japan ▨ At Study Team's expense

## 3. Conclusion

This Work was implemented to achieve the basic policy of the project of performing the creation of detailed topographic data in the flood region of Chao Phraya River in a quick, accurate and flexible manner to capture the microtopography of the region, which is necessary in examining the flood control measures for the mid and lower portions of the flat Chao Phraya River basin.

The project was unprecedented in that detailed topographic data had to be created in 2m grids of a huge area of 24,700km$^2$ using airborne laser scanning survey in a period as short as seven months from February to August 2012 and as such, speediness was the topmost priority. In addition, as it was necessary to complete measurement before the rainy season, which begins in the middle of May, the greatest challenge was to promptly acquire measurement permission to complete the measurement of the entire project area as quickly as possible.

Furthermore, it was necessary to ensure accuracy while quickly performing the work to eliminate rework. Japanese survey work regulation rules place an importance on establishing a process that would never generate defects as long as no error is made about the flow of work. However, a variety of technical issues were observed in applying these rules as they are to another country that is performing the work for the first time and lacks past experience. Therefore, the Consultants are rather doubtful about the appropriateness of applying the rules to such unprecedented work of huge volume that had to be completed in a short period.

In actuality, as the amount of data was huge, a certain amount of defects occurred, and flexibility, which was the subject of the last policy, was relied upon in determining how to deal with these defects. The Consultants realized that for a short-term work, it is also necessary to flexibly utilize Japanese survey work regulation rules, applying Japanese work regulation rules to the product while allowing flexibility to the process.

More specifically, “Work Regulation Rules and Operation Manuals for Creation of Elevation Data by Airborne Laser Scanning Survey (Draft)” that may serve as a reference for performing airborne laser scanning survey in Thailand in the future were created, taking the results of work implementation into consideration and incorporating the recommendations described in 2-2-17.

This Work ultimately resulted in the creation of five kinds of data, namely, original data, ground data, grid data, contour line data and orthophoto data. These data types can be fully utilized by the RID, RTSD and JICA in performing analysis and developing future plans for flood control.

The Consultants expect that the results and experience gained through this Work will contribute to future flood control measures and the prosperity of Thailand.

In conclusion, on behalf of the survey team, the Consultants would like to express their deepest gratitude to the RID, RTSD and other government agencies relating to this project for their hospitality and cooperation extended to the team. The Consultants would also like to express heartfelt gratitude to JICA and Japanese government agencies relating to this project for the valuable advice and guidance.

# Appendix-1

# Minutes of Meeting
# On
# Project For
# Chao Phraya River Basin Flood Control Project
# ( Airborne Laser Scanning Survey)
# In
# Thailand

**Agreed upon between**
**Royal Irrigation Department of Thailand**
**And**
**Japan International Cooperation Agency**

**Bangkok, Thailand**

**8th February, 2011**

本地光一

Mr. Kosol Thianthongnukul
Director of Office of Engineering,
Topographical and Geotechnical Survey,,
Royal Irrigation Department

Mr. Koichi Honji
Team leader of the Study Team,
Japan International Cooperation Agency
(JICA)

The JICA Study Team (hereinafter referred to as "the Team") headed by Mr. Koichi Honji visited Thailand from 5th February, 2012 in order to carry out Chao Phraya Basin Flood Control Project for Airborne Laser Scanning Survey in Thailand (hereinafter referred to as "the Study"). Royal Irrigation Department (hereinafter referred to as "RID") is a counterpart of the Team. During the meeting on explanation of the Inception Report to RID , the Team and RID discussed the several matters as followings and the Team answered the questions raised by RID. Both sides eventually agreed upon the below.

Before proceeding to have questions on the Inception Report, JICA outlined the project and highlighted significance of the surveys and the Team members elaborated on the essence of methodology and measurements in accordance with the Inception Report that was prepared in Japan.

The following questions were followed by the counterpart and related organization to the explanation of the inception report. Significant issues of the question and the replies to them are as follows.

1. Acquisition of data with LIDAR

Counterpart asked the precision of measurement with LIDAR applied to this project. The Team answered that the precision shall be kept less than 25cm according to the standard stipulated in the Japanese regulation of Airborne Laser Scanning. The Team also added promising accuracy to be sustained less than 10cm in average practically.

2. Timing for mobilization of the aircrafts

The Team explained that the aircrafts are supposed to stand by at the airport in Thailand within 4 or 5 days after the flight permission is issued. The Team requested to issue the permission by 20th February, 2012.

The Team also explained that the testing flight will be possible 2 days after the flight is permitted, since one(1) of the proposed aircrafts is currently available at Don Mueang Airport in Thailand, and the equipment to be installed for laser scanning is already available in Thailand.

3. Concerning aerial photography

The Counterpart asked whether the aerial photography will be carried out covering the entire Project area. The Team answered that the aerial photography is proposed to cover the whole areas. On top of it, the Team stated that it could not be guaranteed to take the photographs with all clear objects on the ground due to no specification regarding cloud-free requirement and to the possibility of shooting in the night.

4. Implementation of ground survey

The counterpart will provide benchmark data for survey which will be conducted by JICA team as well as the budget and the provision. The Counterpart enhanced the necessity of conformity in the technical specifications so that the data to be acquired shall not cause any discrepancies between both data in accordance with the JICA operational standard.

In relation to this issue, the Counterpart raised a question whether JICA can disclose the standard and /or operational instruction of allocating GCP's specifically.

In response to the question, the Team answered that it can be disclosed as the specification is based on the Japan's regulation of Airborne Laser Scanning.

5. Processing of Laser Scanning Data

The Counterpart asked the Team what sort of software will be used for data processing and if the software would be donated to the Counterpart after termination of the Project. The Team replied that TERRASCAN and ARC GIS are to be used, however they are not supposed to be donated.

6. Topic of Technology Transfer

The topic on the Technology Transfer was raised from RTSD in the meeting asking the possibility of attending Technology Transfer program in order to learn a series of technical process and knowhow to utilize effectively data obtained.

The Team answered that any OJT (training) is not officially programmed in this project as the project inaugurated for the purpose of conducting an emergency rehabilitation model. The Team, however, added comments that the counterpart staff will be able to have opportunities to learn the knowledge about Airborne Laser Scanning and introductory data use from time to time when needed.

7. Outputs to be delivered

Counterpart asked if the Team could furnish relevant organizations with data at the time when the raw data are acquired accordingly. The Team explained the proposed plan that the final data shall be delivered only when data covering all the area are processed because raw data need to be processed with a specific software and can not be dealt easily due to enormously time consuming and costly work.

The Team suggested masking of the processed data be made in accordance with RTSD from security point of view. The Team also added to envisage that data for dissemination shall be masked and/or degraded in resolution.

**Appendix**

## List of Attendants

### Thai Side

-Royal Irrigation Department-

| | |
|---|---|
| Mr. Kosol Thianthongnukul | Director of Office of Engineering, Topographical and Geotechnical Survey. |
| Ms. Suwanna Euvananont | Photogrammetrist (expert level of Office of Engineering, Topographical and Geotechnical Survey. |
| Mr. Kanchadin Srapratoom | Project Management Officer of International Corporation Division |

-Department of Water Resources-

| | |
|---|---|
| Mr. Ammart Suthammajaras | Civil Engineer of Bureau of Water Resources Conservation and Rehabilitation |
| Mr. Supapap Patsinghasanee | Professional Civil Engineer of Water Crisis Prevention Center |

-Geo-Informatics and Space Technology Development Agency-

| | |
|---|---|
| Dr. Chaowalit Sillapathong | Director of Geo-Informatics Center |

-Royal Thai Survey Department-

| | |
|---|---|
| Mr. Winai Semsawat | Deputy Director |
| Mr. Bunjerd Ramkomut | Director of Plans and Project Division |
| Mr. Chaiwat Promthong | Director of Geodesy and Geophysics Division |
| Mr. Krit Bunthid | Director of Geography Division |
| Mr. Suppalert Chaichana | Director of Mapping Division |
| Mr. Surasak Toedkiatkun | Director of Aerial Survey Division |
| Mr. Sarapong Pramsane | Director of Education Division |
| Mr. Chakorn Boonphakdee | Deputy Director of Plans and Project Division |
| Mr. Piya Charukarn | Chief of Geophysics Section |
| Mr. Nitiwadee Lamkham | Chief of Research and Development Section |
| Mr. Chochchai Puathanachockchai | Map Editing and Revising Section |
| Mr. Pratya Nakhonkao, | Technical Officer |

### Japanese side

-JICA Study Team-

| | |
|---|---|
| Mr.Koichi Honji | Team Leader |

| | |
|---|---|
| Mr. Motohiko Nakao | Flight Planning Expert |
| Mr. Yasutaka Nakano | Airborne Laser Scanning Expert |
| Mr. Kaoru Tsuda | Coordinator |

-ICA Thailand Office-

| | |
|---|---|
| Hajime Taniguchi | Representative |
| Kobchai Songsrisanga | Program Officer |

-Embassy of Japan-

| | |
|---|---|
| Mr. Tetsuo Hasegawa | First Secretary in charge of ICT, Telecommunications, Science and Technology |

# Appendix-2

**Minutes of Meeting**
**On**
**Project for Comprehensive Flood Management Plan**
**For**
**Chao Phraya River Basin**
**(Sub-Component 1-1 Aerial Survey by LIDAR)**
**In**
**Thailand**

**Agreed upon between**
**Royal Irrigation Department of Thailand**
**And**
**Japan International Cooperation Agency**

**Bangkok, Thailand**

**29th August, 2012**

Mr. Chachawal Punyavateenun
Deputy Director General
Royal Irrigation Department (RID)

本地光一
Mr. Koichi Honji
Team Leader of the Project Team
Japan International Cooperation Agency
(JICA)

Japan International Cooperation Agency (JICA) Project Team for "Project for Comprehensive Flood Management Plan for Chao Phraya River Basin (Sub-Component 1-1 Aerial Survey by LIDAR) (hereinafter referred to as "The Team") , Royal Irrigation Department (hereinafter referred to as "RID") , and other relevant organizations held a meeting concerning the Final Report of "Project for Comprehensive Flood Management Plan for Chao Phraya River Basin (Sub-Component 1-1 Aerial Survey by LIDAR) (hereinafter referred to as "The Project") on 29th of August 2012 from 10:00 to 11:30 at a meeting room of RID office.

