The Republic of Zimbabwe
The Department of the Surveyor-General (DSG)

THE DEVELOPMENT

OF

A GEOSPATIAL INFORMATION DATABASE PROJECT

IN

THE REPUBLIC OF ZIMBABWE

FINAL REPORT

June 2017

Japan International Cooperation Agency (JICA)

Asia Air Survey Co., Ltd.

PASCO Corporation

EI
JR
17-065

USD 1.00＝JPY 111.326

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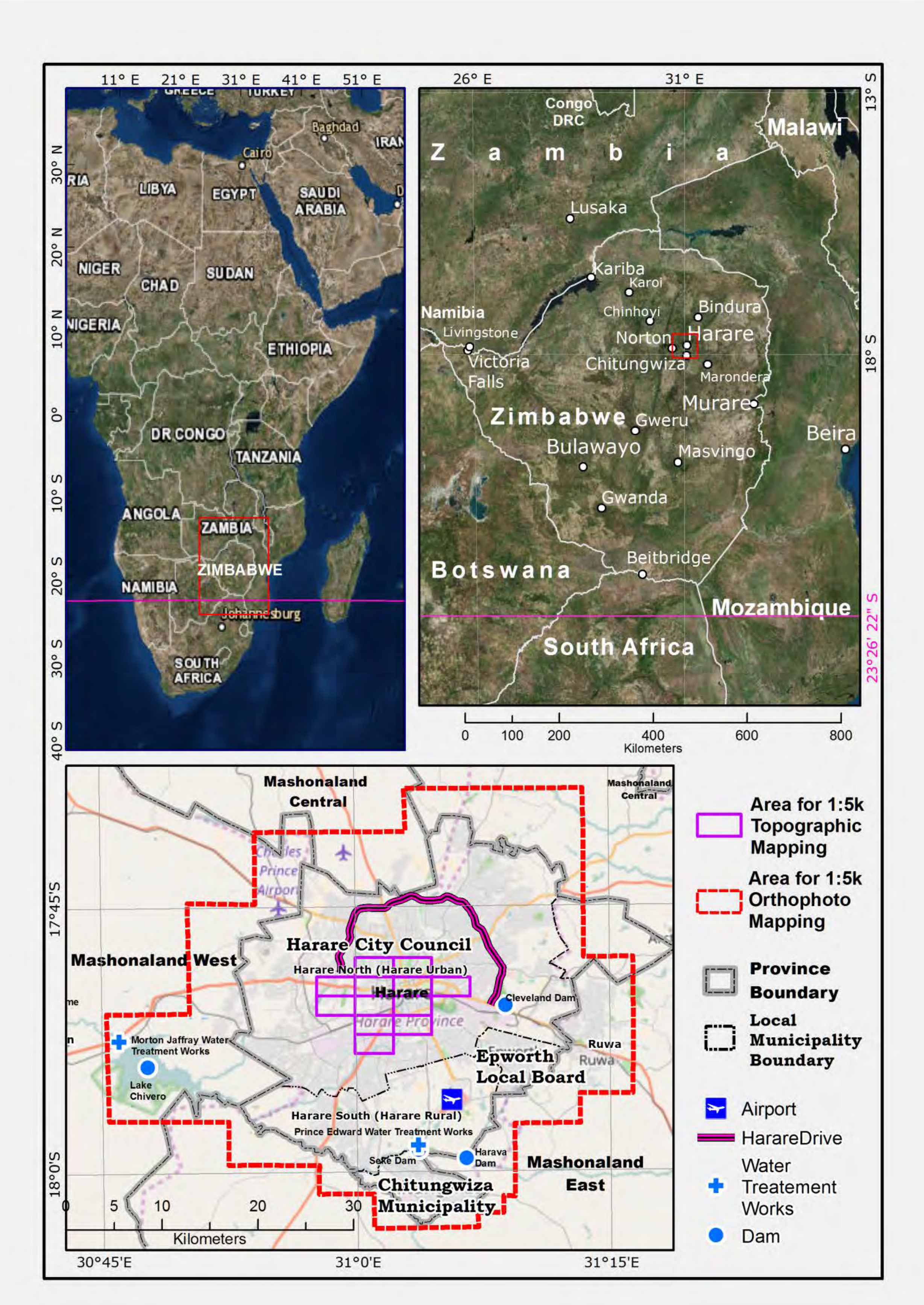
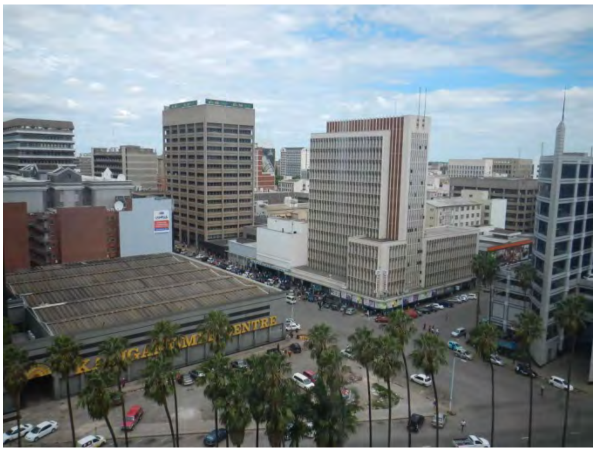
Project Location Map



(Source: JICA Study Team)

Photo Album



City Center in Harare City

Skyscrapers in Harare City

A major road (Milton street) in Harare city

Distant view of Chitungwiza Municipality

Inception seminar

Existing National Geodetic Point 387/T（GPS-35）

Existing National Geodetic Point 3118/T（GPS-38）

Existing National Benchmark BM21M 366

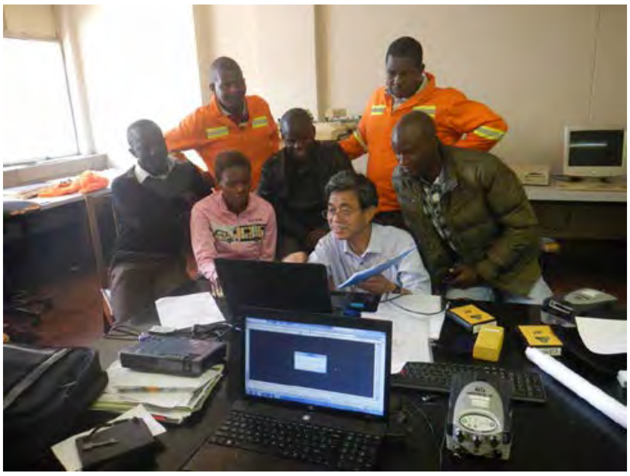
Aircraft for aerial photography

Digital aerial camera

Training on leveling

Training on GNSS observation

Training on an air mark installation



Lecture on analysis of observed data from GNSS survey

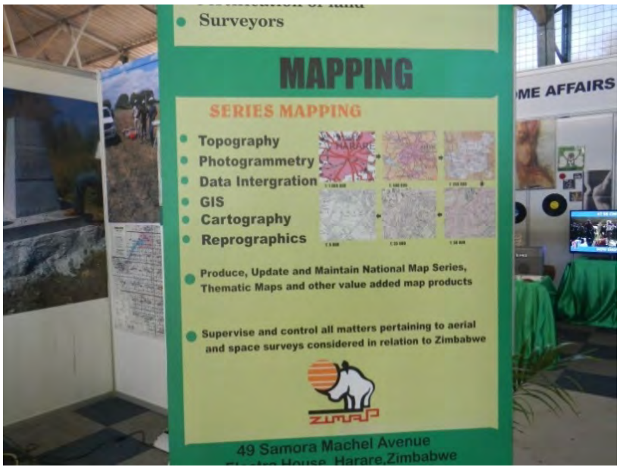
DSG-owned analytical plotter

Digital plotter procured in this project

Training in stereoscopic viewing using digital plotting system

Voluntary training by trainees

Workshop for sales and dissemination promotion at Chitungwiza City hall



DSG booth at Agricultural Expo

Study tour of the CORS at GSI in Tsukuba (Training in Japan)

Presentation on project result in the final seminar

Display booth in the final seminar

Group photo in the final seminar

List of abbreviation (1)

Abbreviation word	An official name
AfDB, ADB	African Development Bank
AusAID	Australian Government Agency for International Development
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTER GDEM	ASTER Global Digital Elevation Model
AWF	African Water Facility
CAD	Computer Aided Design
CBD	Central Business District
CIDA	Canadian International Development Agency
CORS	Continuously Operating Reference Station
C/P	Counterpart
DEM	Digital Elevation Model
DF/R	Draft Final Report
DPW	Digital Photogrammetry Workstation
DMC	Digital Matrix Camera
DSG	Department of the Surveyor General
EMA	Environmental Management Agency
ESRI	Environment Systems Research Institute, Inc.
EU	European Union
FGD	Fundamental Geospatial Data
F/R	Final Report
GCP	Ground Control Point
GGRF	Global Geodetic Reference Framework
GIS	Geographic Information System
GIZ	German Corporation for International Cooperation GmbH
GNSS	Global Navigation Satellite System
GoJ	Government of Japan
GoZ	Government of Zimbabwe
GPS	Global Positioning System
IC/R	Inception Report
ID	Identification
IGS	International GNSS Service
ICT	Information Communication Technology
IMU	Inertial Measurement Unit
IT/R	Interim Report
ITRF	International Terrestrial Reference Frame
JICA	Japan International Cooperation Agency

List of abbreviation (2)

Abbreviation word	An official name
JCC	Joint Coordination Committee
LAN	Local Area Network
M/M	Minutes of Meeting
M/M	Man /Month
METI	Ministry of Economy, Trade and Industry
MDP	Millennium Development Goals
MLRR	Ministry of Land and Rural Resettlement
MTP	Medium Term Plan
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
ODA	Official Development Assistance
OJT	On the Job Training
PC	Personal Computer
PDCA	Plan - Do - Check - Action
PDF	Portable Document Format
R2V	Raster to Vector
R/D	Record of Discussion
SDGs	Sustainable Development Goals
SPOT	Satellite Pour l'Observation de la Terre
Tiff	Tagged Image File Format
TS	Total Station
TSM	Town Survey Mark
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UNOCHA	United Nations Office for Coordination of Humanitarian Affairs
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
UN-GGIM	United Nations initiative on Global Geospatial Information Management
WAN	Wide Area Network
WASH	Water and Sanitation and Hygiene
WB	World Bank (The International Bank for Reconstruction and Development)
WGS84	World Geodetic System 1984
Zim Asset	Zimbabwe Agenda for Sustainable Socio-Economic Transformation
Zim-Fund	Zimbabwe Multi-Donor Trust Fund
ZIMSTAT	Zimbabwe National Static Agency
ZINWA	Zimbabwe National Water Authority

Contents

List of Figures, Tables and Photos

1 Outline of the Project

1.1 Project Background

The Republic of Zimbabwe (hereinafter referred as "Zimbabwe") formulated the "Zimbabwe Agenda for Sustainable Socio-Economic Transformation" (ZimAsset, 2013-2018) in 2013 to guide national development as well as provide an enabling environment to achieve sustainable development and social transformation. This economic blue print has four strategic clusters, one of which is the “Infrastructure and Utilities”. The “Infrastructure and Utilities” cluster aims to rehabilitate infrastructure assets and recovery of utilities services such as: (1) water and sanitation infrastructure, (2) public amenities, (3) information and communication technology (ICT), (4) energy and power supply, and (5) transport (road, rail, marine, and air).

Harare City is the capital and largest city of Zimbabwe as well as the country`s commercial center. The population of Harare has been increasing at a fast rate since independence in 1980. The population increased from 658,000 people in 1982 to approximately 1.6 million people in 2012.

However, the construction of houses and the development of the associated infrastructure did not keep pace with rapid population growth. As a result, problems such as inadequate basic urban services, the collapse of public infrastructure and utilities, the cholera epidemic in 2008, traffic congestion as well as proliferation of informal settlements have since increased, particularly after 2000 when the social and economic crisis started. Therefore, the ensuing problems -that were exacerbated by hyperinflation- needed urgent urban planning, and maintenance and management of the existing water and sanitation infrastructure as well as improvement of public amenities in Harare and its environs. This required accurate and large-scale topographical maps and geospatial information showing the current topographic and land use information for Harare and its environs, which are essential for urban planning, and maintenance and management of public infrastructure. However, the Department of the Surveyor-General (hereinafter referred to as "DSG") had out-of-date large-scale topographic maps that were produced more than 30 years ago. Furthermore, DSG lacked the capacity to produce new topographic maps or geospatial information.

Taking into consideration this background, the Government of Zimbabwe (GoZ) requested the Government of Japan (GoJ) to implement "The Development of a Geospatial Information Database Project" (hereinafter referred to as "the Project") with the following two objectives: Preparation of 1:5,000 scale Digital Topographic maps and orthophoto maps of Harare City and its surrounding area, and technical transfer for the preparation, updating and utilization of Digital Topographic maps and orthophoto maps..

In response to this request, the Government of Japan (GoJ) agreed to implement the technical cooperation in order to assist the Government of Zimbabwe (GoZ). The Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched a “Preliminary Survey Team” for the Project in January 2015 and the minutes of meeting (M/M) between JICA and the Ministry of Lands and Rural Resettlement (hereinafter referred to as "MLRR") was signed.

Also, the Record of Discussion (R/D) concerning the contents of technical cooperation was signed between JICA and MLRR in February 2015. The Department of the Surveyor-General in the Ministry of Lands and Rural Resettlement (hereinafter referred to as "DSG") national survey and mapping organization in Zimbabwe was decided as the counterpart agency for the Project on this R/D.

1.2 Project Objectives

The objectives of the Project are as follows:

Objective 1. Preparation of updated geospatial information database at Harare and its environs

The 1:5,000 scale Digital Topographic maps and ortho-photo maps with contour lines covering Harare City and its environs (the Greater Harare) based on the newly taken aerial photos will be prepared. As a result, the geospatial information for Harare City and its environs that has not been updated for approximately 30 years, will be updated.

Objective 2. Strengthen the capabilities of DSG for preparation of geospatial information database and promotion of utilization of geospatial information database

Activities to strengthen the capabilities of DSG related to preparation, updating and utilization of Digital Topographic maps and orthophoto maps will be implemented.

In past times, DSG could prepare the topographic maps and geospatial information by themselves. The topographic maps currently being used in Zimbabwe are ones that were prepared by DSG at approximately 30 years or more ago. However, due to the economic stagnation with hyperinflation after the year 2000, the investment for digital photogrammetry technology, that is a main stream of topographic mapping at present, could not be made by DSG. As a result, DSG was not able to cope with introducing the digital photogrammetry technology which is currently main stream of digital topographic mapping, and consequently updating of the topographic map by DSG has not been done.

In order to overcome this situation, it is necessary for DSG to reconstruct a structure that can independently update topographic map and geospatial Information. For above, it is indispensable to strengthen the ability to prepare Digital Topographic maps employed digital photogrammetry technique.

For this purpose, technical transfer of digital photogrammetric mapping to the staff of DSG will be executed, and necessary equipment for technical transfer will be procured.

1.3 Project Area

The project area for the preparation of geospatial information database which covers Harare and it environ is shown in Figure 1. The area for each type of data to be prepared by the Project is as follows:

1) 1:5,000 scale Digital Topographic maps 96km^2
2) Digital Orthophoto (20cm ground resolution) 1,700km^2
3) Contour lines data 1,700km^2
Main contour interval: 4metres
Supplemental contour interval: 2metres

Digital aerial photography for a target area of 1,824km2 was executed to be able to cover the whole project area and also aerial triangulation.

The digital aerial photography area includes the entire City of Harare, as well as the adjacent Chitungwiza Municipality Epworth local board and Ruwa local board.

The background for determination of the project area (geospatial information database preparation area) is as follows:

As explained at Section 1.2 Project Objectives, it is expected that the geospatial information database to be prepared by the Project (1:5,000 scale Digital Topographic maps and orthophoto maps with contour lines) will contribute to the development and maintenance of infrastructure in the project area.

Background issues when the target area was determined in the detailed planning survey for this project were as follows.

- For the improvement and maintenance of water supply and sewage infrastructure, and public hygiene, The Manyame River system including Lake Chivero, which is the source of water for the Harare Water and main river system in this region, needs to be included in the project area. The Harare Water is a Department of Harare City that operates the water supply and sewage system in Harare City. In addition to Harare City, water is also supplied to its adjacent areas including Chitungwiza Municipality, Epworth local board, Ruwa local board and Norton town council. Regarding the sewage system, Chitungwiza Municipality manages and operates the sewage system for Chitungwiza municipality.
- The Manyame River system is used as the source of water for Harare City water supply system. However, the appropriate treatment for domestic wastewater flowing into the Manyame River from the surrounding areas including Chitungwiza Municipality is an issue. For the improvement of water supply and sewage system infrastructure, and public hygiene, not only Harare City but also Chitungwiza Municipality must be included in the project area.
- The developing areas are expanding towards the suburbs across the administrative districts. For the appropriate development in the future, geospatial information will be necessary as basic information for planning and monitoring. Therefore, areas that are currently being developed as well as area in the suburbs that are expected to be developed in the future are necessary to be included in the project area.
- Harare City, Chitungwiza Municipality, Epworth local board, Ruwa local board and Norton town council which are collectively called "The Greater Harare" currently have close social and economic

relationship. In order to solve the broad array of issues in this region, geospatial information consisting of large scale Digital Topographic maps and orthophoto maps with contour lines that comprehensively covers the region is necessary.

- Department of Civil Engineering and Works, City of Harare, Harare Water and other users have a high level need for contour lines expressing the ground elevation and undulations.
- DSG has expressed the opinion that the priority of the Project will be placed on boosting the capability of DSG to be able to prepare the digital topographic maps and orthophoto maps by themselves.