The Team explained about the followings based on the Final Report.

a) Objective of the Project
b) Target Area
c) Basic Policy and Results
d) Final Outputs
e) Implementation Workflow
f) Survey Standard
g) Collected Existing Materials
h) Inspection Results for Each Work
i) Data Format
j) Final Results
k) Recommendation
l) Case Study
m) Work Schedule
n) Conclusion

After the explanation by the Team, the questions to the explanation of the Final Report raised by the participants are as follows:

1. Data Accuracy

   The participants from GISTDA and RID asked the Team about the accuracy of fix control points, master control points and Orthophoto data and LIDAR data. The Team answered the accuracy referred to the Final Report and the presentation paper and informed them that all of the survey results are within the acceptable level authorized by Geospatial Information Authority of Japan.

2. Data Distribution

   The participants from GISTDA asked the Team how to distribute the final output to organizations which need the geospatial information. The Team replied that since all the data belong to RID, the organizations which are interested in the data should consult them under security regulation of RID.

3. Information Sharing

   The participants made a request to the Team to exchange the geospatial information continuously because the Government of Thailand had commenced the LIDAR Project. The Team stated that JICA would support the Government of Thailand as much as they could.

At the end of the meeting, RID stated to agree on the Final Report prepared by the Team in principle.

The members attended the meeting are listed in Appendix.

**Appendix**

## LIST OF ATTENDANTS

### Thai Side:

| | |
|---|---|
| Mr. Chachawal Punyavateenun | Royal Irrigation Department |
| Mrs. Suwanna Euvananont | Royal Irrigation Department |
| Mr. Somyot Keawmora | Royal Irrigation Department |
| Mrs. Suchada Hokcharoen | Royal Irrigation Department |
| Mr. Sathit Phomee | Royal Irrigation Department |
| Mr. Chakaphan Choyhiran | Royal Irrigation Department |
| Mr. Kanchadin Sraprathoom | Royal Irrigation Department |
| Mr. Suphanat Pariyachat | Royal Irrigation Department |
| Mr. Cheewin Intharanukul | Royal Irrigation Department |
| Sr. Col. Supalerk Chaichana | Royal Thai Survey Department |
| Col. Sukrich Lapkriengkri | Royal Thai Survey Department |
| Mr. Montree Boonphanitch | National Economic and Social Development Board |
| Mr. Chamnong Phawaphook | National Economic and Social Development Board |
| Ms. Chuthamas Panaklin | Geo-Informatics and Space Technology Development Agency |
| Mr.Chatchai Saensena | Geo-Informatics and Space Technology Development Agency |
| Mr.Tatiya Channatrakul | Geo-Informatics and Space Technology Development Agency |

### Japanese Side:

| | |
|---|---|
| Mr. Koichi Honji | Team Leader of JICA Project Team |
| Mr. Motohiko Nakao | Project member |
| Mr. Kaoru Tsuda | Project member |
| | |
| Mr. Tatsuo Kunieda | JICA Expert in RID |
| Mr. Takahiro Mishina | JICA Expert for Project for Flood Management Plan |
| | |
| Mr. Kimio Takeya | JICA in Japan |
| Mr. Kunihiro Yamauchi | JICA in Japan |
| Mr. Hideaki Matsumoto | JICA in Japan |
| Mr.Yojiro Miyashita | JICA in Thailand |
| Mr.Kobchai Chongsrisa-ngha | JICA in Thailand |

# Appendix-3

# Work Regulation Rules and Operation Manuals for Creation of Elevation Data by Airborne Laser Scanning Survey (Draft)

**August 2012**
**PASCO Corporation**

## Table of Contents

# Chapter 1 General Provisions

## Section 1 General Rules

### Article 1 Objectives

The purposes of this manual are to standardize the specifications of elevation data (hereinafter referred to as the “Elevation Data”) and to ensure that the elevation data has required accuracy by providing the methods to be used for the creation of the elevation data with the airborne laser scanning survey.

### Article 2 Relations with Other Manuals

A series of processes for creation of the elevation data shall be carried out in accordance with this manual, unless otherwise provided.

### Article 3 Definitions of Terms

The following terms shall be interpreted herein as follows:

- i “National base map unit” shall mean a unit of an area of 2.0 km (in the north-south direction) by 2 km (in the east-west direction) demarcated from the Universal Transverse Mercator Zone47 (hereinafter referred to as the “national base map sheet”).
- ii “Surface object” shall mean any item of land cover with the elevation of its upper surface significantly higher than that of the ground surface, such as artificial structures, including buildings and bridges, and vegetation, including trees.
- iii “Scanning data” shall mean data obtained in the airborne laser scanning.
- iv “Filtering” shall mean a process to remove scanning data other than that of the ground surface, such as data of surface objects, in the creation of ground data.

## Section 2 Specifications and Accuracy of the Elevation Data

### Article 4 Specifications of the Elevation Data

The specifications of the elevation data are provided in the following paragraphs:

- i Thai survey standards shall be followed as to the standards for positions.
- ii Coordinetes shall be Projection: UTM Zone47, Ellipsoid: WGS84, Geodetic datum: WGS84(ITRF2008) and Vertical datum: Mean Sea Level (Based on existing Bench Marks).
- iii Elevation data grids shall be created by dividing national base map sheets at 2m

interval.

iv The elevation data of a grid is the elevation at the center of the grid expressed in meters to the first decimal place.

Article 5 Accuracy of the Elevation Data

The accuracy of the elevation data shall be as follows:

| Case | Accuracy (Standard deviation) |
|---|---|
| A grid with ground data | Less than 0.3 m |
| A grid without ground data | Less than 2 m |

## Section 3 Components of the Scanning and Order of Implementation

Article 6 Components of the Scanning and Order of Implementation

In principle, the scanning work shall consist of the following components, which shall be implemented in the order shown below.

i Work planning
ii Scanning planning
iii Establishment of GPS base stations
iv Airborne laser scanning
v Establishment of control points for correction
vi Creation of three dimensional scanning data
vii Creation of original data
viii Creation of ground data
ix Creation of the elevation data
x Creation of digital data files

<Article 6 Enforcement Rule>

Appendix 1, “Workflow,” shall be followed.

## Section 4 Composition and Accuracy Control of the System

Article 7 Airborne Laser Scanning Survey System

An airborne laser scanning survey system shall consist of an airborne GPS receiving antenna, an airborne GPS receiver, GPS analysis software, IMU (inertial measurement unit), a laser distance meter and analysis software.

<Article 7 - Enforcement Rule>

The performance of the component equipment shall be as follows:

- i Airborne GPS receiving antenna and receiver
  - a A GPS antenna shall be able to be mounted on the top of an aircraft securely.
  - b A GPS receiver shall be capable of acquiring GPS observation data at an interval of one second or less.
  - c A GPS receiver shall be capable of dual-frequency carrier phase data observation.
- ii GPS analysis software
  - a Software shall have a kinematic baseline vector analysis function.
  - b Software shall have a function to display evaluation of analysis results.
- iii IMU (inertial measurement unit)
  - a IMU shall be capable of measuring tilts and acceleration in three axes, *i.e.* roll, pitch and heading, and have performance, in terms of the standard deviations obtained in the analysis, equivalent to or better than the performance shown below.

| Sensor part | Performance |
|---|---|
| Roll | 0.015° |
| Pitch | 0.015° |
| Heading | 0.035° |
| Data acquisition interval | 0.005 second |

  - b IMU shall be able to be mounted directly on a laser distance meter.
- iv Laser distance meter
  - a A laser distance meter shall be able to measure at least two pulses, the first and the last pulses.
  - b It shall have a scanning function.
  - c It shall have a function to prevent it from having adverse effects on the human body, including human eyes.
  - d It shall be provided with clearly stated safety standards.
- v Analysis software
  - a Analysis software has to enable calculation of three-dimensional (3-D) position of a measurement point.

## Article 8 Inspection of Equipment

An airborne laser scanning survey system inspected at a calibration site within six months prior to the scanning shall be used. When an airborne laser scanning survey system, which has been dismantled from an aircraft within the six months, is to be used, the system shall have to be calibrated anew.

2 The Geospatial Information Authority of Japan shall designate equipment other than an airborne laser scanning survey system whose use in the scanning requires certification.

### <Article 8 Enforcement Rule>

i A person who implements the scanning shall appropriately maintain an airborne laser scanning survey system.

ii Form 1-1 shall be used for keeping records of the inspection stipulated in Article 8-1 and, in principle, the records of the inspection shall be shown to a supervisor prior to the work using the equipment concerned.

## Article 9 Work Process Management

Work processes shall have to be managed appropriately in the entirety of the work

## Article 10 Preparation of Work Sheets

A work sheet to record progress of the work shall be prepared immediately after completion of each work component.

### <Article 10 – Enforcement Rule>

Progress of the work shall be recorded in Form 1-2.

## Article 11 Accuracy Control

A person in charge of accuracy control shall control accuracy of measurement data appropriately throughout the work in order to ensure accuracy of survey and shall have to prepare other required materials, without delay, on the basis of the results of the implemented accuracy control.

## Article 12 Compilation of Outputs

Outputs, records and other required materials shall be compiled after completion of the work without delay.

## Chapter 2　Creation of the Elevation Data

### Section 1　Work Planning

Article 13　Work Planning

Work Planning is a process to formulate an appropriate plan on work methods, major equipment to be used and work schedule prior to the commencement of a work, with conditions in a work area, amount of work and completion date taken into consideration.

<Article 13 – Enforcement Rule>

Full consideration shall be given regarding the major equipment to be used, required personnel, work procedures and implementation methods during the formulation of a work plan in order to ensure efficient implementation of a series of work components.

### Section 2　Scanning Planning

Article 14　Scanning Planning

Planning of airborne laser scanning is a process to formulate specifications for the scanning, a flight path plan, a plan for locations of establishment of GPS base stations and a GPS observation plan, with locations of GPS satellites taken into consideration.

<Article 14 – Enforcement Rule>

i　The specifications for the scanning include ground elevation, ground speed, percentage of sidelap, number of scans, scan angle, pulse rate and standard distances between data acquisition points in the direction of flight paths and in the direction perpendicular to flight paths.

  a　A scan angle shall be within a range of ±20°, in principle.　A standard distance between points of 3-D scanning data acquisition shall be so designed that there will be at least one acquisition point in an area of 2.0m x 2.0m.

  b　The percentage of sidelap shall be at least 30%.

ii　A flight path plan shall be so designed that standard distances between data acquisition points are uniform.　Nevertheless, uniformity of standard distances between data acquisition points shall be achieved by using sidelap of areas scanned from adjacent flight paths (or flights on same paths in both directions), with topographical or climatic conditions taken into consideration. The extension distance shall be 50km at the longest.

- iii Horizontal locations of scanning data shall have accuracy of a standard deviation of less than 1 m.
- iv A scanning plan shall be so designed that scanning shall be extended up to a certain extent outside the border of an intended scan area.
- v Locations of establishment of GPS base stations shall be designed with view of the sky and baseline distances taken into account.
- vi A GPS observation plan shall be formulated with the number of satellites available for receiving signals from using the latest information on their orbits.
- vii The designed scan specifications, flight path plan maps and locations of establishment of GPS base stations shall be recorded in Form 2-1.

## Section 3 Establishment of GPS Base Stations

### Article 15 Establishment of GPS Base Stations

Establishment of GPS base stations is a process to establish ground GPS base stations in order to measure the position of a laser distance meter used in airborne laser scanning with the kinematic GPS survey.

<Article 15 – Enforcement Rule>

- i An electronic control point may be used as a GPS base station.
- ii GPS base stations shall be established within a scan area in such a way that baseline distances between them shall not exceed 50 km.
- iii GPS observation data shall have to be acquired at an interval of one second or less.
- iv A GPS base station shall have to be established at a place with clear view of the sky.
- v A horizontal position and elevation of an intended location of establishment of a GPS base station shall be measured with surveys conforming to the first order control point survey (Appendix-2) and third order leveling (Appendix-3).

### Article 16 Preparation of Description of GPS Base Station

A description of GPS base station shall be prepared whenever a GPS base station has been installed.

<Article 16– Enforcement Rule>

Form 2-2 shall be used for the preparation of a description of GPS base station.

Article 17　Verification

A person implementing the scan shall have to carry out verification of a GPS base station and control accuracy of data on it when it has been established.

<Article 17 – Enforcement Rule>

The following shall be verified.

i　Guarantee of clear view of the sky and presence/absence of data acquisition

ii　Appropriateness of the selection of the location in a scan area

iii　Guarantee of accuracy of horizontal position and elevation of a GPS base station

iv　Stability of receiving antenna installation

2　In order to enable evaluation of the accuracy of the results of the GPS observation in accordance with the Rules for Manual, documents such as observation notebooks and recording notebooks in which such data as locations of GPS satellites is recorded and an accuracy control sheet in which results of the baseline analysis are entered shall be prepared.

## Section 4　Airborne Laser Scanning

Article 18　Airborne Laser Scanning

Airborne laser scanning is a process to acquire scanning data with an airborne laser scanning survey system.

Article 19　Acquisition of Scanning Data

Acquisition of scanning data refers to acquisition of GPS observation data at GPS base stations and acquisition of GPS observation data, IMU observation data and laser distance measurement data on an aircraft.

<Article 19 – Enforcement Rule>

i　In principle, one airborne laser scanning survey system shall be used to scan an entire scan area.

ii　In principle, airborne laser scanning on a flight path shall be implemented on a straight path at a fixed elevation.

iii　Ground speed of the aircraft shall be maintained as uniformly as possible during a scan on a single flight path.

iv　Scanning data shall be acquired by extending the outer circumference of a scan area to a certain extent.

v GPS observation shall be implemented as follows:

  a GPS observation data shall be acquired at an interval of one second or less both at GPS base stations and on an aircraft.

  b PDOP of 3 or less shall be the standard for satellites used for GPS observation.

  c At least five GPS satellites shall be used when acquiring GPS observation data.

Article 20 Acquisition of Digital Photographs for Airborne Laser Scanning

A Digital Photograph for Airborne Laser Scanning Survey is aerial image data of the land surface taken with a digital camera attached to an airborne laser scanning survey system. It is acquired for the filtering and verification.

<Article 20 – Enforcement Rule>

i In principle, a digital photograph for airborne laser scanning shall be taken at the same time as airborne laser scanning.

ii A digital photograph for airborne laser scanning shall have a resolution which allows identification of Surface Objects such as buildings and the standard ground pixel dimension shall be 1.0m or less.

iii Ground surface image data shall be acquired from an entire scan area.

Article 21 Verification

An airborne laser scanning survey system shall be verified before commencement and after completion of airborne laser scanning.

<Article 21 – Enforcement Rule>

The following shall be verified:

i Condition of operation and data recording of the GPS units in GPS base stations and on an aircraft

ii Presence/absence of cycle slips

iii Guarantee of coverage of airborne laser scanning: quality of digital photographs for airborne laser scanning

iv Appropriateness of the ground elevation and routes of flight paths

Article 22 Sorting

Data shall be sorted after the completion of airborne laser scanning.

<Article 22 – Enforcement Rule>

- i The number of satellites available and a PDOP diagram during a period of scanning, which should be obtained as an output of GPS data analysis/processing, shall be produced.
- ii A map to detect areas from which no scanning data has been acquired (measurement loss) shall be created by marking an area scanned from each flight path on the same map.
- iii A track chart shall be created by overlaying actual flight tracks on flight path maps.
- iv A record of airborne laser scanning shall be created using Form 2-3. An airborne laser scanning log shall be prepared using Form 2-4.

## Section 5 Establishment of Control Points for Correction

### Article 23 Establishment of Control Points for Correction

Establishment of control points for correction is a process to establish control points to verify and correct 3-D scanning data.

<Article 23 – Enforcement Rule>

- i A control point for correction shall be established on a flat place where a position provided by 3-D scanning data can be easily identified on the ground and which can be surveyed without difficulty.
- ii A standard number of control points for correction shall be the nearest integer larger than (the size of a scan area (in $km^2$) / 100) + 1. They should be at least four points.
- iii A control point for correction shall be established at a site that satisfies the following conditions:
  - a In principle, control points for correction shall be established near the four corners of a scan area and other points shall be established as uniformly as possible over an entire scan area to ensure data accuracy.
  - b In principle, a base station shall be established on a flat place of a minimum size of 2m x 2m and without an obstacle, such as a tree or steps on a pedestrian path (*e.g.* a playing ground, vacant lot, road, park or flat rooftop).
  - c A base station shall be established near a benchmark.

Article 24　Measurement of a Control Point for Correction

Measurement of a control point for correction shall be taken with factors, such as conditions in a scan area, accuracy of data applicable to verification of elevations and measurement methods taken into consideration.

<Article 24 – Enforcement Rule>

i　Measurement of a control point for correction shall be taken with a survey conforming to the fourth order control point survey (Appendix-2) and the fourth order leveling (Appendix-3).

ii　If there is no benchmark required as an established control point near a control point for correction, single point observation based on the network RTK positioning may be used.

a　In the single point observation based on the network RTK positioning, correction data or plane correction parameters calculated by a provider is received by a radio equipment at a rover station simultaneously with signals from GPS satellites, required analysis is conducted on the received data and the same observation and analysis is carried out at another rover station.　There are two types of single point observation based on the network RTK positioning.　The VRS method uses virtual control points and the FKP method uses plane correction parameters to acquire coordinate values.

b　The table below shows the standards for the single point observation based on the network RTK positioning.

| Number of satellites used | Number of observations | Data acquisition interval | Allowable range of difference between sets | | Summary |
|---|---|---|---|---|---|
| Five or more satellites | 2 sets of 10 or more epochs after obtaining a fix solution | 1 second | △X | 20mm | |
| | | | △Y | 20mm | |

c　With regard to the preceding paragraph, after completion of the first set of observations, the equipment shall be re-initialized and a second set of observations shall be made.　If the difference between the sets is within the allowable range, the means of the two sets of observed values shall be considered as the outputs of the observations. The observed values and the difference at each station shall be recorded in Form 2-5 “Observed Values and Verification of Difference between Sets.”

d If the difference between the two sets exceeds the allowable range, the equipment shall be re-initialized and a third set of observations shall be made. If there is no combination of a pair of sets of observations with the difference within the allowable range even after the third set of observations, the fourth set of observations shall not be made on the same day. Instead, new sets of observations shall be made on a separate day.

e It shall be made a standard procedure to make observations for verification at an established control point in a scan area before and after the observations at the rover stations.

iii If there is no benchmark near a control point for correction, the measurement may be taken with the static method with an observation period of 2 hours or more, using GPS receivers installed at two or more benchmarks closest to a control point for correction and a measurement point of a control point for correction.

Article 25 Sorting

Observation data shall be appropriately sorted after the measurement of control points for correction.

<Article 25 – Enforcement Rule>

i Form 2-6 “Description of Control point for Correction” shall be filled in for each control point for correction. A photograph should be taken and arranged so that it can be used as a proof of absence of obstacles to scanning, including steps.

ii A distribution map of control points for correction shall be prepared as shown in Form 2-7.

## Section 6 Creation of Three-Dimensional (3-D) Measurement Data

Article 26 Creation of 3-D Scanning Data

Three-dimensional scanning data shall be created by analyzing airborne laser scanning data in an integrated way.

<Article 26 – Enforcement Rule>

i During creation of 3-D scanning data, measurement errors, including noise created by the laser being reflected more than once on buildings, etc. nearby shall be removed using displays of cross section views and birds' eye views.

ii Ground coordinates in 3-D scanning data shall be measured to 1 cm accuracy.

iii Creation of 3-D scanning data shall be extended up to a certain extent outside the border of a scan area.

### Article 27 Verification of 3-D Scanning Data

Verification of 3-D scanning data is a process to verify elevations of measurement points in 3-D scanning data by comparing them with an elevation of a control point for correction.

<Article 27 – Enforcement Rule>

The verification shall be implemented as follows:

i. Three-dimensional scanning data acquired from measurement points within a 2.0m-radius circle or a 2m x 2m square shall be compared with an elevation of a base station.

ii. The difference between an elevation of a base station and an elevation in the scanning data of each measurement point shall be calculated and the mean, maximum, minimum and RMS error of the differences shall be calculated.

iii. Results of the verification shall be compiled in Form 2-8, "Three-dimensional Scanning Data Verification Sheet."

2 If an RMS error in the verification is 25 cm or larger, an investigation shall be carried out to identify a cause or causes of such a large error and an appropriate corrective measure, such as re-calculation or re-scanning, shall be taken.

3 Results of the verification of an entire scan area shall be compiled in Form 2-9, "Control point for Correction Survey Sheet," and be used as reference in the correction process.

### Article 28 Verification of Elevation between Flight Paths

Verification of elevation between flight paths is a process in which elevations measured from two adjacent flight paths of a verification point selected in an area of sidelap between areas scanned from the two flight paths are compared and verified.

<Article 28 – Enforcement Rule>

The selection of verification points and the verification shall be implemented as follows:

- i The number of verification points shall be the nearest integer larger than (length of flight paths (in km) / 10 ).
- ii Verification points shall be distributed uniformly over the top and bottom of an area of sidelap from where flight paths begin.
- iii If it is impossible to satisfy the conditions mentioned above because of topographic constraints, such as mountainous terrain or thin strips of land, the number and distribution pattern of verification points may be modified.
- iv The mean elevation obtained from scanning data of measurement points within a 2.0m-radius circle or a 2m x 2m square located in a flat area with good visibility shall be used as an elevation of a verification point.
- v The difference between the two elevations of each verification point shall be calculated and the mean and standard deviation of the difference shall be calculated for each area of sidelap.
- vi If the mean of the difference in elevation in an area of sidelap is 30 cm or larger, elevations shall be corrected through selection of a new set of verification points or recalculation, such as re-correction of calibration values using the verification result.