Considering the above-mentioned needs and circumstances, the project area was decided as follows:

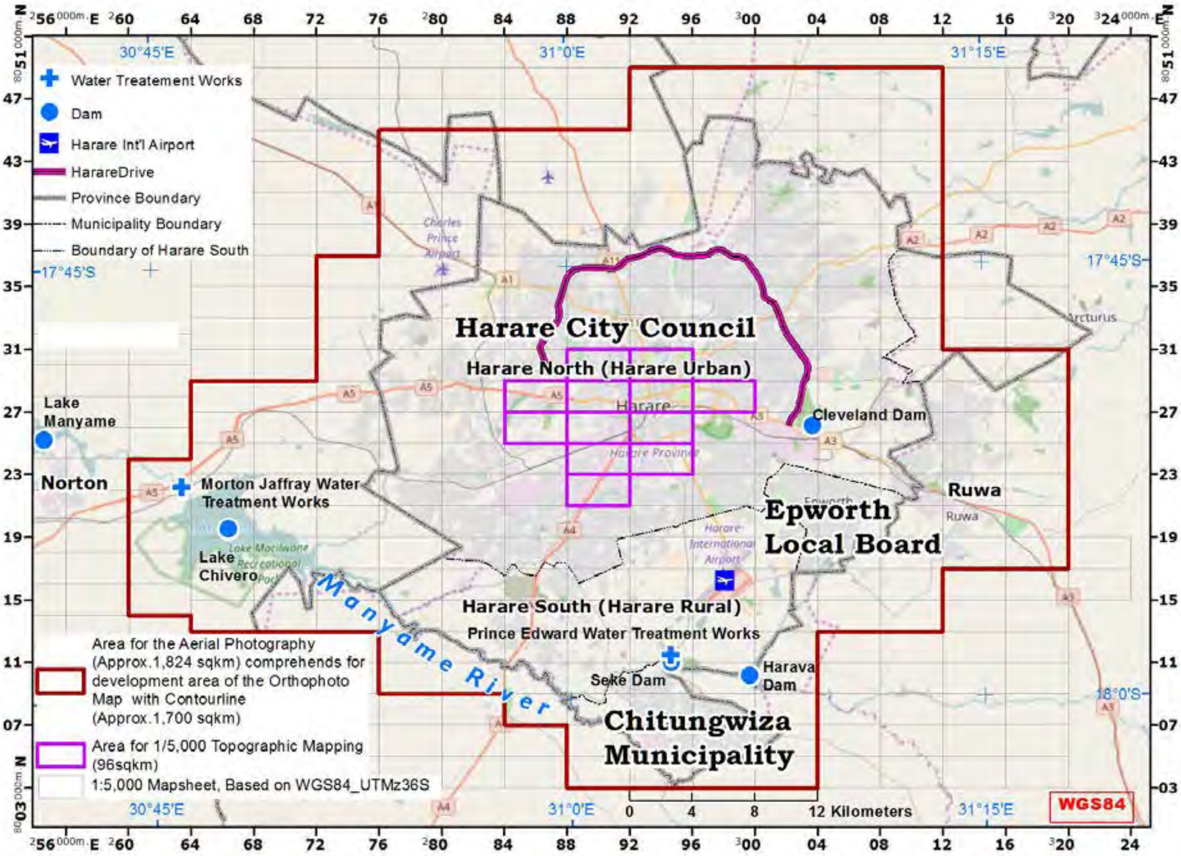
In order to cover the area of Manyame River system and new developing area in the suburbs with 1:5,000 scale Digital Topographic maps, the necessary cost for the Project will become huge.

The main land use of the area where development is planned in the suburbs is farmland or fallow land. Regarding the land use of farmland and fallow land, Digital Orthophoto can provide more information than the Digital Topographic maps (line map), and also it is easy to identify the locations on the Digital Orthophoto rather than the digital topographic maps.

Therefore, it is decided that the 1:5,000 scale Digital Topographic maps will be prepared for the central area of Harare City (96km^2) and the 20cm resolution Digital Orthophoto with contour lines , showing detail land use, ground undulations and elevations, will be prepared for whole project area (1,700km^2).

Finally, the 20cm resolution Digital Orthophoto and contour lines covering the Manyame River system and the surrounding newly developed area will be prepared.

The 1:5,000 scale Digital Topographic maps will be prepared for the central area of Harare City (96km^2) by the Project, and it is expected that the 1:5,000 scale Digital Topographic maps at the remaining area (approximately 1,700km^2) will be prepared by DSG based on the results of technical transfer during the Project period after completion of the Project.



Service Layer Credits: (c) OpenStreetMap and contributors, Creative Commons-Share Alike License (CC-BY-SA)

Source: JICA Study Team

Figure 1 Project Area

1.4 The Department of the Surveyor-General and Current Status of the Existing Geospatial Information Database and its Utilization at the Greater Harare

(1) The Department of the Surveyor-General (DSG)

DSG is under organization of the Ministry of Lands and Rural Resettlement (MLRR) is the counterpart agency for the Project, and also the target organization for the technical transfer of capabilities for geospatial information database development and promotion of utilization.

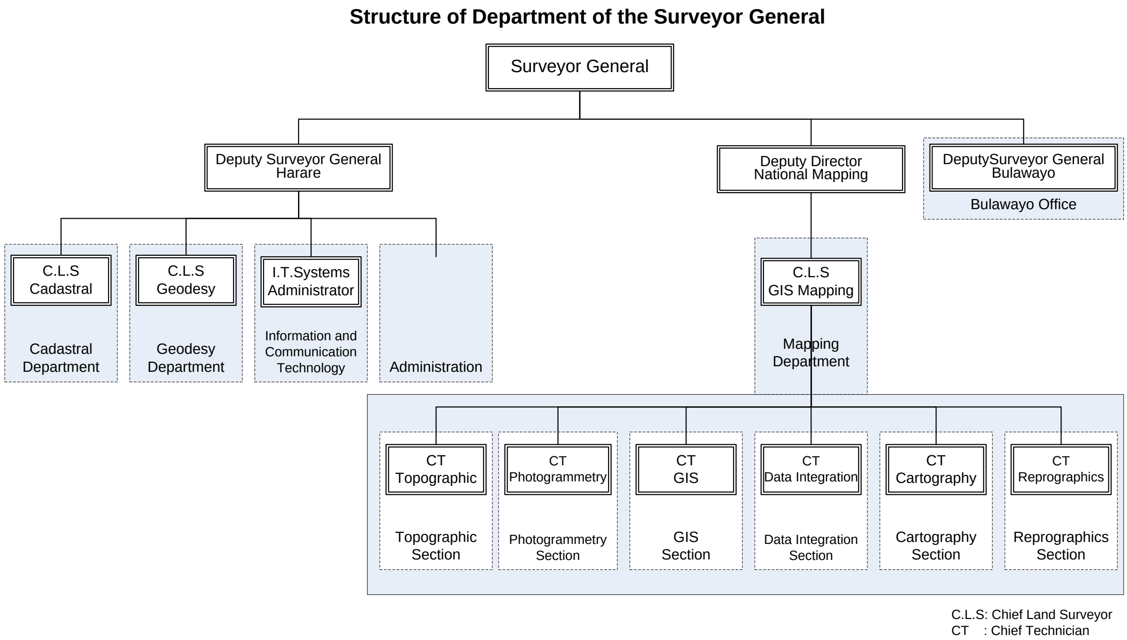
DSG, is a statutory organization which owes its existence to the Land Survey Act (LSA)[Chapter 20:12], which mandates the DSG to undertake administrative, regulatory, advisory and technical functions pertaining to land, aerial and space surveys and mapping, as well as storage and provision of Geospatial information obtained in relation to Zimbabwe.

As the Mission Statement of DSG, DSG has declared "Our Mission is to provide our valued clients and customers with high quality and needs oriented Land Information, Geodetic, Cadastral and Mapping products and services on a timely basis."

DSG is mandated to carry out following duties as a national mapping authority.

(i) Examination and approval of cadastral survey records
(ii) Cadastral survey of all state land in terms of section 25 of the LSA
(iii) Production of topographic base maps and other thematic maps
(iv) Densification and maintenance of the National geodetic control network
(v) Commissioning and maintenance of Zimbabwe's International boundary

The organizational structure of DSG is shown in Figure 2.



Source: DSG

Figure 2 Organizational Structure of DSG

DSG is comprised of the Technical and Support Services divisions. The Technical divisions consist of Geodesy, Cadastral, Mapping, IT and Bulawayo Branch Office. The Mapping Branch is the main Project counterpart. The Mapping Branch comprises the Photogrammetry, Cartography, Topography, GIS, Data Integration and Reprographic Sections.

(2) Present situation of the existing geospatial information at the Greater Harare and its usage

The development and usage status of geospatial information prepared by the DSG at the Greater Harare are as follows:

- DSG prepared 1:5,000 scale and other topographic maps with its own budget and technology during the period when the country was called as Rhodesia.
  In the mid-1990s after formation of Zimbabwe in 1980, topographic maps were prepared and updated, and cadastral data was computerized by DSG.
  However, topographic maps and other geospatial information have almost not been newly prepared or updated at all since around the year 2000.

- Infrastructure of water supply, sewage, electrical supply and other social infrastructure were developed in Harare City from before 1960s.
  During this period, 1:5,000 and 1:2,500 large scale topographic maps were prepared for Harare City and these topographic maps were used for the development of social infrastructure at Harare City.
  These old topographic maps prepared before the mid-1990s are still used by various organizations for infrastructure development projects, even though these old topographic maps have secular changes of land use and artificial features. Consequently, 1:5,000 scale Digital Topographic maps and orthophoto maps with contour lines which will be prepared by the Project will be utilized effectively by the various organizations and users.

1.5 Implementation of the Project

In accordance with the Record of Discussion (R/D) signed between JICA and MLRR, the Project was implemented as a technical cooperation between the Government of Japan and the Government of Zimbabwe.

The following activities were implemented in order to achieve the two objectives stated in section 1.2, i.e. "Preparation of updated geospatial information database at Harare and its environs" and "Strengthen the capabilities of DSG for preparation of geospatial information database and promotion of utilization of geospatial information database".

The Project was started on June 1, 2015 and ended on June 30, 2017 (total project period is 25 months).

(1) Outline of Geospatial Information Database Preparation

The work items of the preparation of geospatial information database and the outline of the activities are shown in Table 1.

Table 1 Work items of geospatial information database preparation and the activities

1.	Aerial photography (July 2015)	Implementation of aerial photography necessary for the preparation of Digital Topographic maps, Digital Orthophoto and contour lines • Aerial photography area 1,824 km^2 • Number of aerial photo images 1,127 sheets • Overlapping 60%±5% • Side lapping 30%±5% • Flight altitude 3,800 m from the ground surface • Ground resolution of aerial photo image 20cm • Date of aerial photography 19 July 2015 (during winter and dry season) • GNSS ground control point station 2 stations
2.	Reference point survey (June 2015～July 2015)	Reference point survey for the determination of the coordinates of 2 reference points based on WGS-84 by long base line analysis of GPS observation using IGS points as given points. • 72 hours (3 days) continuous observation 8 IGS points were used as given points for long base line analysis IGS: International GNSS Service

3.	Ground control point survey (June 2015～August 2015)	Horizontal coordinates and elevations of ground control points necessary for aerial triangulation were decided by GPS survey and leveling. GPS survey • GPS observation for 36 ground control points • GPS observation for 6 existing benchmarks • Prior to GPS observation, site selection of ground control points and establishment of photo signals • Calculation Leveling • Length of leveling routes: 264.5km • Elevations of 19 ground control points were decided by leveling. • Leveling route selection and site selection of leveling points along the leveling routes • Calculation
4.	Aerial triangulation (September 2015)	Aerial triangulation based on the digital aerial photo image and ground control points survey results to determine the coordinates of tie points and external orientation parameter by block adjustment • Number of models for aerial triangulation: 949 models
5.	Field identification (October 2015～December 2015) Field completion (August 2016～September 2016)	Place names and road names necessary for 1:5,000 scale Digital Topographic maps and orthophoto maps were collected. • Target area: 1,700 km^2
6.	Digital plotting, compilation and integration of field completion results (August 2016 ～ October 2016) (February 2017 ～ March 2017)	Digital topographic mapping using digital aerial photo image and field survey data • Digital topographic mapping area: 96km^2 • These works were executed in Japan.
7.	Orthophoto mapping (January 2016 ～ August 2016)	Preparation of orthophoto maps based on the digital aerial photo images including Digital Orthophoto production, contour line drawing and orthophoto mosaicking. • Target area: 1,700km^2
8.	Map representation and map finishing (July 2016 ～ February 2017)	Preparation of Digital Topographic map data applying map representation and map finishing. ・Target area: 96km^2 (12 sheets)
9.	Preparation of Fundamental geospatial dataset (January 2016)	Based on the 1:5,000 scale digital topographic data, Fundamental geospatial dataset was prepared. • Target area: 96km^2
10.	Data file preparation (November 2016 ～ February 2017)	Final check and correction of Digital Topographic map data, Digital Orthophoto data, PDF file of Digital Topographic maps and orthophoto maps, Fundamental geospatial dataset , and stored in record media • Target area for Digital Topographic maps and Fundamental geospatial dataset : 96km^2 • Target area for orthophoto maps: 1,700km^2
11.	Preparation of Harare Street Map (August 2016～November 2016)	Based on the new aerial photos and WGS-84, 1:34,000 scale Harare Street Map was updated. • Target area: 1,008km^2

Source: JICA Study Team

(2) Outline of Technical Transfer to the staff of DSG

Technical transfer to the staff of DSG was implemented in order to strengthen the capabilities of the staff of DSG to prepare, update and utilize the Digital Topographic maps. Table 2 shows the items implemented by the members of JCIA Survey Team, implementation period and assignment period for the technical transfer to the staff of DSG. Table 3 shows the list of equipment used for the Project.

Table 2 Technical Transfer Items, Implementation Period and Assignment Period

	Technical transfer items	Assignment period and M/M	
1.	Technical transfer for mapping standards, specifications and technical training programme	Team leader/mapping standard and specifications/technical training programme 6 June 2015～5 July 2015 26 August 2016～9 September 2016 23 March 2017～21 April 2017	2.50
2.	Technical transfer for aerial photography (July 2015)	Aerial photography 15 July 2015～6 August 2015	0.77
3.	Technical transfer for ground control point survey (June 2015～August 2015)	Ground control point survey-1 6 June 2015 6～August 2015	2.07
		Ground control point survey-2 17 June 2015～23 August 2015	2.27
4.	Technical transfer for field identification (October 2015～December 2015) Technical transfer for field completion (August 2016～September 2016)	Field identification/field compilation-1 22 October 2015～20 December 2015 10 September 2016～6 October 2016	3.17
		Field identification/field compilation-2 12 November 2015～20 December 2015 8 August 2016～10 September 2016	2.43
5.	Technical transfer for digital plotting, compilation, integration of field completion results and map representation and map finishing (August 2016～October 2016) (February 2017～March 2017)	Digital plotting/digital compilation/integration of field data/map finishing-1 23 August 2016～1 October 2016 22 February 2017～23 March 2017	2.33
		Digital plotting-2 1August 2016～20 August 2016	0.67
		Digital plotting/digital compilation/integration of field data/map finishing-2 21 August 2016～1 October 2016	1.40
6.	Technical transfer for aerial triangulation and preparation of Digital Orthophoto image (October 2016～November 2016)	Aerial triangulation/Digital Orthophoto 17 October 2016～27 November 2016	1.40

7.	Technical transfer for data management and preparation of Fundamental geospatial dataset (February 2017～March 2017)	Procurement of equipment/preparation management of Fundamental geospatial dataset 6 June 2015～8 July 2015 19 February 2017～23 March 2017	1.10
8.	Technical transfer for the promotion of utilization of geospatial datasets (June 2015～July 2015) (August 2016) (March 2017)	Promotion of the use of geospatial datasets 17 June 2015～16 July 2015 8 August 2016～27 August 2016 12 march 2017～31 March 2017	2.30

Source: JICA Study Team

Table 3 List of survey equipment

Equipment name	Specifications	Volume
Leveling equipment	Auto level: AE-7, Nikon Tripod: CMF-II, Nikon Staff: SKT-55D Staff base: SSB-S	4 sets
Handheld GPS	GPS map 62s, Garmin	5 sets
Digital camera	Coolpix AW20, Nikon (with GPS compass)	5 sets
Note PC	Dell Mobile Precision M2800, Dell Intel Core i7-4810MQ,15.6" UltraSharp,FHD(1920x1080),8GB (2x4GB) 1600MHz DDR3L,1TB (5.400 Rpm) SS, Hybrid with 8GB Flash, DVDRW, Backlit ,AMD FirePro W4170M w/2GB GDDR5,Wireless, BT, Win 7 Pro (64Bit Win 8.1 Lic)3Yr ProSupport	4 sets
Desktop PC	Hardware for digital photogrammetry workstation 64 BIT Photogrammetry Workstation to run IMAGINE/IMAGINE Photogrammetry software, Intel i7 Quad Core Processor, 32 GB RAM (4 x 8GB), 2 x 2TB Hard drive, Good quality power supply, DVD Drive, Graphics Card: NvidiaQuadroK4200, Windows 7 Professional 64 bit Operating System, Standard Keyboard and mouse, Monitor: 3D monitor with NVIDIA 3D Vision® 2 kit or similar.	1 set
GIS software	ArcGIS for Desktop Advanced, ESRI	1 sets
Digital photogrammetry workstation	Software for digital photogrammetry workstation IMAGINE Photogrammetry, IMAGINE AutoDTM, IMAGINE Terrain Editor, PRO600 CART, PRO600 DTM, ORIMA DP-TE/GPS, ERDAS	1 sets
CAD software	Software for digital plotting and compilation (CAD software) Bentley Map v8i	2 sets
3D mouse for photogrammetric mapping	Intergraph TopoMouse with USB	1 sets
UPS	SMT1000, APC	1 sets
Inkjet plotter (A-0 size)	HP DESIGNJET T930, Hewlett-Packard	1 sets
Printer	BizHub C360, Konica Minolta	1 sets