2 The result of the verification of difference in elevations measured form different flight paths shall be compiled in Form 2-10, “Difference between Measurements Taken from Different Flight Paths.” The distribution map of the verification points shall be indicated in Form 2-7, “Distribution Map of Control points for Correction and Verification Points for Measurements Taken from Different Flight Paths.”

Article 29 Re-verification

A person in charge of verification shall re-verify 3-D scanning data at the completion of creation of 3-D scanning data.

<Article 29 – Enforcement Rule>

- i Distribution and locations for establishing control points for correction shall be verified with “Distribution Map of Control points for Correction” and “Description of Control point for Correction.”
- ii Whether the mean and standard deviation of the difference between elevation of a control point for correction and elevations in 3-D scanning data of measurement points are within the allowable ranges or not, shall be verified with

"Three Dimensional Scanning Data Verification Sheet" and "Control point for Correction Survey Sheet."

iii Distribution and locations of selected points for verification of difference in elevations measured from different flight paths shall be verified with digital photographs for airborne laser scanning and "Distribution Map of Verification Points for Measurements Taken from Different Flight Path."

iv Whether the mean of the difference between elevations of verification points measured from different flight paths is within the allowable range or not, shall be verified with the table, "Difference between Measurements Taken from Different Flight Paths."

### Article 30 Creation of Ortho Image Data

Ortho image data shall be created through orthogonal conversion of digital photographs for airborne laser scanning with 3-D scanning data.

<Article 30 – Enforcement Rule>

i Ortho image data for each national base map sheet shall be created by joining orthogonally converted digital photographs for airborne laser scanning.

ii The TIFF format shall be used as the format of the ortho image data.

iii Ortho image data shall be created by extending the outer circumference of a scan area to at least 50 m.

iv A positional data file showing geographic coverage of ortho image data shall be created as an ASCII file in accordance with Form 2-11.

### Article 31 Creation of Water Surface Polygon Data

Polygon data of water surface shall be created from ortho image data for areas of water surface.

<Article 31 – Enforcement Rule>

Water surface polygon data shall be created as follows:

i Polygon data shall be created for shore lines of a river with a water course width of 7.5 m or more and a pond of 7.5 m x 7.5 m or larger. Polygon data shall be created for a river that as a whole has a watercourse width of 7.5 m or more, even if it has an area with a watercourse width of less than 7.5m.

ii If a water surface is found in a structure elevated from the surrounding ground (such as a swimming pool in a school or artificial reservoirs surrounded by retaining walls in a sewage treatment plant), data on the water surface shall not be acquired because its foundation structure should be subject to filtering.

iii A sandbank smaller than 7.5 m x 7.5 m in a water surface shall be included in polygon data of the water surface, instead of acquiring polygon data of its shoreline.

iv If a shoreline has a very complex shape with presence of rocks and artificial structures, its shape may be edited in an appropriate way with the condition that such editing shall not compromise the accuracy requirement on elevation data.

v If there is no water surface in a scan area, this process may be omitted.

Article 32 Calculation of the Proportion of Measurement Loss

Calculation of the proportion of measurement loss is calculation of a proportion of areas for which 3-D scanning data has not been acquired for the entire measurement area.

<Article 32 – Enforcement Rule>

A measurement loss shall be verified as follows:

i If no 3-D scanning data has been acquired in a 2.0m x 2.0m grid, such a grid shall be considered as a data-missing grid.

ii The proportion of measurement loss shall be calculated for each national base map sheet with the equation shown below. The result of the calculation for each national base map sheet shall be compiled in Form 2-12, “Survey Sheet for Calculation of Proportion of Measurement Loss.” The area inside the border of water surface polygon shall be disregarded in the calculation.

Proportion of measurement loss = (Number of data-missing grids / total number of grids) × 100

iii The proportion of measurement loss shall be less than 10 % in each sheet of national base map. If the proportion is 10 % or more, an investigation shall be carried out to identify the cause of such a large proportion and a new measurement shall be taken if necessary.

Article 33 Verification

A compiler and other appropriate equipment shall be used in verification.

<Article 33 – Enforcement Rule>

The following items shall be verified:

- i Presence/absence of significant discontinuity of ortho image data at edge matching with focus on major feature (such as road)
- ii Presence/absence of missing water surface polygon data
- iii Appropriateness of edge matching of water surface polygon data
- iv Appropriateness of proportion of measurement loss

## Section 7 Creation of Original Data

### Article 34 Creation of Original Data

Creation of original data is a process to create data by correcting elevation data in 3-D scanning data using control points for correction mentioned in Section 5.

<Article 34 – Enforcement Rule>

- i If the mean of the difference between elevations of control points for correction and elevations of measurement points in 3-D scanning data is 25 cm or more, the standard requires correction for an entire scan area.
- ii The correction to be implemented shall be a uniform increment or decrement of elevation values in 3-D scanning data for an entire scan area.
- iii Result of the Creation of Original Data shall be compiled in Form 2-13, “Residual Difference at Control points for Correction.”

### Article 35 Verification

A person in charge of creation of original data shall verify the data before and after the correction and a person in charge of verification shall verify the data after the completion of the creation of original data.

<Article 35 – Enforcement Rule>

When original data has been created with correction, the following shall be verified.

- i Quality of the result of the correction

## Section 8 Creation of Ground Data

### Article 36 Creation of Ground Data

Ground data is part of the original data that shows elevations and is created by filtering original data.

<Article 36 – Enforcement Rule>

i Ground data shall be created by extending the outer circumference of a scan area to a certain extent.

ii The table below shows the standard items for the filtering.

iii Ground data at a place where a large surface object makes it impossible to represent topography of the place appropriately shall be created by interpolation with non-filtered ground data of a surrounding area.

| | | |
|---|---|---|
| Transport facilities | Road facilities | Road bridges (with a length of 5m or more), viaducts, pedestrian crossings, lampposts, traffic lights, road information boards, etc. |
| | Railroad facilities | Railroad bridges (with a length of 5m or more), viaducts, over bridges, platforms, sheds on platforms, electric poles and signal posts |
| | Mobile objects | Parked vehicles, railroad carriages and ships |
| Buildings | Buildings and accessory facilities | Residential houses, factories, warehouses, public facilities, railroad station buildings, wall-less structures (hothouses and greenhouses), stands of stadiums, gates, pools (including foundation) and fences |
| Small objects | | Monuments, gateways of Shinto shrines, water tanks, fertilizer storage tanks, water supply towers, cranes, chimneys, high towers, radio towers, |

|  |  |  |
|---|---|---|
|  |  | lighthouses, light buoys, pipelines (on the ground and elevated) and power transmission lines |
| Water surface | Structures related to water surface | Pontoons, water level observatories and river sign boards |
| Vegetation |  | Trees(*1), bamboo forests(*1), hedges(*1) and rice plants in paddies(*1) |
| Others | Others | Areas with large-scale land development(*2), open pits excavated for construction of subways and materials in open-air storage |
| Notes | *[1] Data which can be recognized as that of ground surface shall be used as much as possible<br>*[2] If existing condition can be recognized almost certainly as permanent, data on the existing condition shall be used. |  |

Article 37 Consistency with Existing Data)

In order to establish consistency with existing data, existing data and ground data of selected areas of overlapping coverage by these two types of data shall be compared for verification.

<Article 37 – Enforcement Rule>

For the comparison and verification, areas which satisfy the following conditions, shall be established.

i At least one such area shall be established within an area covered by each national base map sheet and there shall be at least 100 measurement points in each of such areas.

ii If there is a control point for correction, it shall be included in an area for the comparison.

iii An area for the comparison shall be located on a large and flat space (*e.g.* a playing ground, vacant lot, road, park, etc.) where data is not likely to be affected by surface objects.

2 The verification shall be implemented as follows:

i The mean of the ground data within an area of overlapping coverage shall be obtained for the comparison and verification.

ii The mean and standard deviation of the difference between the existing data and ground data shall be obtained.

iii If the standard deviation is 30 cm or more, an investigation into the original data shall be carried out to identify the cause of such a large standard deviation and an appropriate measure, such as re-calculation or re-measurement, shall be taken.

iv Result of the verification shall be compiled in Form 2-14, "Result of Verification of Existing Data."

## Article 38 Creation of Filtering Verification Maps

Filtering verification maps shall be created for the purpose of verifying whether the filtering has been implemented appropriately or not and presence/absence of abnormality in created ground data.

<Article 38 – Enforcement Rule>

i Filtering verification maps shall be created by 3D map ( "slope classification map", "shading map", "layer tint map", etc.,).

ii Filtering verification maps shall be created at a scale of 1/4,000 and for each national base map sheet.

iii Filtering verification maps shall be created by extend to a certain extent from the neat lines.

## Article 39 Verification

Quality of the filtering shall be verified with the filtering verification maps and a compiler.

<Article 39 – Enforcement Rule>

The following items shall be verified:

i Presence/absence of unnecessary contour data on vegetation and artificial structures, such as bridges and buildings, which can be interpreted in ortho image data

- ii Presence/absence of original data of vegetation and artificial structures, such as bridges and buildings, which can be interpreted in ortho image data
- iii Whether a water surface polygon matches with the water surface in ortho image data and satisfies the data acquisition criteria or not

2 If it is difficult to verify quality of the filtering, a cross section display created by a compiler shall be used for the verification.

3 2% of the whole data shall be verified.

## Section 9 Creation of the Elevation Data

### Article 40 Creation of the Elevation Data

The elevation data shall be created by interpolating from ground data.

<Article 40 – Enforcement Rule>

- i Elevation at the center of a grid created by dividing an area covered by a national base map sheet at 2m intervals both in the north-south and east-west directions shall be the elevation data of the grid.
- ii For a grid with no measurement point at its center, the elevation at the center shall be interpolated from data of the measurement points nearby.
- iii The TIN method shall be used to interpolate elevation.
- iv Elevation data shall be rounded to the nearest unit of 10 cm.

### Article 41 Comparison with Control Points for Correction

Comparison with control points for correction refers to comparison between an elevation at a control point for correction and the elevation data.

<Article 41 – Enforcement Rule>

Selection of control points for the comparison and data comparison shall be implemented as follows:

- i More than half of the established control points for correction distributed as evenly as possible over a scan area shall be selected for the comparison.
- ii The elevation data of a measurement point nearest to a control point for correction shall be used in the comparison.
- iii The mean and standard deviation of the difference in the elevation in all the comparisons shall be calculated.
- iv Comparison results shall be compiled in Form 2-16, “Elevation Data Survey

Sheet.”

v If the comparison has revealed a standard deviation of 30 cm or more, an investigation shall be carried out to identify the cause or causes of such a large standard deviation and an appropriate corrective measure, such as re-calculation, shall be taken.

Article 42 Assignment of Attribute Data

An attribute showing the condition of filtering of ground data used in the calculation or the condition of being a water surface shall be assigned to each point of the elevation data.

<Article 42 – Enforcement Rule>

Attribute data shall be created as follows.

i Attribute data shall be created for an area for which the elevation data has been created.

ii The data to be created is attribute data to the elevation data.

iii An attribute value of an attribute data item shall be ‘true,’ if there is ground data in a grid for which the elevation data has been acquired, and ‘false,’ if there is no ground data in a grid as a result of the filtering or missing data. Data of areas with surface objects acquired through interpolation shall not be regarded as ground data. A grid whose center is located in a water surface polygon shall be regarded as a “water surface.”

## Section 10 Creation of Digital Data Files

Article 43 Creation of Digital Data Files

Creation of digital data files is a process of recording various types of data on electromagnetic recording media.

<Article 43 – Enforcement Rule>

The digital data files for the following shall be created:

i Original data
ii Ground data
iii Elevation data (CSV format)
iv Water surface polygon data
v Ortho image data
vi Positional data file
vii List of stored data

2 Attribute data shall be described in the elevation data (in CSV format).

3 The data formats provided in Form 2-18 shall be used.

4 Folder composition shall be as described in Form 2-19

Article 44 Verification

A compiler shall be used for the verification of created digital data files.

<Article 44 – Enforcement Rule>

The following shall be verified:

- i Quality of the data format and contents
- ii Presence/absence of data omission

## Section 11 Outputs

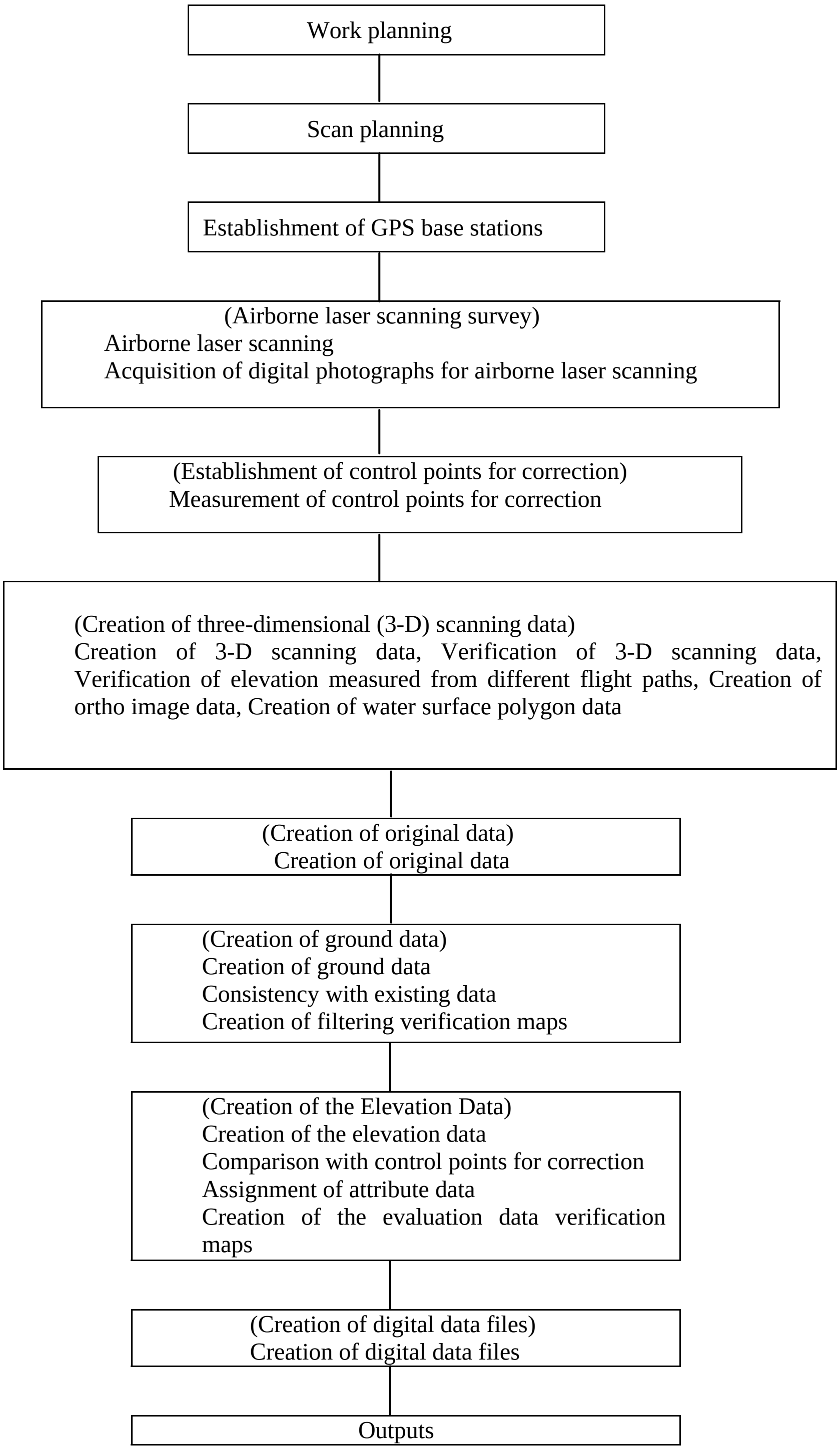
Article 45 Outputs

The following outputs shall be produced:

- i Digital data files
- ii Record of the work
- iii Other relevant documents

## Appendix -1　Workflow

Creation of the Elevation Data



## Appendix -2 Specification of Control Point Survey

(Type of Known station)

| Order<br>Type | 1st Order Control Point survey | 4th Order Control Point survey |
|---|---|---|
| Known Points | Electronic reference Station<br>Triangulation station(1-4 order)<br>1st Control point | Electronic reference Station<br>Triangulation station(1-4 order)<br>Control point(1-3 order) |
| Distance between known points(m) | 4,000 | 500 |
| Distance between unknown points(m) | 1,000 | 50 |

(Method of control points survey)

| Order<br>Type | 1st Order Control Point survey | 4th Order Control Point survey |
|---|---|---|
| Number of Known Points in a Traverse network | More than (2 + number of unknown points/5) Roundup decimals | More than 3 |
| Number of sides in a unit polygon | less than 10 | - |
| Number of sides in a route | less than 5 | less than 10 |
| Distance between nodal points | More than 250m | More than 20m |
| Route Length | Less than 3km | Less than 500m |
| Observation method | Static | Static |
| Observation time | More than 60 minutes (Distance < 10km) | More than 60 minutes |
| | More than 120 minutes (Distance > 10km) | |
| Data logging interval | Less than 30 second | Less than 30 second |

(Equipment)

Equipment for GPS observation shall be 2nd order GPS receiver or high

(Tolerance)

| Order<br>Type | | 1st Order<br>4th Order | Remarks |
|---|---|---|---|
| Error of closure (Base line) | Horizontal( Δ N, Δ E) | 20mm $\sqrt{N}$ | N: number of sides<br>Δ N: Horizontal Error of closure(north-south)<br>Δ E: Horizontal Error of closure(east-west)<br>Δ U: Vertical Error of closure |
| | Vertical( Δ U) | 30mm $\sqrt{N}$ | |
| Discrepancy of Duplicated Base line | Horizontal( Δ N, Δ E) | 20mm | |
| | Vertical( Δ U) | 30mm | |

Appendix -3 Specification of Leveling

(Type of Known bench mark)

| Order<br>Items | 3rd Order Leveling | 4th Order Leveling |
|---|---|---|
| Known bench mark | 1st – 3rd order Bench mark<br>1st – 3rd Level Bench mark | 1st – 3rd order Bench mark<br>1st – 4th Level Bench mark |
| Distance between known bench marks (km) | 50 | 50 |

(Method of Leveling)

| Order<br>Items | 3rd Order Leveling | 4th Order Leveling |
|---|---|---|
| Observation | Direct leveling(round trip ) | Direct leveling(round trip ) |
| Collimation Distance(m) | Less than 70 | Less than 70 |
| Reading unit(mm) | 1 | 1 |

(Equipment)

Equipment for Leveling shall be 3rd order Level or high.

Staffs for Leveling shall be 2nd order Level or high.

(Tolerance)

| Order<br>Type | 3rd Order | 4th Order | Remarks |
|---|---|---|---|
| Discrepancy of Round trip observation value | 10mm $\sqrt{S}$ | 20mm $\sqrt{S}$ | S: Observation distance (one way, km) |
| Error of closure | 10mm $\sqrt{S}$ | 20mm $\sqrt{S}$ | |
| Error of closure Between known bench marks | 15mm $\sqrt{S}$ | 25mm $\sqrt{S}$ | |

## Form 1-1 Airborne Laser Scanning Survey System Inspection Record

# Inspection Record for Airborne Laser Scanning (Boresight Calibration)

| | | | |
|---|---|---|---|
| Project Name | | | |
| Aircraft | | Inspected date | |
| Pilot | | Person in charge | |
| Base (Airport) | | Team Leader | |
| Name of Calibration Site | | | |
| Name of Equipment | | | |
| Take-off Time | | Commencement time | |
| Landing Time | | Completion time | |

## Roll Calibration

| Name of flight path | Ground speed <kts> | Flight hight above the ground <Ft> | FOV <Degree> | Pulse Rate <Hz> | Scan Rate <Hz> | Angle of correction <Degree> | Remark |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## Pitch Calibration

| Name of flight path | Ground speed <kts> | Flight hight above the ground <Ft> | FOV <Degree> | Pulse Rate <Hz> | Scan Rate <Hz> | Angle of correction <Degree> | Remark |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## Horizontal scale calibration

| Name of flight path | Ground speed <kts> | Flight hight above the ground <Ft> | FOV <Degree> | Pulse Rate <Hz> | Scan Rate <Hz> | Angle of correction <Degree> | Remark |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

## Hight (measurement of distance) calibration

| Name of flight path | Ground speed <kts> | Flight hight above the ground <Ft> | FOV <Degree> | Pulse Rate <Hz> | Scan Rate <Hz> | Value of correction <cm> | Remark |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| | |
|---|---|
| **Difference in elevation after the calibrations <cm>** | |