Source: JICA Study Team

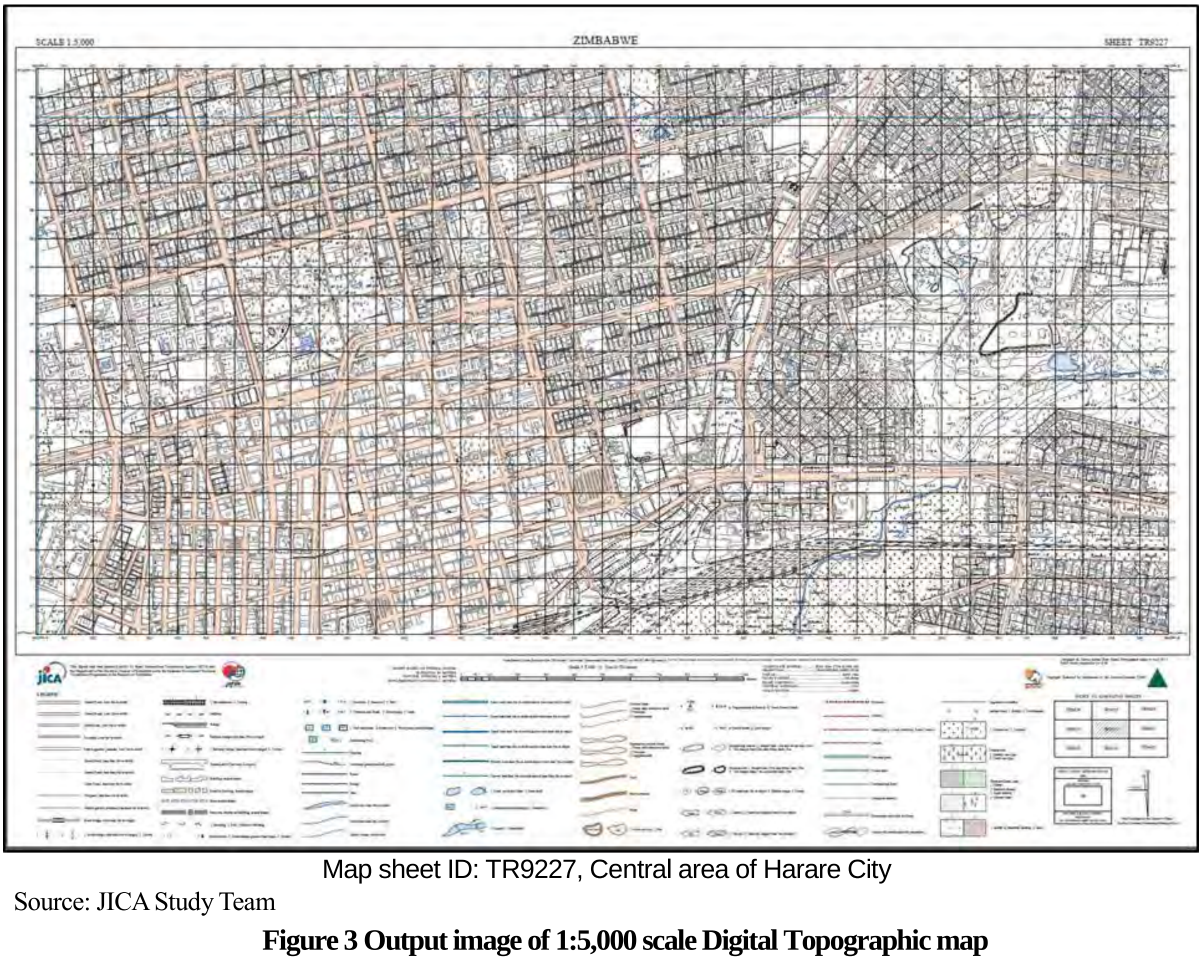
1.6 Outline of geospatial information database preparation by the Project

(1) Results of Digital Topographic maps and orthophoto maps preparation

Digital Topographic maps (mapping area: 96km2, 12 sheets) and orthophoto maps with contour lines (mapping area: 1,700km2, 228 sheets) covering the area shown in Figure 1 in section 1.3 were respectively prepared by the Project. Figure 3 and Figure 4 shows the sample of 1:5,000 scale Digital Topographic map and orthophoto map respectively prepared by the Project.

New digital aerial photos with high ground resolution were taken for the preparation of 1:5,000 scale Digital Topographic maps in order to ensure the horizontal and vertical accuracies of 1:5,000 scale Digital Topographic maps to be prepared by the Project.

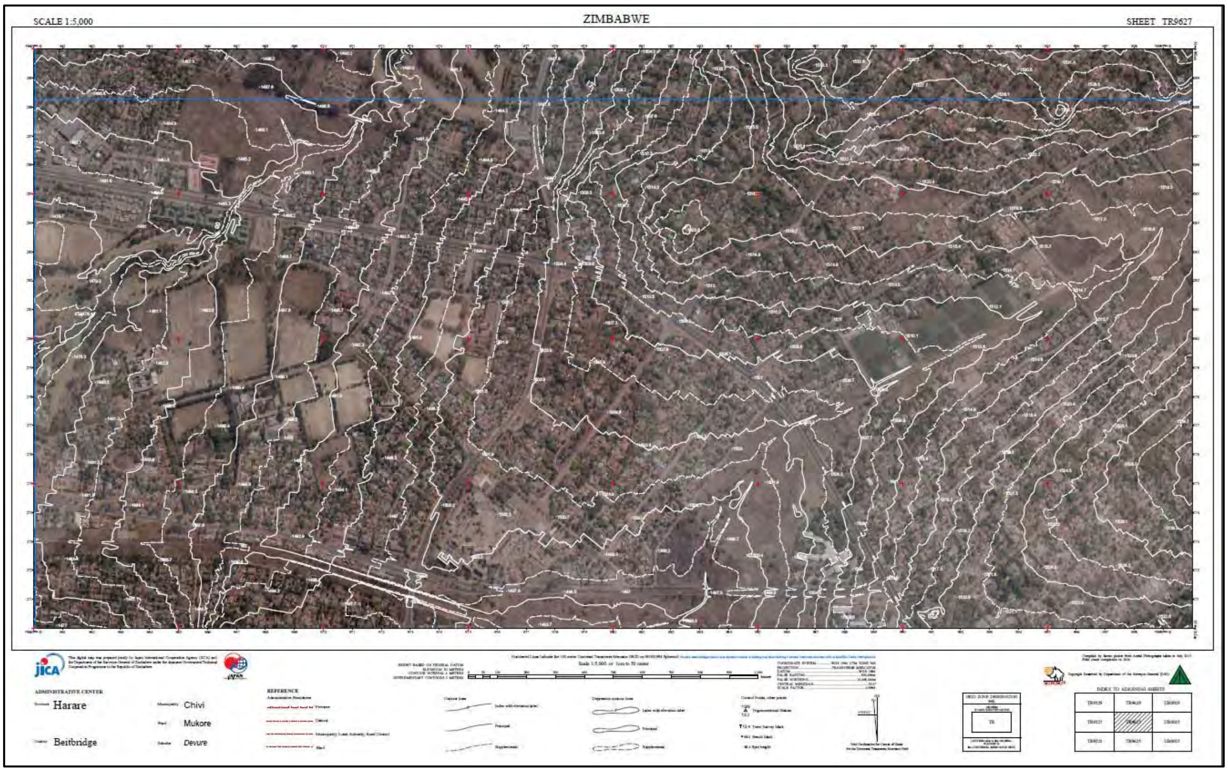
Considering the importance of the information on the undulations of land (topographic condition) for the planning and management of water supply, sewage and other utilities, the contour lines same as 1:5,000 scale Digital Topographic maps were shown on the orthophoto maps.



Map sheet ID: TR9227, Central area of Harare City

Source: JICA Study Team

Figure 3 Output image of 1:5,000 scale Digital Topographic map



Map sheet ID: TR9207, Central area of Chitungwiza Municipality

Source: JICA Study Team

Figure 4 Output image of orthophoto map with contour lines

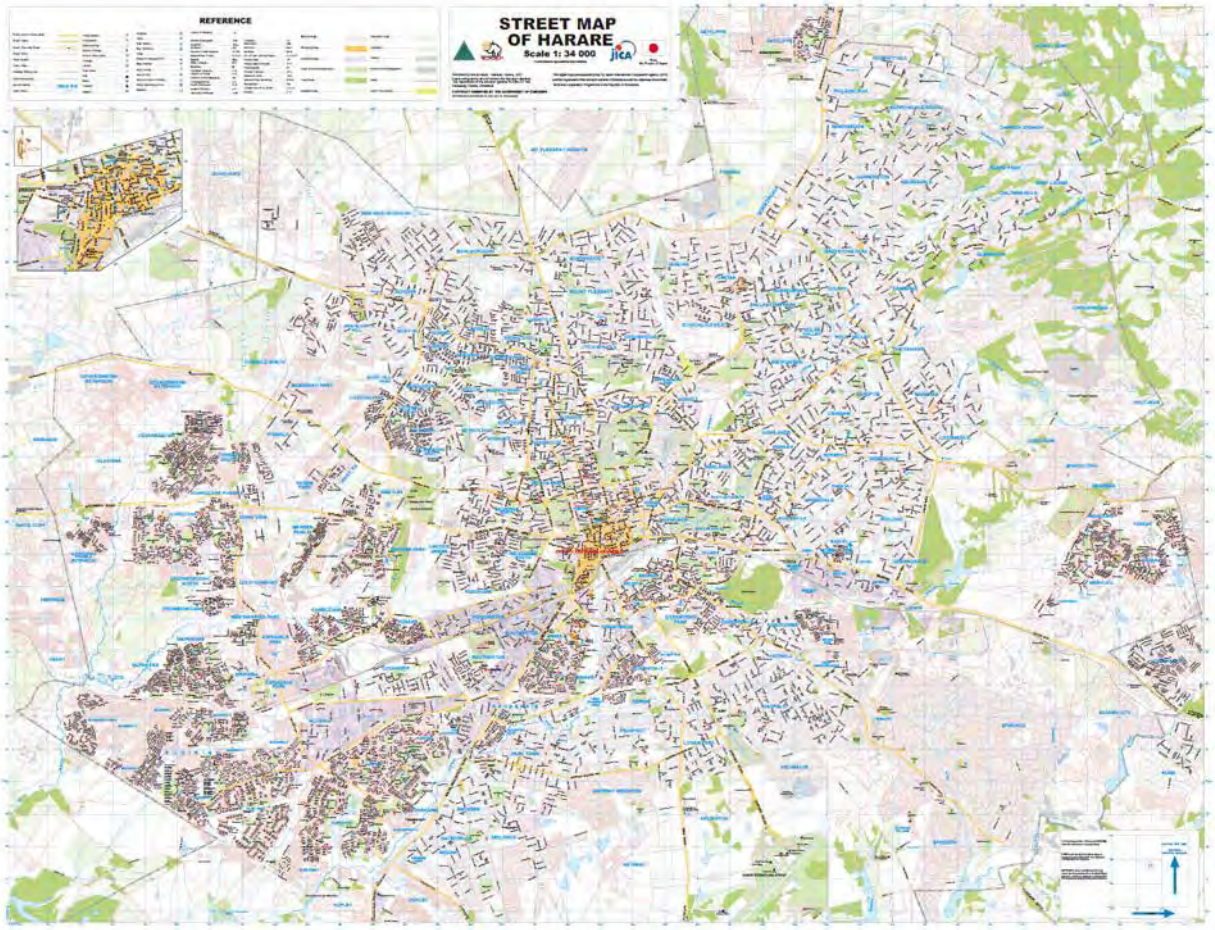
(2) Results of Harare Street Map Preparation

The Street Map of Harare (Scale: 1:34,000) based on the Digital Orthophotos was updated as a sample of the utilization of geospatial data to be created by the Project.

The Harare Street Map is a map covering the area of Harare Urban corresponding to the old Harare City area that was prepared and updated by DSG in the period up until around the year 2000, which was widely used by ordinary citizens.

It is desired that the latest Harare Street Map will be widely used by many people, and also will contribute to the publicity of the Project to the government and private sectors of Zimbabwe.

Figure 5 shows the latest version of the Harare Street Map prepared by the Project.



Source: JICA Study Team

Figure 5 Harare street map prepared by the Project

1.7 Flowchart of the Project

Figure 5 shows the flowchart of the Project. The respective survey and activity items of the Project were grouped into the three components shown in Figure 5. The three components consist of "Development of Digital Topographic maps and orthophoto maps", "Technical transfer" and "Preparation and Promotion of Utilization of Geospatial Information Database" which are considered as the main objectives of the respective survey and activity items of the Project.

Table 4 Three components of the Project and corresponding indexes

Component	Corresponding Index	
	Report*	Flowchart
Preparation of Digital Topographic maps and orthophoto maps	(XXX)-A	【A-XXX】
Technical transfer to the staff of DSG	(XXX)-B	【B-XXX】
Preparation and promotion of utilization of geospatial information database	(XXX)-C	【A-XXX】

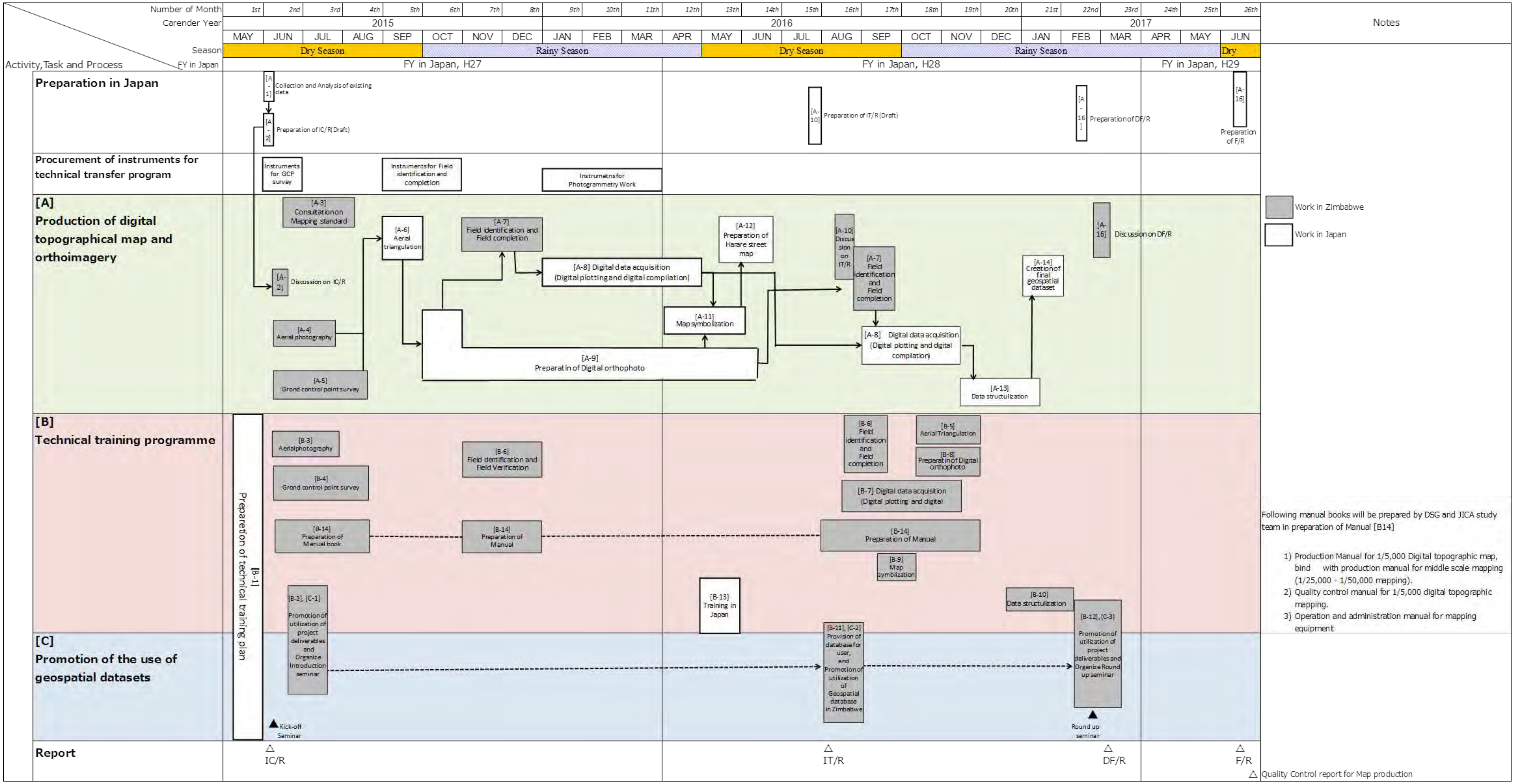
*: Regarding index of this item, number is only assigned for items when same process is separated into multiple parts.

Source: JICA Study Team

The flowchart (Table 5) is separated into the three components with graphics that indicate the respective items.

The items are grouped from the top as follows:
- Preparation in Japan
- Procurement of equipment for technical transfer programme
- Preparation of Digital Topographic maps and orthophoto maps
- Technical transfer
- Preparation and promotion of utilization of geospatial information database
- Submission of report

Table 5 Work flow



1.8 Project Implementation Policy

The preparations of Digital Topographic maps and orthophoto maps, and technical transfer to the staff of DSG were implemented in accordance with the following policy.

1.8.1 Policy for preparation of Digital Topographic maps and Digital Orthophotos

(1) Adoption of GGRF (Survey Standard)

Presently, utilization of GPS becomes popular and also the simultaneous utilization of topographic maps and GPS are commonly performed by various map users. However, there is a several hundred meters discrepancy between the horizontal position obtained by GPS and the topographic maps based on old datum in Zimbabwe (coordinates transformation is required).

From the view point of user convenience of topographic maps, it is desirable to adopt the WGS-84, one of the GGRF (Global Geodetic Reference Framework) as mapping datum instead of old datum in Zimbabwe. Therefore, WGS-84 was adopted as mapping datum for digital topographic mapping and orthophoto mapping in the Project. The standard of digital topographic mapping of the Project such as map datum, ellipsoid, map projection and so on is shown in Table 6.

Table 6 Standard of digital topographic mapping of the Project

Standard	Contents
Map datum	WGS-84
Reference ellipsoid	WGS1984
Map projection	Universal Transverse Mercator (UTM) Zone 36S Central meridian: 33 degree East Datum point: Intersection point between central meridian and equatorial line False easting: 500,000m, False northing: 10,000,000m Scale factor at central meridian: 0.9996
Basis of elevation	The existing national bench marks locating in the Project area were used as given points for elevation.
Unit of distance	Meter (m)
Sheet size and neat line plan	Sheet size: 4km for east-west direction and 2km for north-south direction Size of 1:5,000 scale topographic map and numbering system are same as the existing 1:5,000 scale topographic maps of DSG. Due to the change of reference ellipsoid, the location of neat lines of new 1:5,000 scale topographic maps based on WGS-84 were sifted approximately 300 m in north direction from the neat lines of the existing 1:5,000 scale topographic maps of DSG.

Source: JICA Study Team

Considering the necessity of information on undulations of land (topographic information) for planning and management of water supply, sewage and other public infrastructure, the contour lines are also shown on the 1:5,000 scale orthophoto maps in the same manner as for the 1:5,000 scale topographic maps.

The contour line interval of the 1:5,000 scale Digital Topographic maps and orthophoto maps prepared by the Project is shown in Table 7. The contour line interval of the 1:5,000 scale Digital Topographic maps and orthophoto maps prepared by the Project are same as the existing 1:5,000 scale topographic maps and orthophoto maps of DSG.

Table 7 Contour line interval of each type of map

Type of maps	Main contour line interval	1/2 supplemental contour line interval	Index contour line interval
1:5,000 scale Digital Topographic map	4m	2m	20m
Orthophoto maps	4m	2m	20m
Harare Street Map	20m	---	100m

Source: JICA Study Team

1.8.2. Policy for strengthening of DSG capabilities

(1) Technical transfer by OJT

The technical transfer to the staff of DSG was mainly executed by OJT and also by the method of repeating the cycle of practical operation, effect measurement of technical understanding, achievement evaluation and countermeasures for the issues on technical transfer with the staff of DSG.

The aim of the technical transfer to the staff of DSG was so that the staffs of DSG acquire the basic knowledge and technique of 1:5,000 scale Digital Topographic maps and orthophoto maps with contour lines preparation and be able to manage and update these data by themselves after completion of the Project.

(2) Training in Japan

In addition to technology transfer by OJT, training in Japan was implemented with the objective of providing an understanding of the Digital Topographic map and orthophoto preparation process in Japan, utilization examples and the geospatial information management and sales system.

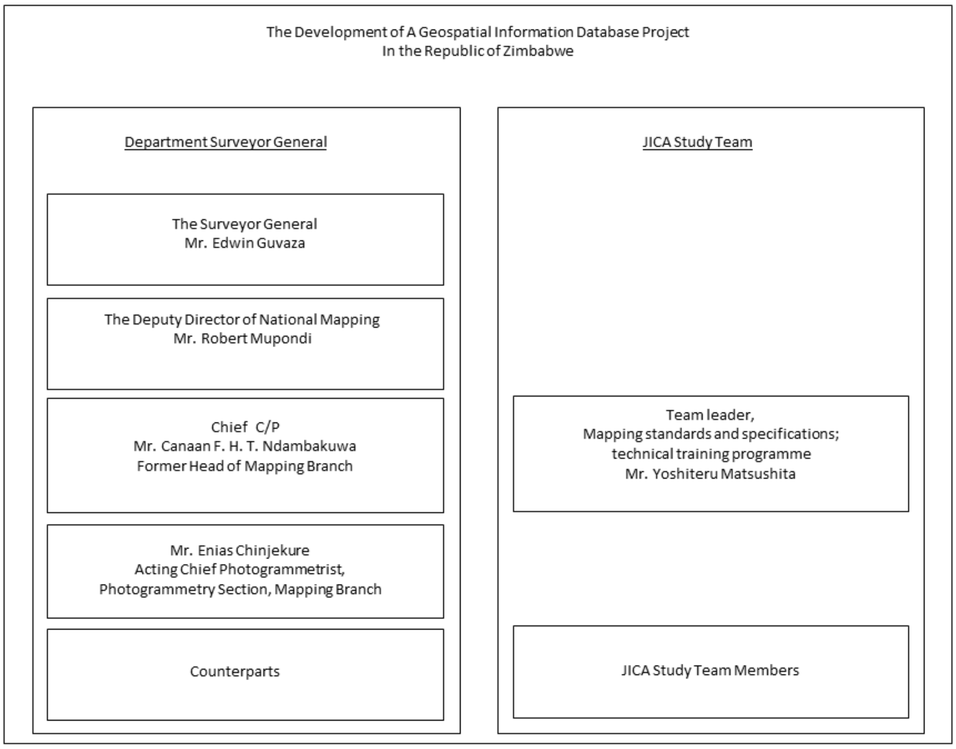
1.8.3. Policy for geospatial information database preparation and promotion of utilization of geospatial information database

A major objective for the preparation of the 1:5,000 scale Digital Topographic maps and orthophoto maps is to be used for the development and maintenance for social infrastructure and public hygiene services.

Therefore, the activities will be implemented so that the 1:5,000 scale Digital Topographic maps and orthophoto maps with contour lines will be used promptly and appropriately by the various organizations and users, and also DSG will be able to prepare and update the geospatial information data by themselves after completion of the Project.

1.9 Project Implementation Framework

The implementation framework of the Project consisting of JICA Team and the staff of DSG is shown in Figure 6



Source: JICA Study Team

Figure 6 Project implementation structure

The names and assignments of the members of JICA Survey Team are shown in Table 8.

Table 8 Members of JICA Survey Team

Assignment	Name	Organization
Team leader, mapping standards and specifications, technical training programme	Yoshiteru MATSUSHITA	Asia Air Survey Co., Ltd.
Deputy team leader, digital plotting/digital compilation, integration of field data, map finishing 1	Toru WATANABE	Asia Air Survey Co., Ltd.
Digital plotting 2	Tsuneo TERADA	Asia Air Survey Co., Ltd.
Aerial photography	Yutaka NAKADA	Asia Air Survey Co., Ltd.
Ground control point survey 1	Junichi KOSEKI	Asia Air Survey Co., Ltd.
Ground control point survey 2	Daikichi NAKAJIMA	PASCO Corporation
Aerial triangulation, Aerial triangulation/orthophoto	Manabu MAYA	Asia Air Survey Co., Ltd.
Field identification, field compilation 1	Yoshiteru MATSUSHITA	Asia Air Survey Co., Ltd.
Field identification, field compilation 2	Daikichi NAKAJIMA	PASCO Corporation
Digital plotting, digital compilation, integration of field data, map finishing 2	Tsuneo TERADA	Asia Air Survey Co., Ltd.

Procurement of equipment, Preparation of Fundamental geospatial dataset , Data preparation and management for providing user	Courage KAMUSOKO	Asia Air Survey Co., Ltd.
Promotion of the utilization of geospatial datasets	Hiromichi MARUYAMA	Infrastructure Development Institute

Source: JICA Study Team

1.10 Work schedule of the project and assignment schedule

Table 9 shows the work schedule of the Project and Table 10 shows the assignment schedule of JICA Survey Team.

Table 9 Work schedule of the Project

Work Plan

	Fiscal Year	2015										2016												2017		
	Work Items	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Preparation of Digital Topographic Maps and Digital Ortho-Photos																										
A-1	Collection, Organization and Analysis of Related Materials and Information	□																								
A-2	Preparation and Discussion of Inception Report	□△																								
A-3	Discussion of Graphics, Work Standard and Specifications	■																								
A-4	Taking of Aerial Photographs	■	■																							
A-5	Control Point Survey and Ground Control Point Survey	■	■	■																						
A-6	Aerial Triangulation				□																					
A-7	Field Identification Survey and Field Completion					■	■									■	■									
A-8	Digital Plotting, Compilation and Completion Compilation									□	□	□	□	□	□	□	□	□	□	□						
A-9	Preparation of Digital Ortho-Photos								□	□	□	□	□	□	□	□										
A-10	Preparation and Discussion of Interim Report															△										
A-11	Map Symbolization														□	□					□	□				
A-12	Preparation of Harare Street Map															□	□	□	□							
A-13	Structuralization of Digital Data																				□					
A-14	Preparation of Data Files																		□	□	□	□				
A-15	Preparation and Discussion of Draft Final Report																				□	□	□	△		
A-16	Preparation of Final Report																								□	□
Technology Transfer Items																										
B-1	Preparation of Technology Transfer Plan and Implementation of Technology Transfer	■	■			■	■									■	■	■	■			■	■			
B-3	Taking of Aerial Photographs		■																							
B-4	Control Point Survey and Ground Control Point Survey	■	■																							
B-5	Aerial Triangulation																	■								
B-6	Field Identification Survey and Field Completion					■	■									■	■									
B-7	Digital Plotting, Compilation and Completion Compilation															■	■					■	■			
B-8	Preparation of Digital Ortho-Photos																		■							
B-9	Map Symbolization																					■	■			
B-10	Structuralization of Digital Data																						■			
B-13	Training in Japan												□													
B-14	Preparation of Manual book	■	■			■	■									■	■	■	■			■	■			
Data preparation and management for providing user, and Promotion of the use of geospatial datasets																										
B-2, C-1	Promotion of the use of geospatial datasets and organize Introduction seminar	■																								
B-11,C-2	Data preparation and management for providing user, and Promotion of the use of geospatial datasets	■														■							■			
B-12,C-3	Promotion of the use of geospatial datasets and organize Round up seminar																						■			

Legend: Work in Zimbabwe: ■ ,Work in Japan: □ , Preparation and Discussion of Reports △

Source: JICA Study Team

Table 10 Assignment schedule of JICA Survey Team

Table for Planned and Record of Assignment of consultants from Japan （Project completion）

1．Assignment in Zimbabwe

Name (Assignment title)	Rank	Trip	Schedule (2015/6 – 2017/6)	Day Total	MM Total
Yoshiteru MATSUSHITA (Team leader, mapping standards and specifications, technical training programme)	2	3	6(30)5, 6(41) 15 (2015/6–8); 10(16)25, 26 (15)9 (2016/8–9); 23 (30)21 22(17) 8 (2017/3–5)	75	2.50
Toru WATANABE (Deputy team leader, digital plotting /digital compilation, integration of field data, map finishing 1)	3	2	23 (40) 1 (2016/8–10); 22(30)23 24(23)15 (2017/2–4)	70	2.33
Tsuneo TERADA (Digital plotting 2)	3		1(20)20 (2016/8)	20	0.67
Yutaka NAKADA (Aerial photography)	4	1	15 (23) 6 (2015/7–8)	23	0.77
Junichi KOSEKI (Ground control point survey 1)	4	1	6 (62) 6 (2015/6–8)	62	2.07
Daikichi NAKAJIMA (Ground control point survey 2)	4	1	17 (68) 23 (2015/6–8)	68	2.27
Manabu MAYA (Aerial triangulation, Digital orthophoto)	4	1	17 (42) 27 (2016/10–11)	42	1.40
Yoshiteru MATSUSHITA (Field identification, field compilation 1)	4	1	16 (8) 23 (2015/8); 22 (60) 20(1)21 (2015/10–12); 10 (27) 6 (2016/9–10)	95	3.17
Daikichi NAKAJIMA (Field identification, field compilation 2)	4	2	12 (39) 20 (2015/11–12); 8 (34) 30 (2016/8–9)	73	2.43
Tsuneo TERADA (Digital plotting, digital compilation, integration of field data, map finishing 2)	4	1	21 (42) 1 (2016/8–10)	42	1.40
Courage KAMUSOKO (Procurement of equipment, Preparation of Fundamental geospatial dataset , Data preparation and management for providing user)	4	2	6 (33) 8 (2015/6–7); 19(33)23 24(23)15 (2017/2–4)	66	2.20
Hiromichi MARUYAMA (Promotion of the utilization of geospatial datasets)	4	3	17 (30) 16 (2015/6–7); 8(19)26 (2016/8); 11(20)30(1)31 (2017/3)	69	2.30
Sutotal for Assignment in Zimbabwe			Plan	705	23.50
			Record	705	23.50

2．Assignment in Japan

Name (Assignment title)	Rank	Trip	Schedule (2015/6 – 2017/6)	Day Total	MM Total
Yoshiteru MATSUSHITA (Technical transfer for mapping standards, specifications and technical training programme)	2		1 (5) 5 (2015/6); 1 (5) 5 (2016/8); 22 (5) 28 (2017/3)	15	0.75
Toru WATANABE (Deputy team leader, digital plotting/digital compilation, integration of field data, map finishing 1)	3		1 (10) 14 (2017/2)	10	0.50
Subtotal for Assignment in Japan			Plan	25	1.25
			Record	25	1.25

Total		Day Total	MM Total
Total	Plan		24.75
	Record		24.75

Regend: Record; Plan; Assignmentcost by consultants accounts; Continuous Assignment for one trip

Reporting	△	△	△	△
	IC/R (2015/6)	IT/R (2016/8)	DF/R (2017/4)	F/R (2017/6)

Source: JICA Study Team

1.11Final Products of the Project

Table 11, Table 12 and Table 13 show the final products of the Project.

Table 11 List of reports

Name of Report	Details and number of report and data					Date of delivery
	English		Japanese (Abstract)	Digital data		
	To JICA	To DSG		To JICA	To DSG	

Inception report (IC/R)	5 sets	10 sets	-	-	-	At the beginning of the Project (June 2016)
Interim report (IT/R)	5 sets	10 sets	-	-	-	Approximately 15 months after the commencement of the Project (August 2016)
Draft final report (DF/R)	5 sets	10 sets	5 sets	-	-	Approximately 22 months after the commencement of the Project (April 2017)
Final report (F/R)	10 sets	10 sets	5 sets	1 set	1 set	At the end of the Project within 1 month after receiving the comments from DSG (Middle of June 2017)

Source: JICA Study Team

Table 12　List of technical cooperation result products

Technical cooperation result products	To JICA	To DSG	Date of delivery
Manual for 1:5,000 scale digital topographic mapping (English version)	1 set	1 set	At the end of the Project
Quality control manual for 1:5,000 scale digital topographic mapping (English version)	1 set	1 set	At the end of the Project
Manual for equipment maintenance (English version)	1 set	1 set	At the end of the Project

Source: JICA Study Team

Table 13　List of other documents and materials

Documents and materials	To JICA	To DSG	Delivery date
Ground control point survey results	1 set	1set	At the end of the Project
Aerial triangulation results	1set	1set	At the end of the Project
Digital data file	1 set	1set	At the end of the Project
1:5,000 scale Digital Topographic map data	1set	1set	At the end of the Project
1:5,000 scale Fundamental geospatial dataset	1set	1set	At the end of the Project
1:5,000 scale digital topographic map data (PDF)	1set	1set	At the end of the Project
Digital Orthophoto data	1set	1set	At the end of the Project
Digital aerial photo data	1set	1set	At the end of the Project
Map specifications	1set	1set	At the end of the Project
Harare Street Map			At the end of the Project
Quality control report			At the end of the Project
List of equipment procured			Within the fiscal year

Source: JICA Study Team

2 Preparation of Digital Topographic Maps and Digital Orthophotos

This chapter describes the project management part, report preparation and discussion, and preparation of Digital Topographic maps and Digital Orthophotos with contour lines in the Project. The technical transfer to staff of the DSG is described in Chapter 3, while the activities to promote the utilization of geospatial information products including project results are described in Chapter 4. In order to achieve the Project objectives and get the expected results, the 1:5,000 scale Digital Topographic maps (96km^2) and Digital Orthophotos maps with contour lines (1,700 km^2) were produced. Following is an outline of the production process.

2.1 Collection and analysis of related materials and information

Flowchart item [A-1]

At the start of the Project, as a preparatory work for the planning, the study team made a collection, sorting out, and analysis of related materials and information. In addition, the study team prepared the Plan of Operation (P/O) of the Project for the Project, and the Study team submitted the P/O to JICA.

(1) As a preparatory work in Japan, the following materials and information were collected and analyzed for formulation of the project implementation plan.

- Confirmation of availability of existing GNSS survey equipment at DSG and arrangement for to rent GPS (GNSS) survey equipment in Japan to prepare as alternative equipment.
- Planning and preparation of ground control point survey
- Analysis of materials collected by the Preliminary Survey Team for the Project
- Collection and analysis of additional information that was obtained in Japan, and geospatial information available at DSG, and the review of data that could be utilized for the Project

(2) As a preparation for the promotion for utilization of the Digital Topographic maps and the Digital Orthophoto, information about the infrastructure development plan and related project in the project area which planned and carried out by GoZ, the City of Harare, and international donor was sorted out by the study team based on the information collected by the detailed planning mission for this project.

(3) Draft of the action plan for data utilization activity was prepared by the Study team based on sorted out a case of utilization of Geospatial information database in Japan.

(4) Based on the information collected by the Preliminary Survey Team for the Project, the study team sorted out the list of organizations and stakeholders that were expected to be user of the Project results. Seminar programmes for promoting the utilization of Digital Topographic maps, and Digital Orthophotos were prepared, as well as draft of invitee list of the Inception Seminar.

(5) As the preparatory work for the preparation for the discussion of the map symbol and the mapping specification for the Digital Topographic map developed by the project, the study team examined the existing topographic map by DSG. And the Study team prepared a draft of map sheet layout plan based on new mapping datum will be adopted in this project.

2.2 Preparation and discussion of the Inception Report

Flowchart item [A-2]

Preparation and discussion of the Inception Report was done in June 2015.

(1) As working in Japan, the study team prepared the Inception Report (draft) including the basic policy, methods, work processes, assignment plan for the Project, technical transfer plan and other details and submitted to JICA. On the Inception Report Review Meeting, the Inception Report (draft) was gained consent of JICA.

(2) In Harare, the study team explained to DSG, the project content, project implementation policy and other details based on the Inception Report (draft). Based on the comment and discussion result between the Study team and DSG, the Inception Report was finalized. The study team and DSG had consensus on the project content and implementation policy mentioned in the Inception Report. The confirmed items in the discussion of the Inception Report are show in Table 14.

Table 14 Confirmation items on Inception Report discussion between JICA Team and DSG

Confirmation Items	
1.	Project implementation method, Work schedule, Assignment schedule
2.	Outline for updating of Harare Street Map Details of specifications will be discussed later.

Source: JICA Study Team

2.3 Preparation of the technical transfer plan and implementation of technical trenfer

Technical transfer was implemented to capacitate DSG in order to produce Digital Topographic maps and Digital Orthophotos using the acquired digital aerial photos even after completion of the Project. The objectives, methods, effect monitoring methods and other details of technical transfer to the staff of DSG were reviewed, and a technical transfer plan was prepared. The outline of the technical transfer plan is shown in Table 15. The technical transfer to DSG was implemented according to this plan. The content and evaluation of technical transfer to DSG are described in Chapter 3 "Technical transfer to the staff of DSG".