## Form 1-2 Record of Creation of Elevation Data with Airborne Laser Scanning Survey

| Fiscal year of the survey | Area name | Duration of the work | Planning institution |
|---|---|---|---|
| | | ～ | Geospatial Information Authority of Japan |

| | | | |
|---|---|---|---|
| Implementing institution | | Chief engineer | |
| | | Head of the work team | |

| Work process | Duration of work | Quantity | Unit | Comments | Condition | Implemented by | Verified by |
|---|---|---|---|---|---|---|---|
| Work planning | | | Set | | | | |
| Establishment of GPS base stations | | | Station | Baseline vector distance<br>Visibility at ground stations | Excellent / Good / Fair | | |
| Airborne laser scanning | | | $km^2$ | Time of scan<br>Ground elevation<br>Ground speed<br>FOV<br>Scan rate<br>Pulse rate<br>PDOP<br>Proportion of measurement loss | | | |
| Acquisition of digital photographs for airborne laser scanning | | | $km^2$ | Lens<br>S/N ratio of lens<br>Shutter speed<br>Resolution | | | |
| Establishment of control points for correction | | | Point | | | | |
| Creation of 3-D scanning data | | | Set | | | | |
| Creation of original data | | | $km^2$ | Amount of adjustment | | | |
| Creation of ground data | | | $km^2$ | | | | |
| Creation of the elevation data | | | $km^2$ | | | | |
| Creation of digital data files | | | $km^2$ | | | | |
| Compilation of outputs | | | Set | | | | |

## Form 2-1 Flight Planning

| | | | |
|---|---|---|---|
| Project Name | | Implementing Company | |
| Flight Area | | Team Leader | |
| Aircraft/System | | Person in charge | |

| Item | Value of Parameter Setting | Remarks |
|---|---|---|
| Flight hight above the ground | | |
| Sea level Altitude | | |
| Ground speed | | |
| Number of flight paths | | |
| Percentage of sidelap (%) | | |
| Pulse rate | | |
| Scan angle | | |
| Number of scans | | |
| Beam diameter | | |
| Pulse mode | | |
| Others | | |

*A flight path plan map shall be attached.
*Locations of the GPS base stations, etc. shall be clearly marked on the flight path plan map.

## Form 2-2　Description of GPS Base Station

| | | | | |
|---|---|---|---|---|
| Point name | | | Operator | |
| Date of Observation | | | Person in Charge | |
| Address | | | | |
| Coordinate System | | | | |
| Coordinates(m) | X | | MSL.Height(m) | |
| | Y | | Ellipsoid Height(m) | |
| Coordinate | lat | | | |
| | lon | | | |
| Type of GPS Receiver | | | Analysis Software | |
| Rate of Observation | | seconds | Positive angle of elevation More then | degree |
| Instrument Height | | m | Duration | hr　min |
| Horizontal location | | | Photo of Observation | |
| | | | | |

## Form 2-3 Record of Airborne Laser Scanning

| | | | | | |
|---|---|---|---|---|---|
| Project Name | | | | | |
| Aircraft | | | | Flight date | |
| Pilot | | | | Person in charge | |
| Base(Airport) | | Elevation at Base | | Team leader | |
| Datum Plane | | | | Flight hight above the ground | |
| Name of Flight Area | | | | Weather Condition | |
| Name of Equipment | | | | Airstream | |
| Take-off Time | | | | Wind Direction | |
| Landing Time | | | | Wind Speed | |
| G Temperature (T) | | G-Temperrarure(L) | | Temperature | |

**Details of Flight Record**

| Name of flight path | Start time | End Time | Remark | Flight Simplified Map |
|---|---|---|---|---|
| | | | | |
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*Entry of flight path number may be omitted if scan was conducted continuously along adjacent flight paths. Entry is required for the time of commencement of the scan on the first flight path and the time of completion of the scan on the last flight path.

*Entry of time of commencement and completion may be omitted for the other flight paths. Entry of drift angle may be omitted if it is not required

## Form 2-4 Flight Operation Report of Aerial Laser Measurement

| | | | |
|---|---|---|---|
| Area Name | | Leader | |
| Base | | Marker | |

| No. | Date | Weather | | Aircraft | Contents of Operation | Remarks |
|---|---|---|---|---|---|---|
| | | AM | PM | | | |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
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| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |
| 21 | | | | | | |
| 22 | | | | | | |
| 23 | | | | | | |
| 24 | | | | | | |
| 25 | | | | | | |

*The weather of a scan area shall be entered in the columns of the weather.

## Form 2-5 Observed Values and Verification of Difference between Data Sets

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Title of work | | Date of observation | | Implemented by | | Head of the work team | |

| Set | 1 Set (m) | | | 2 Sets (m) | | | 3 Sets (m) | | | Difference (m) | | | Mean (m) | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Point name | X | Y | H | X | Y | H | X | Y | H | △X | △Y | △H | X | Y | H | |
| | | | | | | | | | | | | | | | | |
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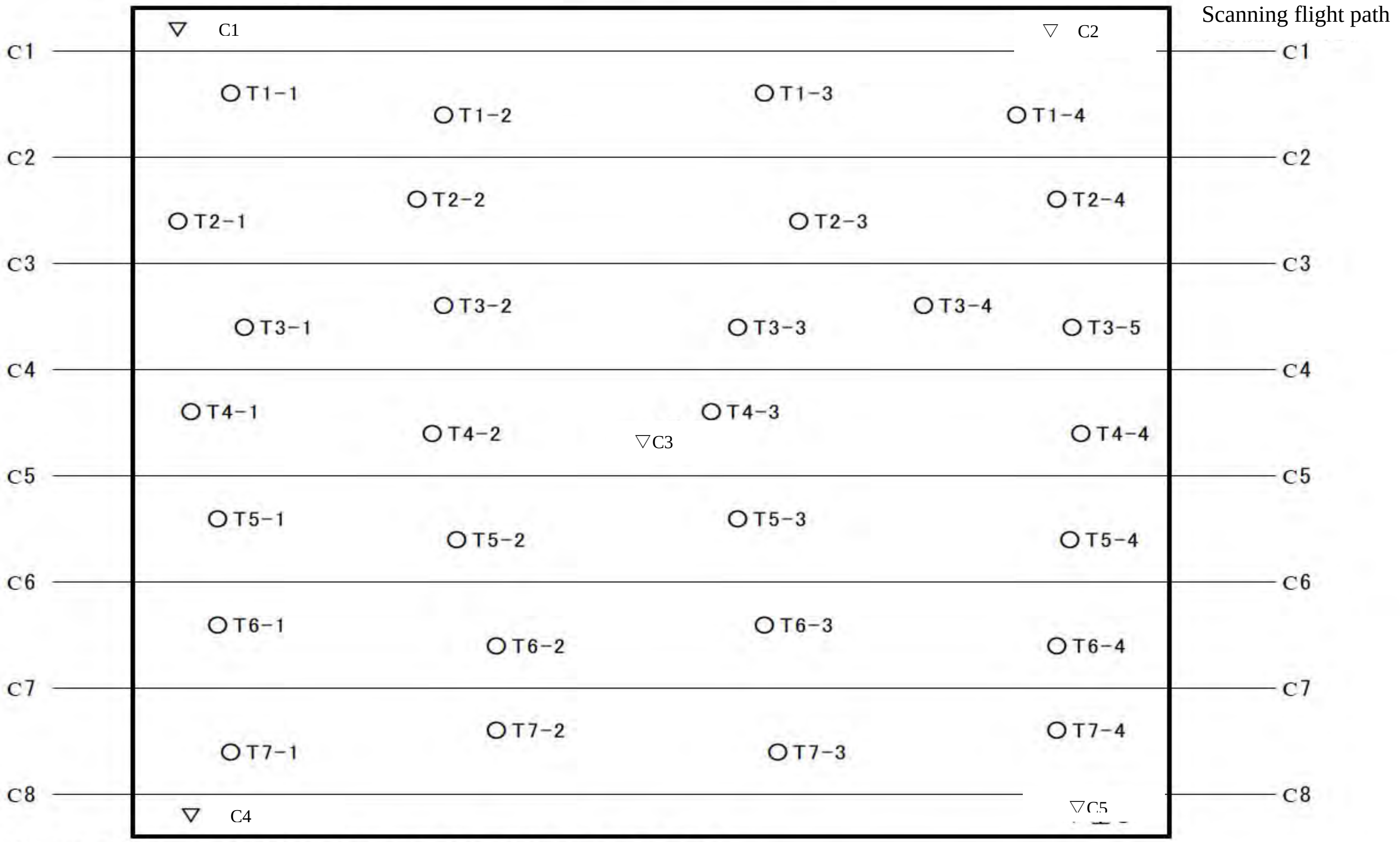
*The allowable range of the differences between data sets: ΔX, ΔY = within 0.020

## Form 2-6 Description of Control Points for Correction

| | | | | |
|---|---|---|---|---|
| Point name | | | Operator | |
| Date of Observation | | | Person in Charge | |
| Address | | | | |
| Coordinate System | | | | |
| Coordinates(m) | X | | MSL.Height(m) | |
| | Y | | Ellipsoid Height(m) | |
| Coordinate | lat | | | |
| | lon | | | |
| MSL.Height(m) | | | WLLIP.Height(m) | |
| Horizontal location | | | Photo of Observation | |
| | | | | |
| Sketch | | | | |

# Form 2-7 Distribution Map of Control Points for Correction and Verificatio Measurements Taken from Different Flight Paths

Fiscal year of the work Scan area Implementing institution



Note: Either a 1/25,000 or 1/50,000 topographic map shall be used for creation of a distribution map.
A control point for correction and a location for verification of the difference shall be represented with a 4 mm equilateral triangle and a 2 mm-radius circle, respectively, with their names described next to the symbols.

## Form 2-8 Three-dimensional Scanning Data Verification Sheet

| | | | | | |
|---|---|---|---|---|---|
| Name of work area | | | Implemented by | | |
| | | | Head of the work team | | |
| Point name | | | Actual measurements H= m | | |
| No | X | Y | Z | Difference (H－Z) | Remarks |
| | | | | | |
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| | | | | | |
| Mean | | | | | |
| Maximum | | | | | |
| Minimum | | | | | |
| Standard Deviation | | | | | |
| RMS error | | | | | |

## Form 2-9 Control Point for Correction Survey Sheet

| | | | |
|---|---|---|---|
| Name of work area | | Implemented by | |
| | | Head of the work team | |

| No | Point name | Leveling result | Output of laser scanning | Difference from the result of leveling | No | Point name | Leveling result | Output of laser scanning | Difference from the result of leveling |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | 11 | | | | |
| 2 | | | | | 12 | | | | |
| 3 | | | | | 13 | | | | |
| 4 | | | | | 14 | | | | |
| 5 | | | | | 15 | | | | |
| 6 | | | | | 16 | | | | |
| 7 | | | | | 17 | | | | |
| 8 | | | | | 18 | | | | |
| 9 | | | | | 19 | | | | |
| 10 | | | | | 20 | | | | |

| | Mean (m) | Standard deviation (m) | RMS error (m) | Maximum (m) | Minimum (m) | Maximum – Minimum | Number of data |
|---|---|---|---|---|---|---|---|
| Difference from the result of leveling for the entire scan area | | | | | | | |

## Form 2-10 Difference between the Measurements Taken from Different Flight Paths

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Name of work area | | | | | | | Implementing institution | |
| Flight path name | C- | | | C- | | | Difference | Remarks |
| Point name | X | Y | H | X | Y | H | △H | |
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| | | |
|---|---|---|
| Minimum | | |
| Maximum | | |
| Mean | | |
| Standard deviation | | |

*A computer printout may be used instead of this form, provided the printout contains all the information required by the form.