Table 15 Outline of technical transfer plan

<table>
<tr><td colspan="4">Objectives of technical transfer
Strengthen the capacity of DSG to produce and update Digital Topographic maps as well as the utilization of geospatial data</td></tr>
<tr><td colspan="4">Points to consider for the technical transfer
1) Implementation of technical transfer programme for the preparation of Digital Topographic maps based on OJT
2) Technology transfer planning designed with aim to make acquire skill and knowledge to the staff of DSG in order that DSG can prepare Digital Topographic maps oneself after the completion of the Project.
3) Introduction of questionnaire, examination result and etc. as objective evaluation items and criterion in goal setting and evaluation for result for monitoring of effectiveness in technical transfer.</td></tr>
<tr><th>Subject areas</th><th>Related section in DSG</th><th colspan="2">Activities</th></tr>
<tr><td>Aerial photography</td><td>Photogrammetry Section</td><td>Lecture</td><td>Aerial photography planning, Ground control point survey planning, Explanation of specification of aerial photography on the contract documents</td></tr>
<tr><td>Ground control point survey</td><td>Photogrammetry Section</td><td rowspan="3">Technical transfer based on OJT,

&

Lecture,</td><td>Ground control point survey planning, Air marking,
Ground control point survey</td></tr>
<tr><td>Aerial triangulation</td><td>Photogrammetry Section</td><td>Aerial triangulation planning,
Tie point observation,
Block adjustment</td></tr>
<tr><td>Preparation of ortho-photo image</td><td>Photogrammetry Section</td><td>DEM preparation, Orthophoto rectification, and Orthophoto mosaic</td></tr>
</table>

Field identification/ completion	Photogrammetry Section & Cadastral Branch	& Preparation of operation manuals	Field survey planning for large scale topographic mapping planning; Narrow down survey items with understanding necessary information for topographic map, Data collection and compiling method.
Digital plotting and compilation	Photogrammetry Section & Cartography section		Mapping specifications, Map symbol, Data acquisition method, Updating and data management method, Quality control
Map representation and Map finishing	Photogrammetry Section & Cartography section		Map representation and Concept and methodology of portrayal of features on topographic map database, Design and creation of map layout and marginal information
Data structuration	Photogrammetry Section & Cartography section		GIS data management, GIS data preparation
Promotion of the utilization of Geospatial information database	Photogrammetry, Cartography section, & Cadastral Branch	Consultation for the promotion of the utilization of geospatial information database, data publication and data sale planning	
Accuracy & Quality control	Photogrammetry, Cartography section, & Cadastral Branch	Concept of quality control, Method of quality control, Implementation of quality control at each stage of work	
Update of the Street Map of Harare	Photogrammetry, & Cartography section	Lecture and practical training, Quality control, Introducing example of updating of middle scale topographic maps	
Equipment procurement	Photogrammetry, Cartography section, & Cadastral Branch	Lecture for checking and maintenance of equipment	

Source: JICA Study Team

2.4 Discussion of map style and symbols, survey standards and mapping specifications

Flowchart item [A-3]

The JICA Study Team and DSG discussed and agreed on map style and symbols, survey standards and mapping specifications for the 1:5,000 scale Digital Topographic maps and orthophotos.

(1) New 1:5,000 scale topographic maps sheet index based on WGS-84

The neat line for the 1:5,000 scale Digital Topographic maps was set to 2 km (width) by 4 km (length) according to the existing 1:5,000 scale topographic map specifications. However, the location of neat line is shifted by adaption of WGS-84 datum. The study team recommended to DSG that the corner ticks showing location of neat line of old existing map based on the conventional map datum (Arc1950) must be indicated on the map in order to minimize inconveniences for the existing map users. DSG agreed to the idea.

(2) Items shown on the topographic map, and data acquisition standards, and map style and symbols

It should be noted that much of the content and map representation of the existing 1:5,000 scale topographic maps produced by DSG were applied in the new 1:5,000 scale topographic maps. The existing 1:5,000 topographic maps and the work manual for the 1:5,000 topographic map prepared by DSG in 1971 were used as reference for determining topographic map specifications such as the definition of features, classification of topographic features, data acquisition standards, map style and symbols.

Since the preparation of the 1:5,000 scale Digital Topographic map (digital plotting, digital compilation and map representation) was to be done in Japan, it was necessary to clarify the topographic map specifications (based on topographic, natural and artificial features in Zimbabwe) through discussions with DSG. This information was conveyed to the photogrammetry engineers and operators in Japan so that they could understand 1:5,000 scale topographic mapping specifications in Zimbabwe. Therefore, major issues due to misunderstanding were not encountered during digital plotting, digital compilation and map representation in Japan.

(3) Preparation of map feature codes for digital plotting

Map feature codes for digital plotting and digital compilation were developed prior to the 1:5,000 scale digital topographic mapping. Note that the existing 1:5,000 scale topographic maps of DSG were produced using analogue method: inking or scribing method by skilled mapping technicians (cartographers) before digital topographic mapping was introduced. On the other hand, Digital Topographic map data prepared with current digital mapping technique using computer and software is collection of figures: -that is point, line, and area (polygon) geometry- as well as text (string) data.

During data acquisition (digital plotting) process, geographic features to be expressed on map will be obtained as figure in initial data of Digital Topographic map data. Figures on Digital Topographic map data will be classified according to the pre-defined data acquisition standard and criteria. The map feature codes are used at this process.

The map feature codes consist of the following information.

- Name of category and definition of geographic feature type
- Identification code for geographic feature type
- Type of geometry: point, line, and area (polygon) as well as text in order to classify and differentiate geographic feature types
- Line symbology type (line type, line width, color,) to be applied when features are displayed on monitor
- Identification of layer or file which will be recorded

Map information can be identified by each geographic feature type in the corresponding data file based on a map feature code.

Map feature code tables, which consist of a list of category and geographic feature type, map representation, and geometry types corresponding to each feature type were organized (Figure 8). Definition of the geographic feature type, and mapping standards for the new 1:5,000 Digital Topographic map was determined with reference to the existing topographic maps prepared by DSG in the past. On the contrary, the categorization and code identification system for the geographic feature type was defined with reference to the 1:5,000 topographic mapping standards in Japan. Several map feature code tables developed by previous DSG technicians from the end of the 1980s to the 1990s are available in the Photogrammetry Section. In particular, one map feature code table was prepared by DSG technicians in 1995, who are the counterparts of the Project. The basic concept of digital mapping and fundamental composition of map feature codes is not so different from 20 years ago. However, computers had limited capacity 20 years ago compared to nowadays. The technicians needed to have a higher level of skills in order to effectively utilize the limited computer capacity.

Therefore, DSG technicians have the experience to develop map feature codes. Although, the Photogrammetry Section had been dormant for some time, a baseline survey indicated that DSG had understanding of basic concepts of developing map feature codes, topographic and digital mapping. The baseline survey evaluation was based on facts and observations analyzed by the JICA Study Team such as the availability of:

- map feature code tables at DSG, and
- Technicians who have experience in developing feature codes.

```
3DD -- Plot Style Report
      Page 1
File: C:\PROJ2\PHOTOLAG.PST
12-27-95  09:15:16
HITECH Mapping Systems Pty Ltd
306/3 Smail Street, Broadway, NSW 2007, Australia

Ident                          Feat Type   Colour  Symbol  Weight
Offset  ReScale
                                                           (mm)
(mm)
_____________________________________________________________________
_______________

1.0    roads
1.1      tarred road
1.1.1        wide tar
1.1.1.1          multi-lan     AOR          RE        9     0.70
1.1.1.2          double-la     AOR          RE        9     0.37
1.1.2        narrow tar
1.1.2.1          double ed     AOR          RE       10     0.00
1.1.2.2          single la     Line         RE       10     0.00
1.1.2.3          air strip     Line         RE       12     0.00
1.2      control pt            Point        RE       25     0.00
1.3      gravel
1.3.1        gravel/eart       Line         RE        4     0.06
1.3.2        other             Line         RE       47     0.05
1.4      strip                 Line         RE       11     0.02
1.5      footpath
1.5.1        track/c-lin       Line         RE       12     0.02
1.6      bridge symbl          Symbol       BK        4     0.30
1.7      other/sports          Line         BK       13     0.10
1.8      bridge                Line         BK        0     0.00
2.0    buildings
2.1      bldg-scaled
2.1.1        bldg edge         AOR          BK       39     0.00
2.1.2        bldg symbol       Point        BK        3     0.15
```

Source: DSG

Figure 7 Feature code table prepared by DSG in 1995 (road)

Code for Major Category	FeatureGroup	Code for Medium Category	Code for Feature Geometric object	Code for depiction class	Feature Code	Category (ref ere	Map Symbol (図式の絵が入る)	Symbol Specification line width or font size	Symbol Specification Color	Name for Map Symbol (Feature Class Name)	Geometry Type of feature Class (地物のジオメトリ)	Application rule ~~(Map content and specifications, Plottable Detail and others)~~ ここは地図記号の説明（図化の取得方法は右欄）
1	Administrative Boundary	1	01	0	11010	Boun		0.4mm	Zim_Red	Between, Province	Line	
1	Administrative Boundary	1	02	0	11020	Boun		0.3mm	Zim_Red	Between, District	Line	
1	Administrative Boundary	1	03	0	11030	Boun		0.4mm	Zim_Red	Between Municipality or Local Authority or Rural Council	Line	
1	Administrative Boundary	1	04	0	11040	Boun		0.2mm	Zim_Red	Wards	Line	
2	Road	1	01	1	21011	Road		0.2mm	Zim_Gray Zim_Red20	Tarred Road, over 5m in width (Depicted as double line)	Line	Carriage way surfaced by asphalt, concreate, or cobble. Both side of feature (edge of carriage way) to be depicted as line.
2	Road	1	01	2	21012	Road		0.5mm 0.3mm	Zim_Gray Zim_Red20	Tarred Road, less than 5m in width (Depicted as single line)	Line	Carriage way surfaced by asphalt, concreate, or cobble. Centerline of feature (center of carriage way) to be depicted as line.
2	Road	1	02	1	21021	Road		0.2mm	Zim_Gray Zim_Gray20	Gravel Road, over 5m in width (Depicted as double line)	Line	Carriage way surfaced by gravel, or crushed stone. Both side of feature (edge of carriage way) to be depicted as line.
2	Road	1	02	2	21022	Road		0.5mm 0.3mm	Zim_Gray Zim_Gray20	Gravel Road, less than 5m in width (Depicted as single line)	Line	Carriage way surfaced by gravel or crushed stone. Centerline of feature (center of carriage way) to be depicted as line.
2	Road	1	03	1	21031	Road		0.2mm	Zim_White	Other Road, over 5m in width (Depicted as double line)	Line	Carriage way non surfaced. Both side of feature (edge of carriage way) to be depicted as line.
2	Road	1	03	2	21032	Road		0.2mm	Zim_White	Other Road, less than 5m in width (Depicted as single line)	Line	Carriage way non surfaced. Centerline of feature (center of carriage way) to be depicted as line.

Source: JICA Study Team

Figure 8 List of feature codes of 1:5,000 scale digital mapping prepared for the Project

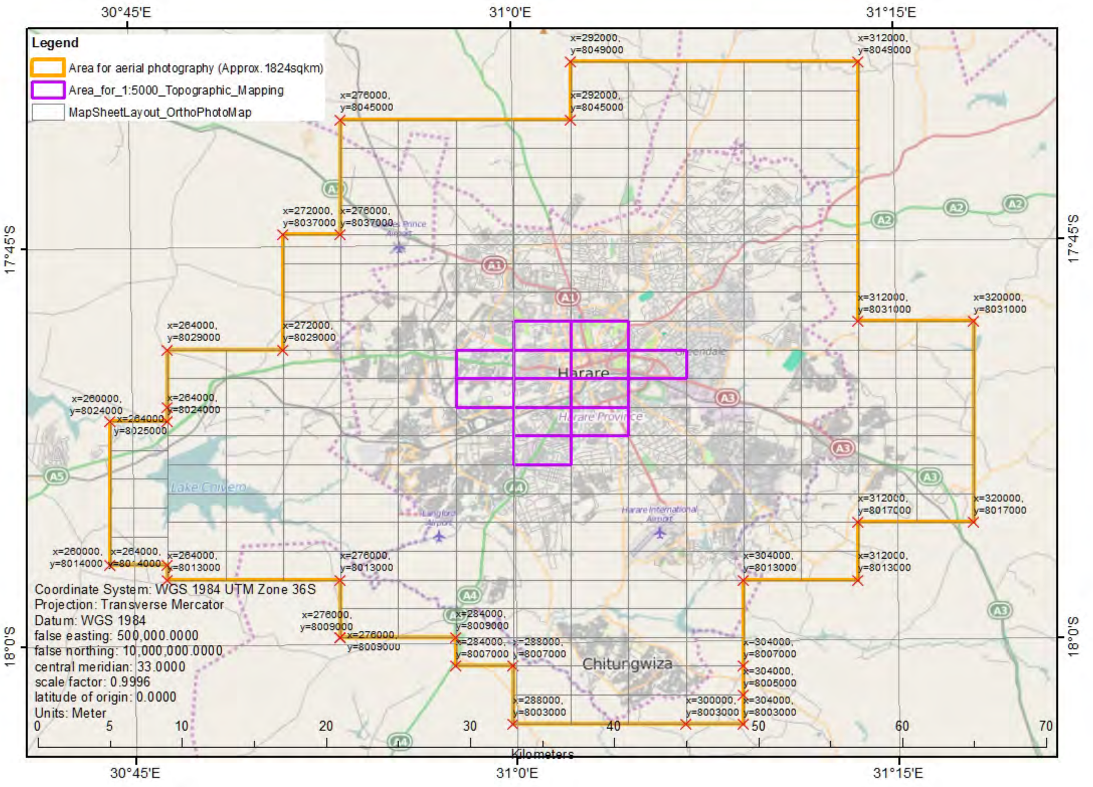
2.5 Aerial Photography

Flowchart item [A-4]

Digital aerial camera was used to acquire aerial photos that are required for the preparation of 1:5,000 scale Digital Topographic maps, Digital Orthophotos and contour lines data. The aerial photos were recorded in digital format (image data files with digital aerial photos). Global Navigation Satellite System and Inertial Measurement Unit (GNSS/IMU) were used to derive the external orientation parameters of digital aerial camera during the flight operation. Table 16 shows the Project aerial photography area, which covers approximately 1,824 km2.

The aerial photography and data processing was sub-contracted to an aerial photography company which will be able to execute all work in Zimbabwe. The selection and contracting of the sub-contractor for the aerial photography work was implemented according to the JICA guidelines.

The aerial photography was executed on 19 July 2015, and all data submitted from the sub-contractor were checked by JICA Study Team and confirmed that all data fulfill the specifications and conditions stipulated in the sub-contract documents (Table 16). Figure 10 shows the airplane track on the day of aerial photography.



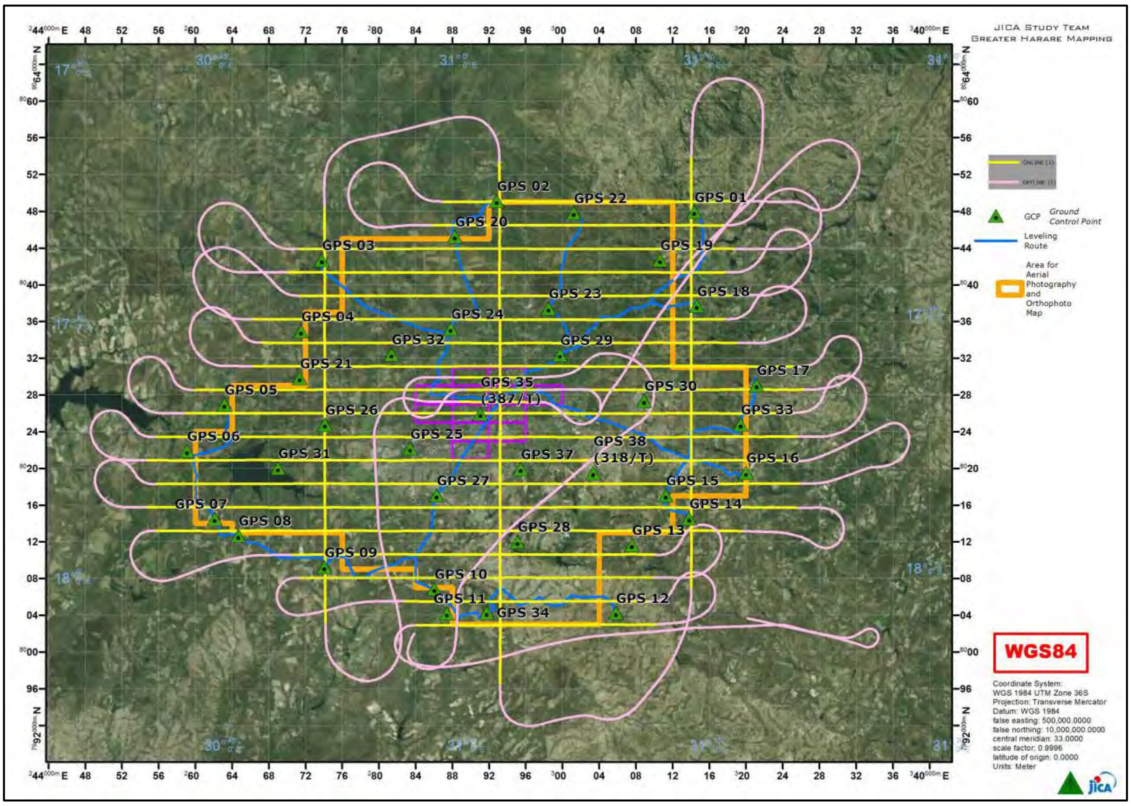
Source: JICA Study Team

Figure 9 Aerial photography area

Table 16 Outline of aerial photography

Component	Contents
Contract type	Contract with sub-contractor (aerial photography and data processing of external orientation parameters) (Sub-contractor: Fugro Geospatial B.V・SKM GISAIR OY (J.V.)
Work contents	• Lecture on aerial photography planning and aerial photography works • Application of flight permission • Implementation of aerial photography work using digital aerial camera • Processing of external orientation parameters • Image processing and data file preparation • Preparation of aerial photography report
Specifications and Results	• Aerial camera; Microsoft (Vexcel) UltraCam Eagle (focal length 100.5 mm) • Aerial photography area: 1,824 km^2 • Number of aerial photos: 1,127 sheets • Overlapping: 60% ±5% • Side lapping: 30% ±5% • Flight altitude: 3,800m from the ground surface • Ground resolution of aerial photo: 20 cm • Date of aerial photography: 19 July 2015 (Winter, dry season) • GNSS ground control station: 2 stations

Source: JICA Study Team



Source: JICA Study Team

Figure 10 Flight lines during the aerial photo acquisition (19 July 2015)

The red rectangle in aerial photograph shows extent of the enlargement photograph asFigure 7Figure 11

Source: JICA Study Team.

Figure 11 Extract of aerial photo image (photo No. 17695), center of Harare
(Caption sheet number TR9227, 1:5,000 scale topographic map).

Source: JICA Study Team.

Figure 12 Enlargement of aerial photo image (photo no. 17695), center of Harare
(Caption sheet number TR9227, 1:5,000 scale topographic map).

2.6 Reference Point Survey and Ground Control Point Survey

Flowchart item [A-5]

2.6.1 Overview of the ground control point survey (GPS survey and leveling)

Ground control point survey was conducted in order to determine the location of the ground control points necessary for the preparation of 1:5,000 scale Digital Topographic maps and orthophoto maps. Horizontal coordinates of ground control points were determined based on GPS survey, while elevation was based on direct leveling. Prior to the GPS observation for ground control point survey, air marks were also marked on each ground control point.

In addition, reference point survey was implemented before the ground control point survey, and two reference points were established that were used as given points for the ground control point survey. The ground control point survey was implemented using the two reference points as given points.

The ground control point survey and the marking of air marks was undertaken by mainly junior staff of the Photogrammetry Section, Mapping Branch and Cadastral Branch through OJT under the supervision of the JICA Study Team and DSG senior personnel.

2.6.2 Reference Point Survey

One of the objectives of the Project is to prepare the 1:5,000 scale Digital Topographic maps and orthophoto maps with contour lines based on the Global Geodetic Reference Framework (GGRF) that is consistent with GNSS satellite positioning. WGS-84, which is a part of the GGRF, was adopted as the geodetic standard for the Project. However, the national geodetic control network of Zimbabwe was developed based on Arc 1950 (Reference ellipsoid: Clark 1880) which is the local geodetic standard, and the coordinates based on WGS-84 have not yet been developed. Therefore, it was necessary to decide the coordinates of the reference points based on WGS-84 which will be used as given points for ground control point survey.

Therefore, in prior to the ground control survey, a reference point survey was executed in order to calculate WGS84 coordinate on the two reference points.

The reference point survey was executed by the following method.

- A 72 hours continuous GPS observation was performed on the two reference points in the Project area in order to obtain GPS observation record at the two reference points.
- And GPS observation results at the eight International GNSS Service (IGS) stations which simultaneously observed as the 72 hours continuous observation on the two reference points were obtained. IGS stations are distributed around the world and regularly receive and record signal from GPS (GNSS) satellites.
- A precise long baseline analysis was executed using the GPS observation record on the same period which were observed by the 72 hours continuous observation at the two reference points in the Project area and eight IGS stations in the world, and finally the coordinates of the two reference points based on WGS-84 were calculated.

(1) Specification for the reference point survey

The specifications for the GPS continuous observation and the precise long base line analysis in the reference point survey are shown in Table 17.

Table 17 Specifications for the reference point survey

Items	Details	Notes
Accuracy required	±5 cm	
GPS receiver	Dual frequency	
Data acquisition interval	30 seconds	

Number of session	3 sessions	1 session is 0:00 – 23:30 in UTC (2:00AM–1:30AM, Local time in Zimbabwe (UTC+2))
Observation period	72 hours continuously	3 days
Calculation software	Bernese	
Number of IGS stations used as given points	8 IGS stations	Select the good status IGS stations.

Source: JICA Study Team

(2) Selection of reference stations

In the reference point survey, the monuments of existing national triangulation points that are managed by DSG were used as the monuments of new reference station. As consequence, the coordinates of the existing national triangulation points were re-calculated as WGS84 coordinate by the reference point survey. The most appropriate two sites (based on the candidate points listed up by DSG) were selected taking into consideration accessibility and security including surrounding areas for performing day-and night GPS observations.

Finally, following two existing national triangulation points were selected as the reference station. One of them is the existing 387/T, Coventry third class triangulation point located on the ground at DSG Coventry office. The other is the existing 318/T, Domboramwari third class triangulation point located on a large monolith in Epworth. The point numbers allocated by the Project were GPS-35 for 387/T, Coventry and GPS-38 for 318/T, Domboramwari. The locations of these two points are shown in Figure 13 and Table 18

Source: JICA Study Team

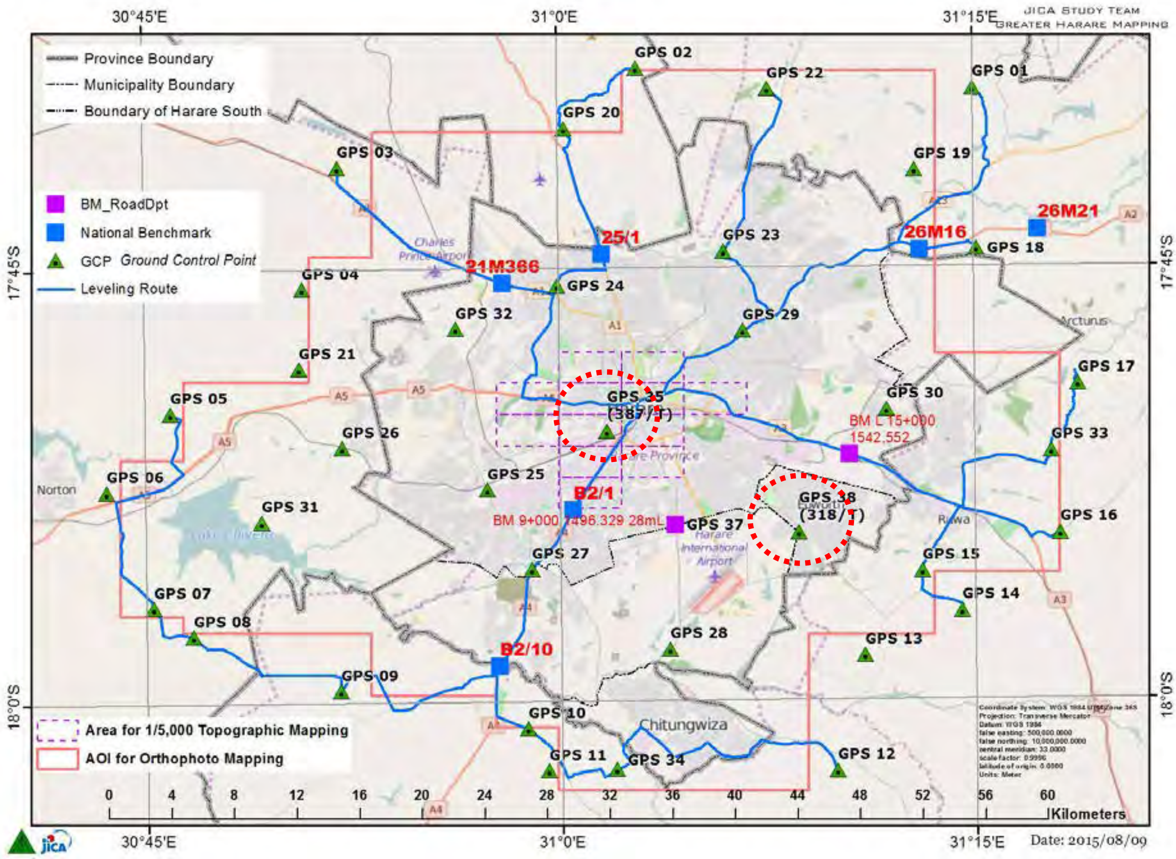
Photo 1 Existing geodetic point at Coventry (GPS-35 and 387/T)

Source: JICA Study Team

Photo 2 Existing geodetic point at Domboramwari (GPS-38 and 318/ T)

Source: JICA Study Team

Photo 3 GPS receiver, Trimble



Source: JICA Study Team

Figure 13 Locations of the existing geodetic points.

(3) Observation period

The seventy-two hours continuous observation was carried out from 8 July 2015 to 11 July 2015. The observation started and ended at 2:00 a.m., which is the local time in Zimbabwe. This corresponded to the Universal Time Coordinates (UTC) at 0:00, which is the session start time for IGS observation results. The GPS receiver used for the observation was an R7 made by Trimble Company.

Table 18 Work period of continuous GPS observation for reference point survey

Date / Point No.	July 7th (188)	July 8th (189)	July 9th (190)	July 10th (191)	July 11th (192)
GPS-35					
GPS-38					

Number in ( ) means the IGS session ID based on Julian date.

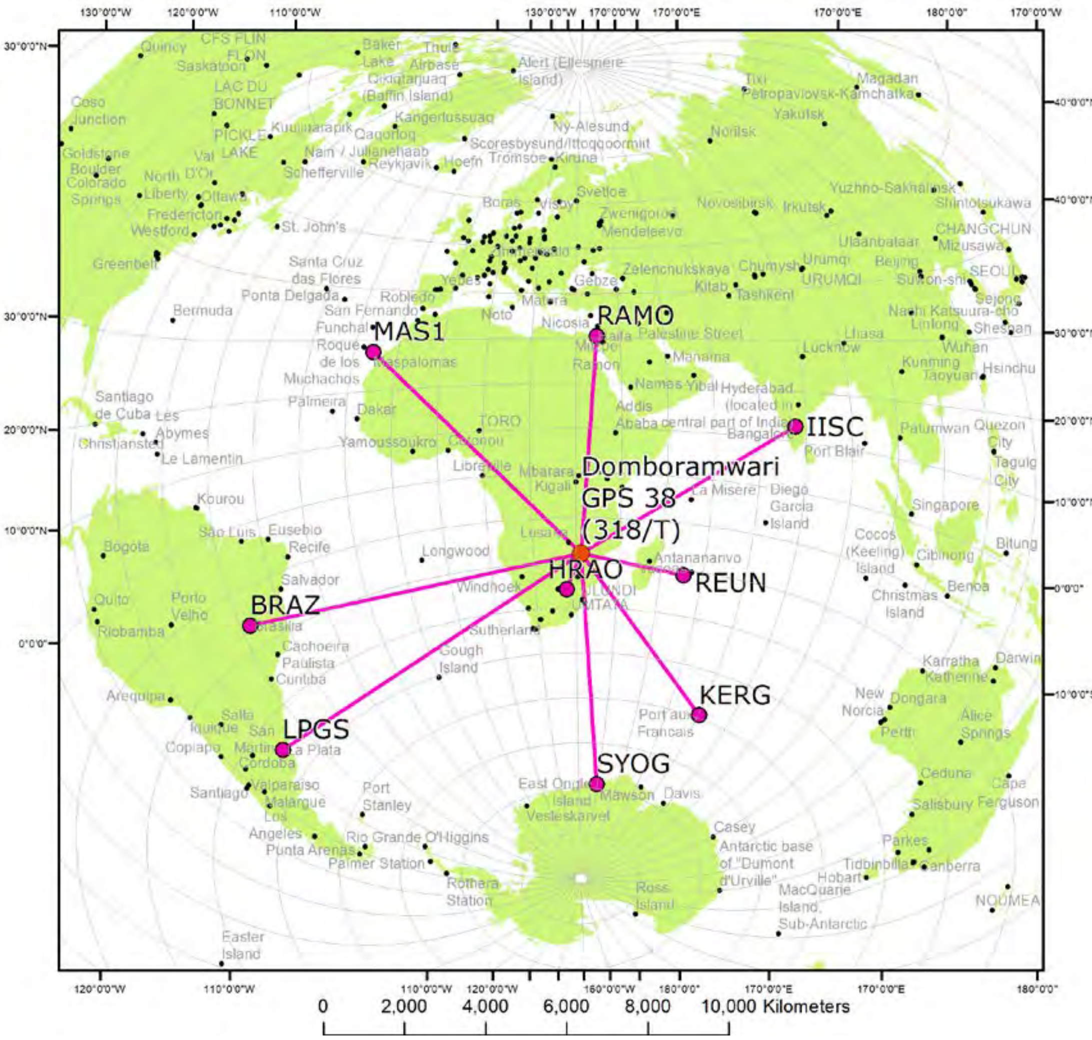
Source: JICA Study Team

(4) Data processing

The Bernese long baseline analysis software was used for precise long baseline analysis. First, the locations of the two reference points at the respective three day observations (8, 9, 10 July 2015) were calculated independently. Secondly, the average processing over the three days results was executed to determine the location of the two reference stations.

(5) IGS reference stations

The locations of eight IGS stations used as the given points and survey baseline are shown in Figure 14. The name of each station, locations and the distance from GPS-38 are shown in Table 19.



Source: IGS website- http://www.igs.org/, the map was prepared by JICA Study Team.

Figure 14 Locations of IGS stations used as given points

Table 19 List of IGS stations used as given points

IGS station name	Location	Distance from observed station
BRAZ	Brazil	7,770 km
HRAO	Hartebeesthoek (South Africa)	953 km
HSC	Bangalore (India)	5,906 km
KERG	Kerguelen Islands	4,816 km
MASI	Maspalomas (Gran Canaria Island)	6,770 km
RAMO	Mitzpe Ramon (Israel)	5,222 km
REUN	Reunion Island	2,569 km
SYPG	Showa Base (Antarctic)	5,520 km

Source: JICA Study Team

(6) Results of horizontal coordinates and elevation

The horizontal coordinates and ellipsoidal heights of the two reference stations (GPS-35 and GPS-38) based on WGS-84 were calculated by the precise long baseline analysis between the two reference stations and eight IGS stations. The horizontal coordinates, ellipsoidal heights, and elevation based on EGM 2008 geoid model of the two reference points are shown in Table 20.

Table 20 Final results of horizontal coordinates and ellipsoid heights of the two reference points

Point No.	Latitude / Y (Easting) (m)	Longitude / X (Northing) (m)	Ellipsoid height (m) / Elevation (EGM2008) (m)
GPS-35	S 17 50 40.5722	E 31 01 42.7429	1474.272
	291,080.294	8,025,905.062	1470.333
GPS-38	S 17 54 14.3525	E 31 08 37.9702	1516.206
	303,372.190	8,019,457.572	1512.307

Source: JICA Study Team

(7) Quality control

As shown in the Table 21, the difference between the coordinate values on each day did not exceed 10 cm. Also, the difference between each baseline was within 10 cm as shown in the Table 21.

Table 21 Difference between the coordinates values on each day

Station	Session (DAY)	Cartesian coord. X(m)	Cartesian coord. Y(m)	Cartesian coord. Z(m)	RMS X(m)	RMS Y(m)	RMS Z(m)
GPS35	189	5205393.320	3131245.891	-1942471.628	0.002	0.002	0.001
	190	5205393.317	3131245.884	-1942471.628	0.002	0.002	0.001
	191	5205393.324	3131245.883	-1942471.630	0.002	0.002	0.001
	3days	5205393.321	3131245.886	-1942471.628	0.001	0.001	0.001
GPS38	189	5197386.540	3140695.484	-1948741.222	0.002	0.001	0.001
	190	5197386.540	3140695.479	-1948741.223	0.002	0.001	0.001
	191	5197386.540	3140695.479	-1948741.223	0.002	0.001	0.001
	3days	5197386.542	3140695.476	-1948741.222	0.002	0.001	0.001

Source: JICA Study Team

Table 22 Difference between each base line on each day

doy	Baseline				
	GPS38 - GPS35 (m)	GPS38 - BRAZ (m)	GPS38 - HRAO (m)	GPS38 - IISC (m)	GPS38 - KERG (m)
189	13882.0133	7769888.6123	952891.5103	5905894.8583	4816496.7873
190	13882.0124	7769888.6121	952891.5104	5905894.8597	4816496.7894
190-189	0.0009	0.0002	-0.0001	-0.0014	-0.0021
191	13882.0135	7769888.6108	952891.5094	5905894.8646	4816496.7870
191-189	0.0002	-0.0015	-0.0009	0.0063	-0.0003

doy	Baseline			
	GPS38 - MAS1 (m)	GPS38 - RAMO (m)	GPS38 - REUN (m)	GPS38 - SYOG (m)
189	6769877.5920	5221588.9055	2569620.3455	5519553.5112
190	6769877.5899	5221588.9071	2569620.3480	5519553.5117
190-189	0.0021	-0.0016	-0.0025	-0.0005
191	6769877.5896	5221588.9055	2569620.3472	5519553.5115
191-189	-0.0024	0.0000	0.0017	0.0003

"doy" means "Day of Year" (Julian date)
Source: JICA Study Team

(8) Final Outputs

Coordinates results
Quality control report

2.6.3 Ground control point survey (GPS survey)

Based on the ground control point survey plan, GPS survey was performed to obtain 3D coordinates of the ground control points. Four sets of GPS equipment were used by four GPS survey teams in the ground control point survey. GPS survey was carried out by DSG staff under the supervision of the JICA Study Team. In addition, air marks were marked at each ground control point prior to the implementation of GPS survey. The objective of air mark was to be identified the locations of the ground control points on the aerial photo images. The details of the air-making are described below.

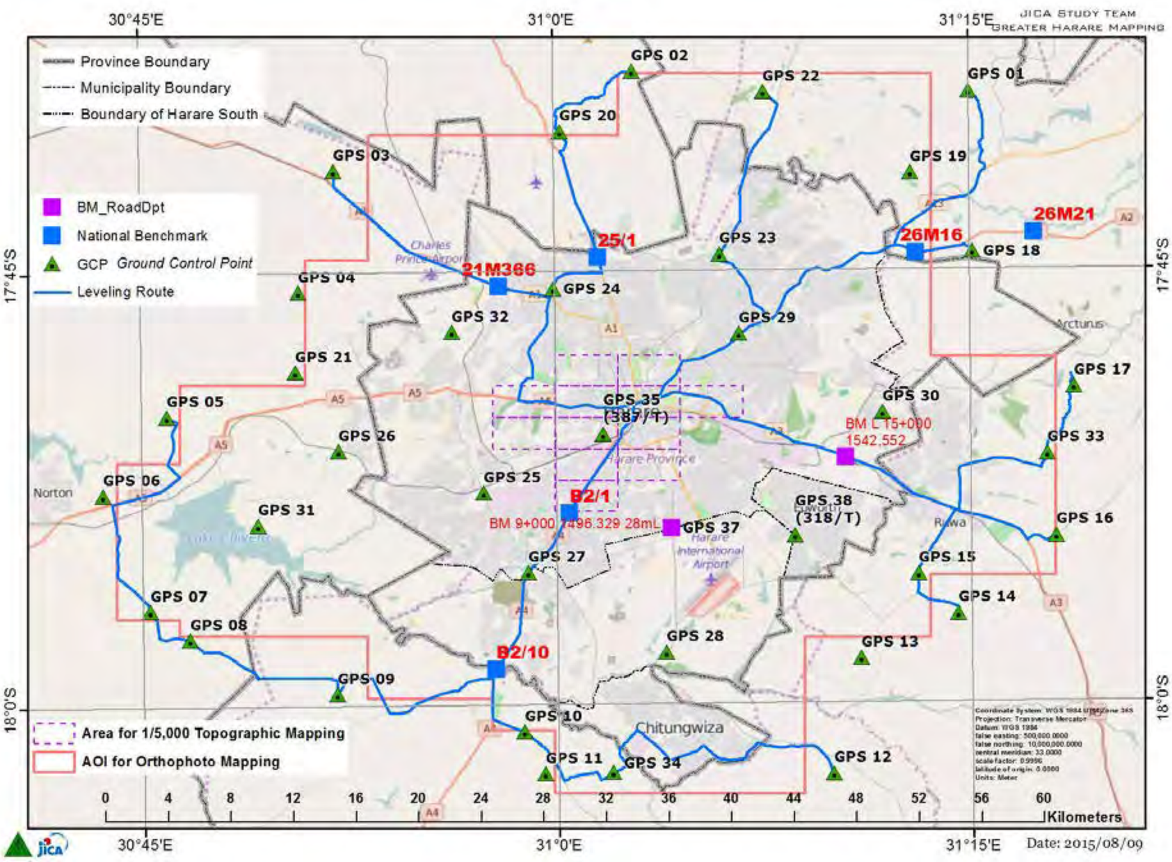
(1) Ground control point distribution plan

The ground control point distribution plan was prepared taking into consideration the components shown in Table 23 and Figure 15 shows the distribution of the ground control points.