Form 2-11 An example of data entry in the form of the positional data file (word file) (with a pixel size of 0.5m)

File name : *****.tfw
0.50 : Pixel size in the x-direction (x-scale)
0.00 : Rotation about x-axis
0.00 : Rotation about y-axis
-0.50 : Pixel size in the y-direction (y-scale)
-25999.75 : x-coordinate of the center of the upper left pixel
-7500.25 : y-coordinate of the center of the upper left pixel

Notes
- Each value shall be aligned to the left.
- The x- and y- coordinates shall be those at the center of the upper left pixel (expressed in meters to the second decimal place).
- The x- and y-coordinate axes shall not be of the geodetic coordinate system but shall be the ones replaced with the Cartesian coordinate axes.
- Small case alphabetical characters and Arabic numerals shall be used in texts.
- A title of a national base map sheet (*e.g.* 09je932) shall be used as "*****" in a filename.

Form 2-12 Survey Sheet for Calculation of Proportion of Measurement Loss

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Name of work area | | | | Implemented by | | | |
| | | | | Head of the work team | | | |
| Map title | Proportion of measurement loss (%) | Map title | Proportion of measurement loss (%) | Map title | Proportion of measurement loss (%) | Map title | Proportion of measurement loss (%) |
| | | | | | | | |
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| Mean of the entire area | | Minimum | | Maximum | | | |

## Form 2-13 Residual Difference at Control Points for Correction

| | | | | | |
|---|---|---|---|---|---|
| Name of work area | | Implementing institution | | | |
| | | Implemented by | | Verified by | |

| Point name | Actual measurements | | | Before correction | | | After correction | Difference | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | X | Y | H | X | Y | H | H | (m) | |
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*A computer printout may be used instead of this form, provided the printout contains all the information required by the form.

| | | |
|---|---|---|
| Correction made (m) | | |
| Minimum | | |
| Maximum | | |
| Mean | | |
| Standard deviation | | |
| RMS error | | |

## Form 2-14 Verification Result of Existing Data

<table>
<tr><td>Name of work area (A)</td><td colspan="3"></td><td>Implemented by</td><td colspan="2"></td></tr>
<tr><td>Name of the adjacent area (B)</td><td colspan="3"></td><td>Head of the work team</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Title of map</td><td colspan="2">Number of measurement points</td><td colspan="2">Mean of the elevations at measurement points</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Area A</td><td>Area B</td><td>Area A</td><td>Area B</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4" rowspan="4"></td><td>Minimum (m)</td><td></td><td></td></tr>
<tr><td>Maximum (m)</td><td></td><td></td></tr>
<tr><td>Mean (m)</td><td></td><td></td></tr>
<tr><td>Standard deviation (m)</td><td></td><td></td></tr>
</table>

## Form 2-16 Elevation Data Survey Sheet

| | | | | | |
|---|---|---|---|---|---|
| Name of work area | | Implementing institution | | | |
| | | Implemented by | | Verified by | |

| Point name | Control point for correction | | | Elevation data | | | Difference | Remarks |
|---|---|---|---|---|---|---|---|---|
| | X | Y | H | X | Y | H | H | |
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| | | | | | Minimum | | | |
| | | | | | Maximum | | | |
| | | | | | Mean | | | |
| | | | | | Standard deviation | | | |

*A computer printout may be used instead of this form, provided the printout contains all the information required by the form.

## Form 2-18 Data Formats

* notes The x- and y- coordinate axes shall be the Cartesian coordinate axes, instead of the geodetic coordinate axes.

Small case alphabetical characters and Arabic numerals shall be used in texts.

A title of a national base map sheet (*e.g.* 5036IV1634) shall be used in a file name.

### Original data

Original data shall be recorded in a csv format in which id and x-, y- and z-coordinates of a measurement point and a pulse number (a number given to each of first, other and last pulses) are described in a single line. If there is a measurement point outside a scan area in a file, data of the point concerned shall not be recorded considering it as a point without data.

File name: *****_org.txt

File structure: ids are a series of numbers and each id appears only once in a file.

| | |
|---|---|
| id1, x1, y1, z1, p1 | x1, y1: Coordinates of a measurement point (expressed in meters to the second decimal place) |
| id2, x2, y2, z2, p2 | |
| : : : : : | z1: Elevation (expressed in meters to the second decimal place) |
| idn, xn, yn, zn, pn | |
| | px: x is a pulse number |

If a scanner which cannot acquire data of other pulses is used, two separate files, *****_f_org.txt for the first pulse and *****_l_org.txt for the last pulse, shall be created. The format for ground data shall be used for these files.

### Ground data

Ground data shall be recorded in a csv format in which id and x-, y- and z-coordinates of a measurement point are described in a single line. If there is a measurement point outside a scan area in a file, data of the point concerned shall not be recorded considering it as a point without data.

File name: *****_grd.txt

File structure: Original data and ground data of a measurement point shall have the same id. Ids of measurement points whose ground data has been obtained through interpolation shall be given a series of numbers with “-“ attached and each id appears only once in a file.

id1, x1, y1, z1 x1, y1: Coordinates of a measurement point (expressed in meters to the second decimal place)
id2, x2, y2, z2
: : : : z1: Elevation (expressed in meters to the second decimal place)
idn, xn, yn, zn

**Elevation data (Grid data)**

Elevation data shall be recorded in a csv format in which x-, y- and z-coordinates and an attribution code of a measurement point are described in a single line. If there is a measurement point outside a measurement area in a file, data of the point concerned shall not be recorded considering it as a point without data.

File name: *****_2g.txt

File structure: ids are a series of numbers given to respective grids in an ascending order starting from the upper left grid, moving to the right and then down and ending at the lower right grid. Each id appears only once in a file.

id1, x1, y1, z1, A1 x1, y1: Coordinates of a measurement point (expressed in meters to the second decimal place)
id2, x2, y2, z2, A2
: : : : :
idn, xn, yn, zn, An z1: Elevation (expressed in meters to the second decimal place)
A1: Attribute : TRUE =1, FALSE = 0

* Attribute ‘TRUE’ shall be given to a 2m-grid if there is ground data in the grid and attribute ‘FALSE’ shall be given to a 2m-grid if there is no ground data in the grid. Attribute values of 1, 0 shall be given to the data items when their attributes are ‘TRUE,’ ‘FALSE’ respectively. If the data is outside the range, it shall not be recorded, being considered as no data.

**Water surface polygon data**

A csv format in which coordinates of polygons are listed or the shape (polygon) format shall be used for water surface polygon data.

An example of a shape-format polygon data file is shown below.

Structure of a polygon file

File name: Water_poly.shp

File structure: A series of numbers shall be used as ids. Each id number appears only once in a file

id1 id1:A polygon label, id1, may be placed at any location in a polygon.
id2 id1:Integer 10 Column
・
idn

Locations of polygon labels of a polygon for a water surface, which has an island (hole) in it:

Polygon labels of a polygon of water surface with an island in it may be placed anywhere in the water surface except on the island (hole) polygon and polygon labels of the island (hole) polygon may be placed anywhere in the island polygon.

Polygon data of the water surface and that of an island (a hole) in it may not have to be placed consecutively in a file.

**Cloud surface polygon data**

A csv format in which coordinates of polygons are listed or the shape (polygon) format shall be used for Cloud surface polygon data.

An example of a Shape-format polygon data file is shown below.

Structure of a polygon file

File name: Cloud_poly.shp

File structure: A series of numbers shall be used as ids. Each id number appears only once in a file

id1 id1: A polygon label, id1, may be placed at any location in a polygon.
id2 id1:Integer 10 Column
・
Idn

Range contained in the cloud polygon, the data is not recorded.

**Contur Line file**

A csv format in which coordinates of polylines are listed or the shape (polyline) format shall be used for water surface polyline data.

An example of a Shape-format polyline data file is shown below.

Structure of a Line file

File name: *****_con.shp

File structure: A series of numbers shall be used as ids. Each id number appears only once in a file

| | |
|---|---|
| id1,contour1,code1 | id1: A line label, id1, may be placed at any location in a line. |
| id2,contour2,code2 | contour1: Elevation of the contour value |
| ・ ・ ・ | |
| idn,contourn,coden | code1: Attribute : total curve =1, principal curve = 0 |

**List of stored data**

A list of 1:4,000 national base map sheets whose polygon data is stored on a recording media shall be indicated in single-byte alphanumeric characters (lower-case letters for alphabetic characters) and shall be stored in the said media as a file entitled “file_itiran.txt”.

(Examples)

503641632

503641634

503641636

503641638

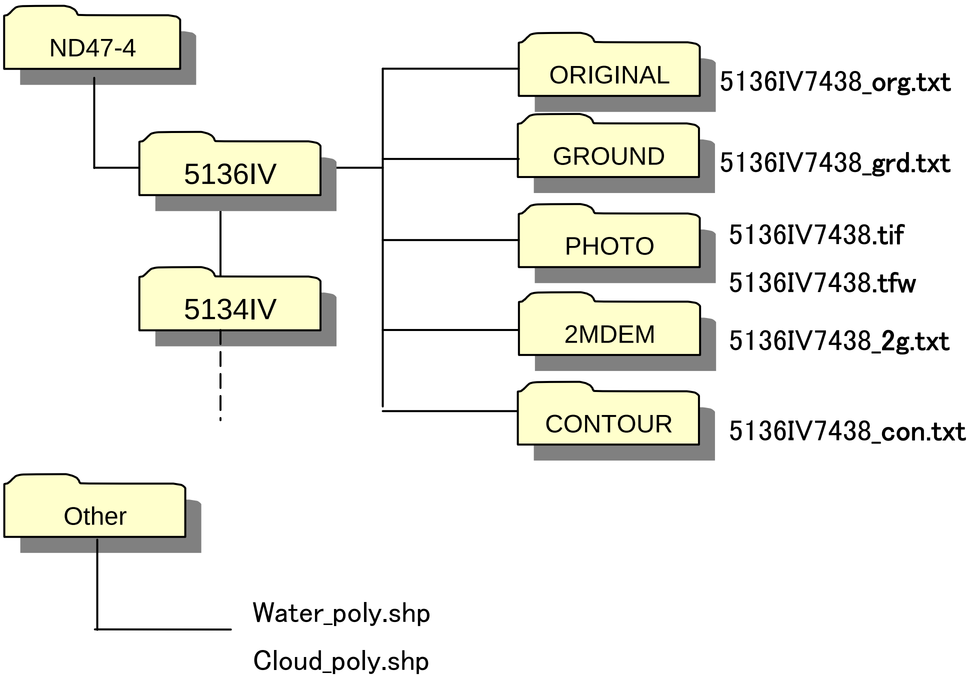
Form 2-19 Folder Structure

The structure of folders is shown below:

A folder “LIDAR_ND47-4” for each survey unit shall contain files of original data, ground data, contour data, ortho image data and elevation data (Grid data in csv format) of the unit. Each data of the same base map shall be stored in each media. Other folder shall be stored water polygon and cloud polygon.