Table 23 Standards for ground control point distribution, accuracy of horizontal position and size of air marks

Component	Details	Note
Required location of ground control points	Peripheral part of the Aerial photography area	However, the number of GCP is able to reduce in GPS/IMU assisted aerial photography.
Horizontal accuracy required	10 cm	
Distance between ground control points	Within 20 km	It is recommended that the distance between ground control points is less than 20 km in order to avoid the effect of ionospheric delay.
Type and size of air marks	Y shape (3 blades) type, Size of one blade is 90 cm×30 cm	Pricking of ground control points on the aerial photos in after aerial photography is also available as a alternative method against air marking before aerial photography.

Source: JICA Study Team



Service Layer Credits: (c) OpenStreetMap and contributors, Creative Commons-Share Alike License (CC-BY-SA)
Source: JICA Study Team.

Figure 15 Ground control points distribution map and leveling routes.

(2) Marking of air marks at ground control points

The air marks made with white painting, boards or other materials were set in parallel with ground control point selection so that the location of the ground control points could be clearly identified on the aerial photographs.

Table 24 shows the work schedule of the selection of ground control points and setup of air marks.
Photo 4 is site photographs of ground control points which shows situation of ground control points and air marks. And
Photo 5 shows a sample of appearance of air-mark on aerial photograph.

Table 24 Work schedule of ground control points selection and establishment of air marks

	Date	Selected GCP point				
1	2015/6/29	35	25	26	21	
2	2015/6/30	4	5	6	7	8
3-1	2015/7/1	9	10	11	34	28
3-2	2015/7/1	27	37	38	30	29
4-1	2015/7/3	16	33	36		
4-2	2015/7/3	15	14	13	12	
5	2015/7/6	18	19	1		
6	2015/7/7	23	22	31		
7	2015/7/8	24	20	2		
8	2015/7/9	32	17			
9	2015/7/10	3				

Source: JICA Study Team

Source: JICA Study Team.

Photo 4 Top-left: Air mark on the road, Top-right: air mark on bare ground. Down-left: air mark on artificial structure, Down-right: air mark on rock.


Source: JICA Study Team.

Photo 5 Air mark on the ground and on the aerial photo image.

(3) Observation

GPS observation was executed according to the specifications shown in

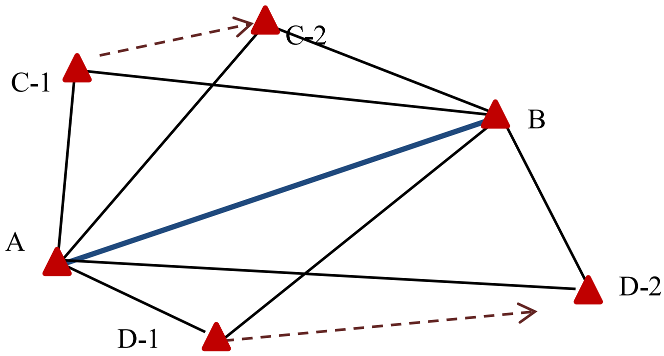
Table 25.

Table 25 Specifications of GPS observation

Component	Details	Notes
GPS receiver	Dual frequency	4 set Trimble, R7: 2 sets, TOPCON, Legacy-H-GT: 2 sets
Observation period	1 hour	
Data acquisition interval	15 seconds	
Upper sky clearance	Less than 15 degrees	Angle from horizontal line

Source: JICA Study Team

The center of the project area corresponds to the center of Harare city. The arterial road network in the project area radiates out from the center of the Harare city. The circular roads are unevenly distributed in the central area of the project area. In addition, there are large farms and private land for which the access was limited. In the suburban areas that are on the outer edge of the radial road network, it was not easy to move between ground control points. Hence, it took a long time for GPS survey teams to move from one point to the next. Therefore, the synchronization of the starting and ending of GPS observation with the four GPS receivers by four GPS survey teams was not efficient in the use of time during the GPS observation. As a measure to deal with the above, two GPS receivers were designated as fixed GPS stations for all day GPS observation. The remaining two receivers were moved to new positions after one hour GPS observation.



Observation was performed with Receiver A (Team A) and Receiver B (Team B) as fixed stations, and with receiver C and D while moving them to new points.
Source: JICA Study Team

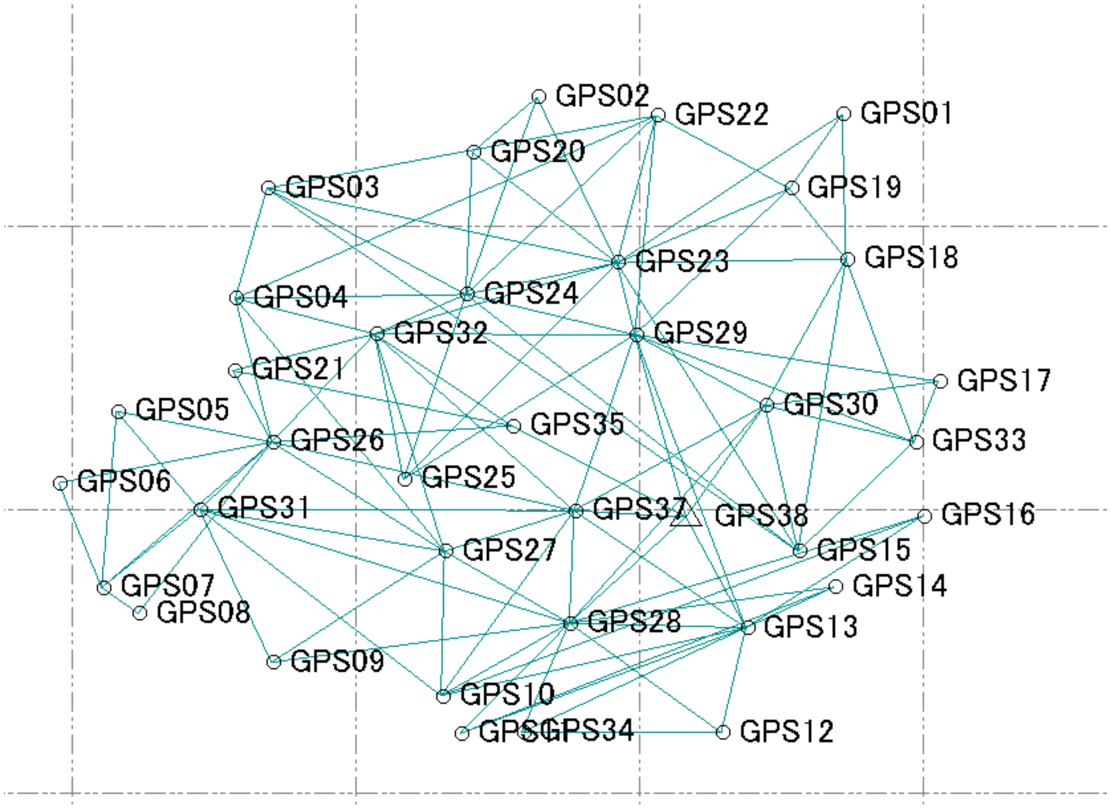
Figure 16 GPS observation method adopted by the Project.

Table 26 Work schedule of GPS observation

No.	Day	Group-A	Group-B	Group-C	Group-D
1	2015/7/13	34	24	35 29 23	25
2	2015/7/14	26	32	4 21	35 27
3	2015/7/15	7	26	5 6	8 31
4	2015/7/16	28	13	10 11 34	16 14 12
5	2015/7/17	30	33	18 29	17 16
6	2015/7/20	23	19	22 1	29 18
7	2015/7/21	3	24	22 15	4 23
8	2015/7/22	37	38	29 30	28 13
9	2015/7/23	31	27	9 10	28 17

Source: JICA Study Team

GPS observation for 110 baselines shown in Figure 17 was performed.



Source: JICA Study Team

Figure 17 GPS point distribution and baseline..

(4) Calculation of horizontal coordinates and elevation

Baseline analysis was performed using baseline analysis software to determine the locations of respective ground control points. The "Trimble Business Center" baseline analysis software was used for baseline analysis. The coordinates and ellipsoid heights of the ground control points decided by the ground control point survey are shown in Table 27.

Table 27 Horizontal coordinates and ellipsoidal heights of ground control points

Point No.	Latitude	Longitude	Ellipsoid Height
	Y (Northing)	X (Easting)	Elevation (EGM 2008)
GPS-01	S 17038′ 52.3015″	E 31015′ 01.0188″	1368.608 m
	8,047,913.558 m	314,382.496 m	1365.933 m
GPS-02	S 17038′ 06.4624″	E 31002′ 51.0544″	1366.211 m
	8,049,112.091 m	292,850.960 m	1362.971 m
GPS-03	S 17041′ 28.7067″	E 30052′ 02.1550″	1458.455 m
	8,042,686.637 m	273,790.654 m	1454.961 m
GPS-04	S 17045′ 40.7532″	E 30050′ 43.0998″	1429.866 m
	8,034,909.896 m	271,549.365 m	1426.214 m
GPS-05	S 17049′ 56.8925″	E 30045′ 55.6553″	1379.169 m
	8,026,934.414 m	263,174.240 m	1375.351 m
GPS-06	S 17052′ 39.7465″	E 30043′ 34.7225″	1357.206 m

	8,021,876.360 m	259,084.375 m	1353.305 m
GPS-07	S 17056′ 41.2033″	E 30045′ 14.7454″	1394.892 m
	8,014,486.937 m	262,119.125 m	1390.824 m
GPS-08	S 17057′ 41.7887″	E 30046′ 41.4318″	1419.112 m
	8,012,654.544 m	264,692.906 m	1415.014 m
GPS-09	S 17059′ 37.6465″	E 30451′ 59.5589″	1408.389 m
	8,009,201.757 m	274,096.340 m	1404.198 m
GPS-10	S 18100′ 58.7119″	E 30158′ 45.6411″	1416.735 m
	8,006,843.034 m	286,071.705 m	1412.519 m
GPS-11	S 18102′ 25.8961″	E 30159′ 30.6668″	1408.855 m
	8,004,176.727 m	287,425.377 m	1404.581 m
GPS-12	S 18102′ 30.1877″	E 31109′ 56.9581″	1472.165 m
	8,004,236.142 m	305,847.806 m	1,467.958 m
GPS-13	S 17158′ 30.0593″	E 31110′ 58.3415″	1,515.830 m
	8,011,636.680 m	307,580.771 m	1,511.800 m
GPS-14	S 17156′ 58.3006″	E 31114′ 31.3734″	1,547.962 m
	8,014,518.069 m	313,821.915 m	1,544.061 m
GPS-15	S 17155′ 35.3975″	E 31113′ 05.6093″	1,518.363 m
	8,017,042.824 m	311,273.795 m	1,514.498 m
GPS-16	S 17154′ 17.6133″	E 31118′ 04.0578″	1,597.400 m
	8,019,516.288 m	320,035.173 m	1,593.765 m
GPS-17	S 17149′ 08.1234″	E 31118′ 45.5486″	1,452.819 m
	8,029,041.945 m	321,170.380 m	1,449.574 m
GPS-18	S 17144′ 25.3924″	E 31115′ 07.1518″	1,338.125 m
	8,037,675.006 m	314,658.254 m	1,335.050 m
GPS-19	S 17141′ 41.7220″	E 31112′ 53.4147″	1,355.064 m
	8,042,669.795 m	310,670.566 m	1,352.071 m
GPS-20	S 17240′ 10.8443″	E 31200′ 14.4565″	1,502.073 m
	8,045,239.571 m	288,274.784 m	1,498.609 m
GPS-21	S 17248′ 26.6668″	E 30650′ 35.7378″	1,414.846 m
	8,029,805.66 m	271,391.147 m	1,411.074 m
GPS-22	S 17238′ 51.5202″	E 31207′ 35.4471″	1,500.200 m
	8,047,811.639 m	301,248.495 m	1,497.073 m
GPS-23	S 17244′ 28.6804″	E 31205′ 58.3210″	1,518.963 m
	8,037,416.995 m	298,490.029 m	1,515.374 m
GPS-24	S 17245′ 37.3942″	E 30259′ 55.6862″	1,496.233 m
	8,035,193.366 m	287,828.275 m	1,492.479 m
GPS-25	S 17252′ 40.4531″	E 30257′ 21.4473″	1,436.951 m
	8,022,136.330 m	283,426.346 m	1,432.974 m
GPS-26	S 17251′ 11.8418″	E 30252′ 09.9102″	1,418.069 m
	8,024,757.423 m	274,134.504 m	1,414.186 m
GPS-27	S 17255′ 26.9030″	E 31258′ 57.5521″	1,413.980 m
	8,017,049.21 m	286,311.234 m	1,409.934 m
GPS-28	S 17258′ 15.0764″	E 31203′ 55.1849″	1,439.662 m
	8,011,971.506 m	295,125.318 m	1,435.555 m

GPS-29	S 17247′ 13.9360″	E 31206′ 39.4151″	1,498.380 m
	8,032,348.383 m	299,751.872 m	1,494.685 m
GPS-30	S 17349′ 59.6635″	E 31311′ 49.2804″	1,584.121 m
	8,027,343.098 m	308,927.662 m	1,580.501 m
GPS-31	S 17353′ 44.5190″	E 31349′ 11.6072″	1,377.710 m
	8,020,003.015 m	269,027.116m	1,373.755 m
GPS-32	S 17347′ 06.0217″	E 31356′ 15.9085″	1,450.063 m
	8,032,398.197 m	281,383.374 m	1,446.274 m
GPS-33	S 17351′ 26.5535″	E 31317′ 46.0793″	1,575.508 m
	8,024,770.344 m	319,457.985 m	1,572.046 m
GPS-34	S 17302′ 24.8416″	E 31301′ 58.1559″	1,414.858 m
	8,004,255.777 m	291,763.273 m	1,410.578 m
GPS-35	S 17350′ 40.5724″	E 31301′ 42.7428″	1,474.283 m
	8,025,905.057 m	291,080.291 m	1,470.344 m
GPS-36	Unused number		
GPS-37	S 17° 53′ 56.9174″	E 31° 04′ 09.2238″	1,510.223 m
	8,019,913.237 m	295,456.010 m	1,506.232 m
GPS-38	S 17° 54′ 14.3525″	E 31 08′ 37.9702″	1,516.206 m
	8,019,457.572 m	303,372.190 m	1,512.307 m

Source: JICA Study Team

The above results were compiled as "Description of Ground Control Points", and handed over for aerial triangulation which is subsequent process in Photogrammetric mapping. .

(5) Accuracy control

Baseline analysis processing, closure error and adjustment computation were checked as quality control Evaluation process in the Trimble Business Center was adopted for accuracy control.

Firstly, baseline processing was evaluated, the GNSS loop closures were evaluated then residuals after adjustment were evaluated. Consequently these results were acceptable.

1) Allowable tolerance

Table 28 shows the allowable tolerance setting of "Trimble Baseline Center" baseline analysis software.

Table 28 Allowable tolerance of GPS observation by Trimble Baseline Center

Component	Acceptable	Caution	Bad
Horizontal	Within 0.050 m + 1 ppm	0.050 m + 1 ppm	0.100 m + 1 ppm
Vertical	Within 0.100 m + 1 ppm	0.100 m + 1 ppm	0.200 m + 1 ppm

Source: Trimble Baseline Center

The processing results were within the allowable tolerance for all points and acceptable.

2) Loop closure test

It was found that the total of 12 baselines had relatively large closure errors comparing with other baselines. However, the maximum closure error of baseline was 76mm, which was within the allowable error (less than 100mm), and resulting were acceptable.

3) Overall adjustment computation

The maximum error was 44 mm, while the other errors were 7 mm and 8 mm, respectively. Therefore, the adjusted coordinates satisfied the allowable limit (within 100 mm).

(6) Final outputs

A report including the following contents was prepared.

List of ground control points coordinates
Description of ground control points
Quality control report

2.6.4 Checking of existing national benchmark result and determination of correction amount of geoid height by GPS indirect levelling

In the project area, existence of five monuments of national benchmark was confirmed. In order to use the multiple bench marks as reference height for the Digital Topographic map, it was necessary to check whether the vertical datum referred by those benchmarks are the same as well as check the condition and accuracy of these existing benchmarks.

In addition, for the ground control points that can not be attached orthometric height by direct leveling , the orthometric height is calculated by adding the geoid height (geoid undulation) from the geoid model to the ellipsoidal height (height on ellipsoid) obtained by the GPS survey. Therefore, the correction amount of geoid height was also necessary to be confirmed. By comparing the two orthometric height of existing benchmark; height determined by the GPS indirect leveling and the MSL height from the existing benchmark result record, it becomes possible to obtain a more accurate correction amount for geoid height.

In order to make confirmation about referenced vertical datum, condition and accuracy of existing benchmarks, and determine correction amount of geoid undulation, a GPS indirect leveling survey for the existing national benchmarks and a comparison of the two orthometric height; MSL height of existing national benchmarks result from benchmark record and height obtained by GPS indirect leveling were performed.

Since the JICA study team had previously got information that there are three different vertical datum in Zimbabwe's national benchmark network from the process of its development, it was attempt to identify the vertical datum referred by each benchmark from record, but it was not possible to identify because record was lost.

Regarding the height value obtained by GPS indirect levelling and the height value from the benchmark result, the difference in the relative height between the existing benchmarks was confirmed. As for the national benchmark 25M/1, GPS observation was carried out, but benchmark record for the result of 25M/1 was not found out, therefore, it was not possible to make comparison with existing height results and GPS indirect leveling result for the benchmark.

It was confirmed that the difference between two relative heights converged within about 10 cm. As a result of the comparison, it was judged that the existing height results of the three national benchmarks were not particularly problematic and that it could be regarded as referring the same vertical datum. For the geoid height correction amount, it can be inferred that the EGM 2008 geoid model is 0.557m lower than the local geoid of Zimbabwe. The correction amount was determined as -0.5 m.