In addition, a list of names of files stored in each media shall be and created and stored.

The folder names shown below shall be used.



### Table -1 Ground Data task of creating accuracy control table

| | | | | | |
|---|---|---|---|---|---|
| Name of work Area | | The amount of work | | Implementing institution | |
| | | | | Verified | |
| | | | | Implemented | |

| Inspection records of filtering | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Map Number | Traffic facility | | | Building | Small Objects | Water | Vegetation | Other | Remarks |
| | Road facilities | Railway facilities | Moving object | | | | | | |
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Table -2 Grid data task of creating accuracy control table

| | | | | | |
|---|---|---|---|---|---|
| Name of work Area | | The amount of work | | Implementing institution | |
| | | | | Verified | |
| | | | | Implemented | |

| Grid data the task op creating Inspection records | | | | | Remarks |
|---|---|---|---|---|---|
| Map number | Error of Elevation value | Lack of grid | Lack of attribute data | Lack of joint | |
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## Table -3 Digital data file task of creating accuracy control table

| | | | | | |
|---|---|---|---|---|---|
| Name of work Area | | The amount of work | | Implementing institution | |
| | | | | Verified | |
| | | | | Implemented | |

| Digital data file task of creating Inspection records | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| Map Number | Original data | | Ground data | | Grid data | | Water Polygon | |
| | Graphic quality of the file structure point | Quality of the file structure attribute point | Graphic quality of the file structure point | Quality of the file structure attribute point | Quality of the header format | Quality of the text format | Quality of the polygon file structure | |
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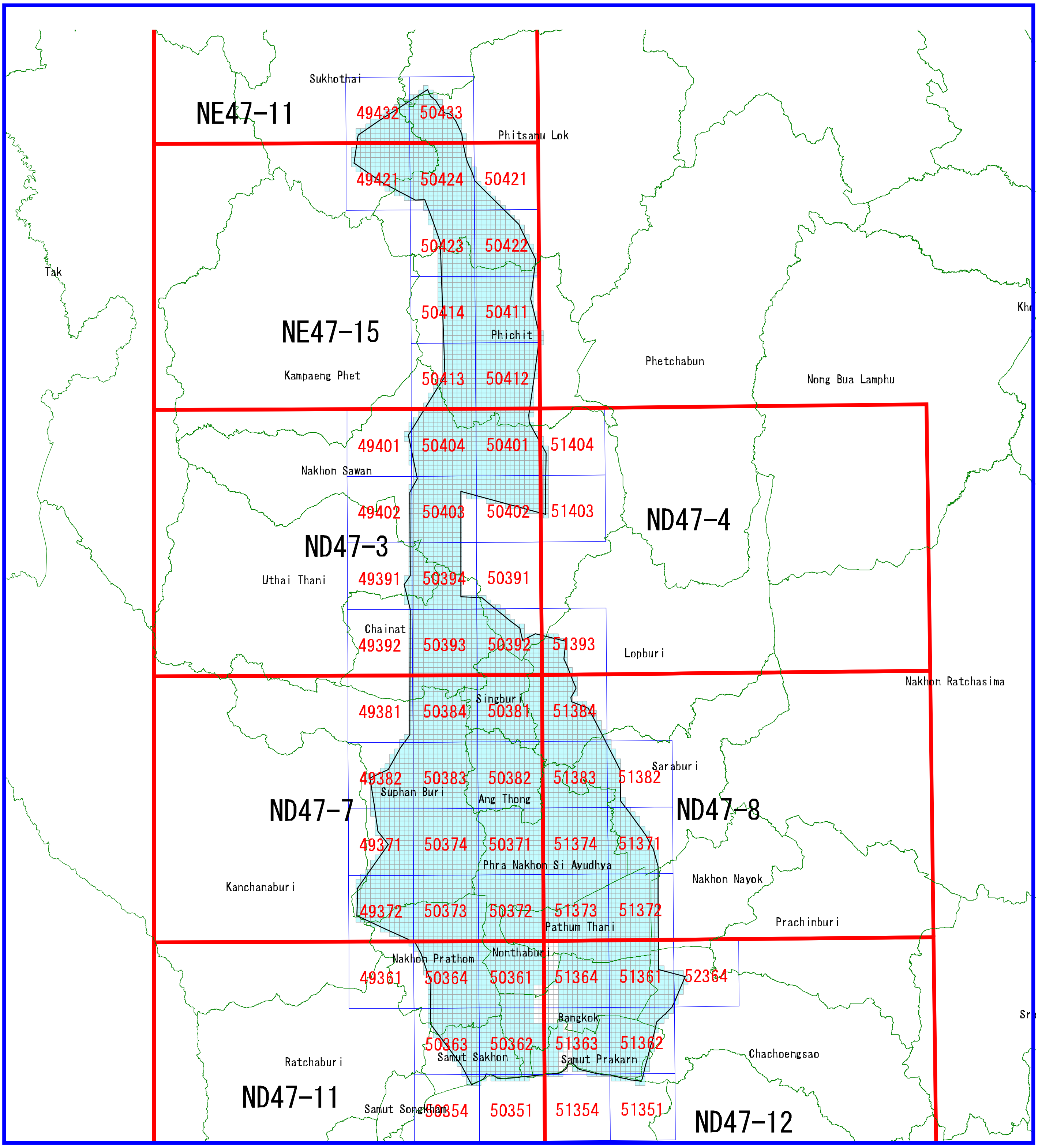
# Appendix-4

22th August 2012

# PROJECT FOR COMPREHENSIVE FLOOD MANAGEMENT PLAN FOR THE CHAO PHRAYA RIVER BASIN

N

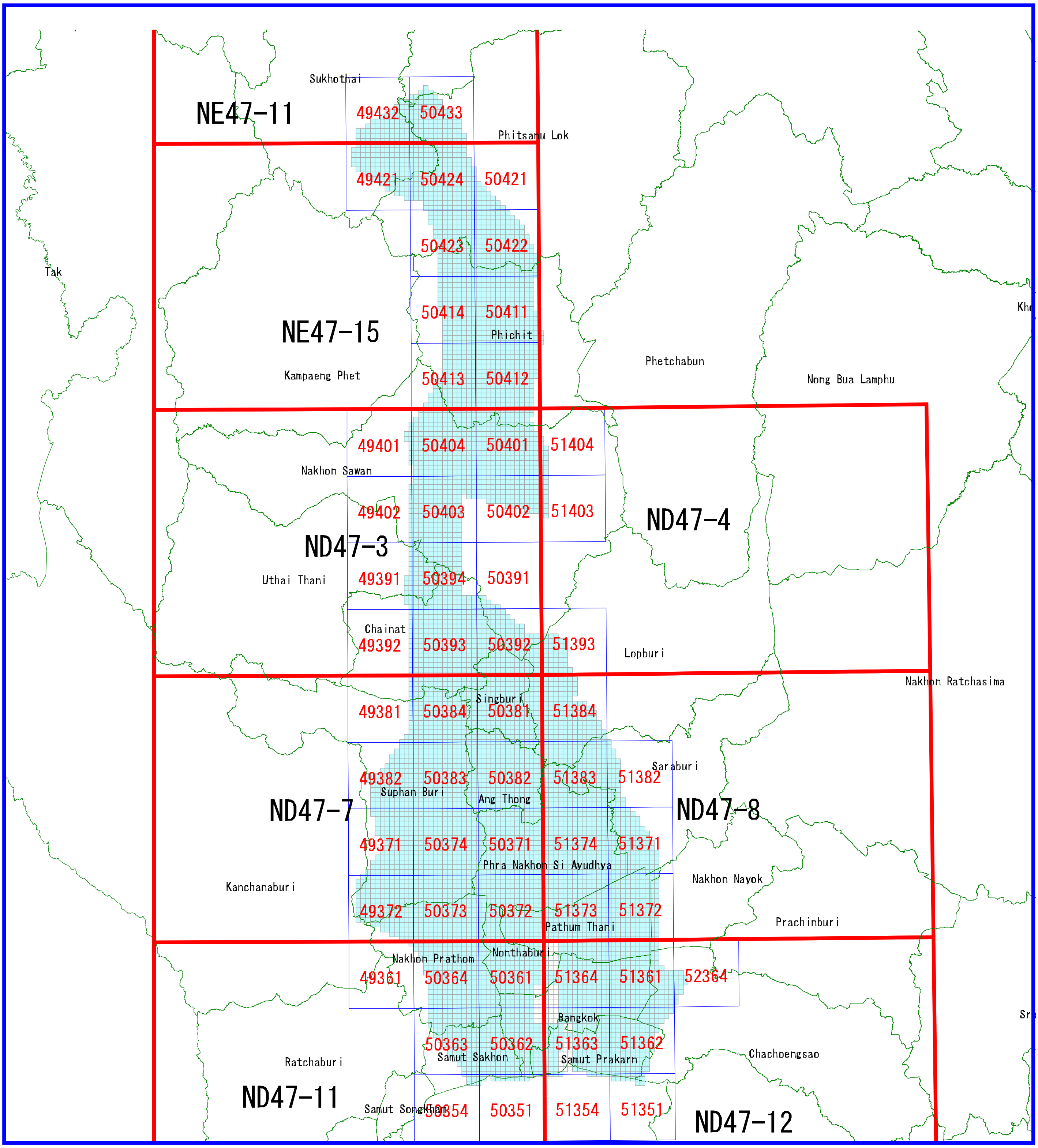


Number of sheet (6666sheets)

ORIGINAL DATA DELIVERY AREA
GROUND DATA DELIVERY AREA
GRID DATA DELIVERY AREA
CONTOUR DATA DELIVERY AREA
ORTHOPHOTO DATA DELIVERY AREA

22th August 2012

N



Number of sheet (6666sheets)