The details of GPS indirect leveling procedure and determination of geoid correction amount are shown in below. In actual fact, in addition to the five national benchmarks mentioned above, GPS indirect leveling and height comparisons were also conducted at one existing benchmarks installed by the road department (BML15+000). A comparison of height was made for the five benchmarks excluding the national benchmark (25M/1) the result record was lost.

(1) Establishment of reference points

Reference points were established at the locations that GPS observation could be performed in the vicinity of the six bench marks.

(2) GPS observation at reference points

GPS observation was implemented at the six reference points and at one ground control point on number GPS-27.

(3) Determination of relative height between the existing bench mark and reference point

Direct leveling was carried out in order to determine the relative height between the existing bench marks and the reference points.

Source: JICA Study Team

Photo 6 Leveling for determination of relative height between the existing bench marks and reference point

(4) Determination of height by GPS observation result

1) Ellipsoidal height of the six (6) reference points and the GPS-27 ground control point (A of Table 29) were determined by baseline analysis of the GPS survey results and adjustment computation.

2) Height by GPS indirect leveling for the each reference point (B of Table 29) was determined by adding geoid height fromEGM2008 geoid model to ellipsoidal height.

3) Ellipsoidal height of existing benchmarks (D of Table 29) was determined by adding relative height with the reference points (C of Table 29) to the value of ellipsoid height of the reference point based on GPS observations. (A of Table 29)

4) Height by GPS indirect leveling for the existing benchmarks (E of Table 29) was determined by adding geoid height from EGM2008 geoid model to ellipsoid height.

Table 29 Determination of existing benchmarks height by the GPS indirect leveling

Reference Point Name(RBM#) / Name of existing BM		X	Y	Ellipsoidal height of reference point	Height of reference point based on EGM2008 geoid model	Relative height between reference point and BM measured by direct leveling	Estimated ellipsoidal height of existing BM	Estimated Height of existing BM based on EGM2008 Geoid model from GPS leveling [H_{GPS}]	MSL Height of Exisiting BM from record or monument [H_{MSL}]	[H_{GPS}] - [H_{MSL}]
								3/08/2015		(Unit: m)
				A	B	C	D=A+C	E	F	G=E-F
RBM1		*284,366.414*	*8,035,343.853*	1,493.323	1,489.576	0.992				
	21M366						1,494.315	1,490.568	1,490.059	*0.509*
RBM2		*290,687.809*	*8,037,294.467*	1,479.967	1,476.276	0.104				
	25/1						1,480.071	1,476.380	Not available	
RBM3		*311,035.590*	*8,037,602.365*	1,345.618	1,342.426	-0.220				
	26M/16						1,345.398	1,342.426	1,341.635	*0.791*
RBM4		*306,580.027*	*8,024,514.888*	1,546.768	1,543.028	0.000				
	BML15+000						1,546.768	1,543.028	1,542.552	*0.476*
RBM5		*288,946.758*	*8,020,879.473*	1,425.797	1,421.789	0.161				
	B2/1						1,425.958	1,421.950	1,421.444	*0.506*
RBM6		*284,220.476*	*8,010,889.104*	1,386.553	1,382.416	0.033				
	B2/10						1,386.586	1,382.449	1,381.944	*0.505*
GPS-27		*286,311.231*	*8,017,049.210*	1,413.974	1,409.928			1,409.928		
									Mean	**0.557**

Source: JICA Study Team

(5) Comparison of Height by GPS in direct leveling and Height by Direct Leveling and determination of correction amount of geoid height

The orthometric height determined by GPS leveling (E of Table 30) and the ortho metric height from existing bench mark result (F of Table 30)were compared. The results of comparison are shown in Table 30.

Table 30 Comparison of orthometric height of existing benchmarks: MSL height from exiting record and GPS-derived orthometric height

								3/08/2015		(Unit: m)
Reference Point Name(RBM#) / Name of existing BM		X	Y	Ellipsoidal height of reference point	Height of reference point based on EGM2008 geoid model	Relative height between reference point and BM measured by direct leveling	Estimated ellipsoidal height of existing BM	Estimated Height of existing BM based on EGM2008 Geoid model from GPS leveling [H_{GPS}]	MSL Height of Exisiting BM from record or monument [H_{MSL}]	[H_{GPS}] - [H_{MSL}]
				A	B	C	D=A+C	E	F	G=E-F
RBM1		*284,366.414*	*8,035,343.853*	1,493.323	1,489.576	0.992				
	21M366						1,494.315	1,490.568	1,490.059	*0.509*
RBM2		*290,687.809*	*8,037,294.467*	1,479.967	1,476.276	0.104				
	25/1						1,480.071	1,476.380	Not available	
RBM3		*311,035.590*	*8,037,602.365*	1,345.618	1,342.426	-0.220				
	26M/16						1,345.398	1,342.426	1,341.635	*0.791*
RBM4		*306,580.027*	*8,024,514.888*	1,546.768	1,543.028	0.000				
	BML15+000						1,546.768	1,543.028	1,542.552	*0.476*
RBM5		*288,946.758*	*8,020,879.473*	1,425.797	1,421.789	0.161				
	B2/1						1,425.958	1,421.950	1,421.444	*0.506*
RBM6		*284,220.476*	*8,010,889.104*	1,386.553	1,382.416	0.033				
	B2/10						1,386.586	1,382.449	1,381.944	*0.505*
GPS-27		*286,311.231*	*8,017,049.210*	1,413.974	1,409.928			1,409.928		
									Mean	**0.557**

Source: JICA Study Team

It can be inferred from these results that the EGM2008 geoid model used is lower than the 0.557m geoid in Zimbabwe. HMSL = HGPS - 0.557 m. Regarding the ground control points for which the height by direct leveling was not assigned, the EGM2008 geoid model height was corrected with this value, and used as the final elevation of the ground control points.

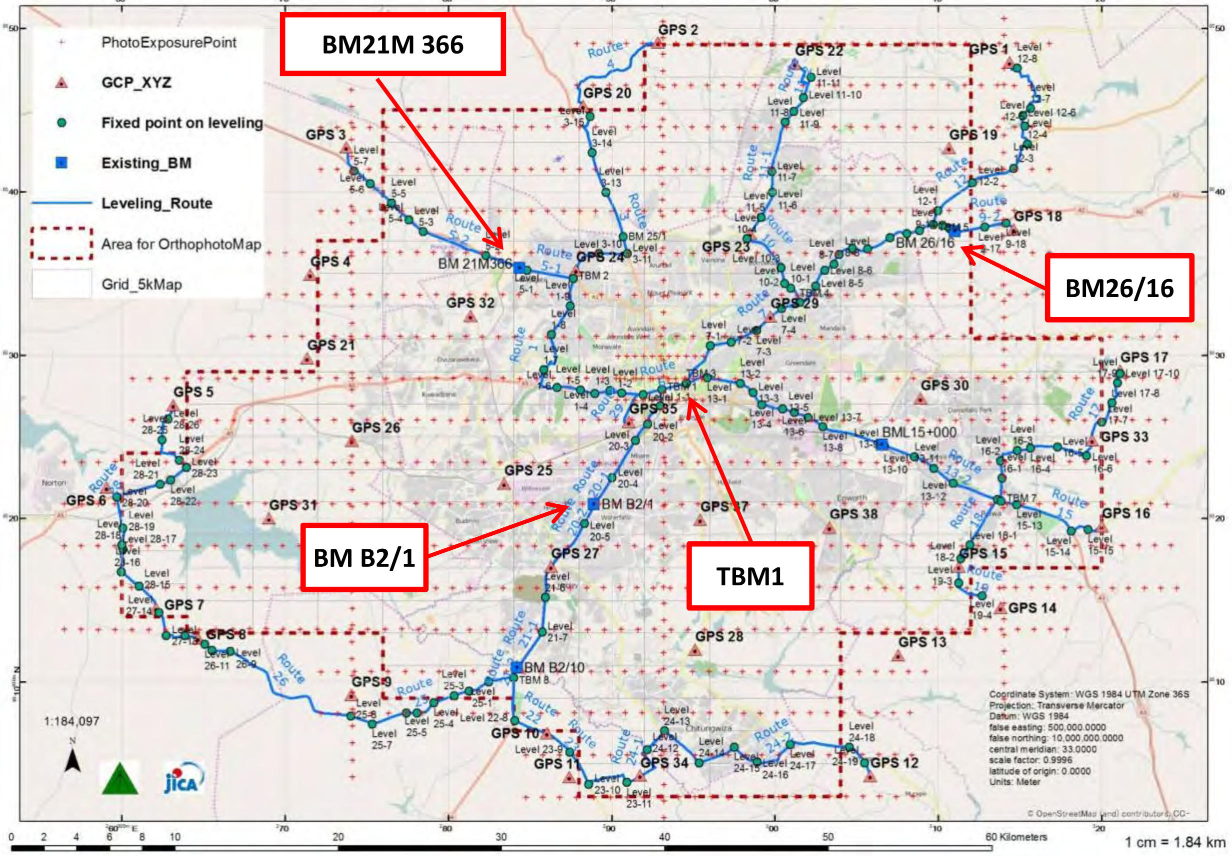
2.6.5 Ground control point survey (Leveling)

In order to determine the elevations of the ground control points, direct leveling was executed based on the existing national bench marks and elevation data. As a result, elevations of twenty points of ground control points were decided by leveling. The leveling was conducted from June to August 2015, covering a total of 264.5 km. The work items are as follows:

- Reconnaissance of leveling route and selection of leveling points
- Observation of leveling
- Calculation

The leveling was executed by four leveling teams with four automatic levels. Locations of leveling points were selected on satellite image and checked in the field. Then, a work plan for leveling was prepared before the implementation of leveling observation. The leveling was done by DSG staff through OJT program under the supervision of JICA Study Team. As a safety measure, traffic observers were employed for each leveling team.

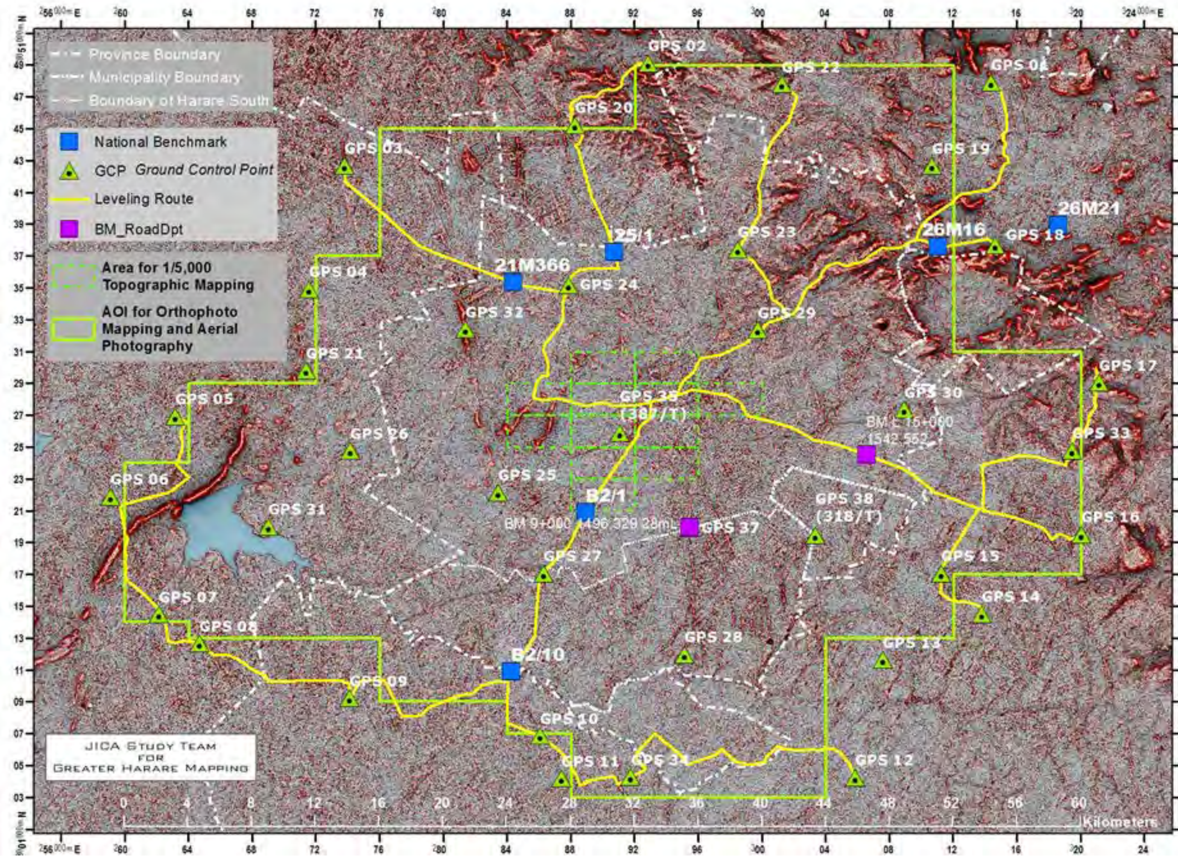
Figure 18 shows the ground control point distribution and leveling routes.



Service Layer Credits: (c) OpenStreetMap and contributors, Creative Commons-Share Alike License (CC-BY-SA)

Source: JICA Study Team

Figure 18 Ground control point distribution and leveling routes.



The Red Relief Image Map: New topography visualizing system, method, and program developed by Asia Air Survey Co., Ltd.
Source DEM data: ASTER GDEM, ASTER GDEM is a product of NASA and Japan's METI.

Source: JICA Study Team

Figure 19 Leveling routes and topographic undulation in the project area

(1) Selection of leveling points along leveling routes in office

The leveling points on the leveling routes were selected, Leveling points were selected at the intersections of each leveling route and the locations of highest and lowest elevations according to undulations of the topography based on the satellite images and contour lines automatically generated from satellite DEM. Furthermore, the leveling points at the locations between the flight lines of aerial photography were established for the height points to be used for aerial triangulation, and also height check points of aerial triangulation results. The horizontal coordinates of the candidate leveling points were loaded in handy GPS devices, and used to navigate to the points during the field survey.

(2) Selection of leveling points on site

Five candidate team leaders were selected from the staff of DSG. The five candidate team leaders verified the candidate leveling points in the field that were selected in the office, and then decided the location of leveling points on site. Paint marks and point numbers were marked to serve as a target during leveling. Handheld GPS devices were used to identify and record the position of the leveling points.

(3) Observation

Four leveling teams engaged in leveling for each respective route. The actual observation time for leveling was four hours per day, excluding the movement time to and from the DSG office to the site, and lunch time. The collimation line of level equipment was checked prior to the leveling execution according to the operation manual of leveling.

While the DSG staff involved in leveling did not have any experience in long distance leveling, the JICA Study Team observed that the DSG staff had basic knowledge to perform leveling (observation and adjustment computation), through the checking of field works and calculation.

At the beginning of the leveling, the following issues that were caused by lack of practical experience frequently occurred:

- Inaccurate reading or recording in field notebook
- Missing either fore sight or back sight reading in field notebook
- Misrepresentation of values, e.g., recording 4 digits as 5 digits in field notebooks
- Inaccurate reading of units, e.g., 5 mm instead of 1 mm
- The distance of fore sight and back sight was more than 60 m
- Numbers of leveling points were not consecutive (inaccurate recording of the number of leveling points in field notebook).
- Mixed use of rise and fall system and instrument height system on field notebook.

However, the DSG staff became more proficient in leveling after one month as no major issues were observed.

Source: JICA Study Team

Photo 7 Leveling by the Staff of DSG.


Source: JICA Study Team

Photo 8 Leveling by DSG staff

Table 31 Work schedule for the leveling teams

ROUTE NUMBER Route No.	DESCRIPTION Leveling section	Distance (km)	GROUP Leveling party	To Completion date of TO observation	For Completion date of Fro observation
Route 01	From TBM 1 to TBM 2	15.1	1	Completed 10/07/2015	Completed 17/08/2015
Route 02	From TBM 2 to GPS 24	0.5	1	Completed 10/07/2015	Completed 03/08/2015
Route 03	From GPS 24 to GPS 20	13.6	1	Completed 14/07/2015	Completed 18/08/2015
Route 04	From GPS 20 to GPS 2	7.8	1	Completed 14/07/2015	Completed 19/08/2015
Route 05	From TBM 2 to GPS 3	17.0	1	Completed 20/07/2015	Completed 21/08/2015
Route 06	From TBM 1 to TBM 3	1.5	2	Completed 08/07/2015	Completed 03/08/2015
Route 07	From TBM 3 to TBM 4	9.0	2	Completed 10/07/2015	Completed 04/08/2015
Route 08	From TBM 4 to TBM 5	10.3	2	Completed 13/07/2015	Completed 20/08/2015
Route 09	From TBM 5 to GPS 18	5.3	2	Completed 14/07/2015	Completed 23/07/2015
Route 10	From TBM 4 to GPS 23	5.8	1	Completed 05/08/2015	Completed 14/08/2015
Route 11	From GPS 23 to GPS 22	11.8	2 & 3	Completed 05/08/2015	Completed 14/08/2015
Route 12	From TBM 5 to GPS 1	15.7	2	Completed 16/07/2015	Completed 23/07/2015
Route 13	From TBM 3 to TBM 6	21.1	3	Completed13/07/2015	Completed 31/07/2015
Route 14	From TBM 6 to TBM 7	0.2	3	Completed 13/07/2015	Completed 21/07/2015
Route 15	From TBM 7 to GPS 16	7.0	3	Completed 14/07/2015	Completed 24/07/2015
Route 16	From TBM 7 to GPS 33	9.3	3	Completed 16/07/2015	Completed 23/07/2015
Route 17	From GPS 33 to GPS 17	5.4	3	Completed 16/07/2015	Completed 24/07/2015
Route 18	From TBM 6 to GPS 15	4.8	3	Complete 17/07/2015	Completed 24/07/2015
Route 19	From GPS 15 to Level 19-4	2.9	3	Completed 17/07/2015	Completed 20/07/2015
Route 20	From TBM 1 to GPS 27	13.1	4	Completed 07/08/2015	Completed 14/08/2015
Route 21	From BM B2/10 to TBM 8	0.7	4	Completed 03/08/2015	Completed 03/08/2015
Route 22	From TBM 8 to GPS 10	4.8	2	Completed 04/08/2015	Completed 04/08/2015
Route 23	From GPS 10 to GPS 34	7.9	2	Completed 05/08/2015	Completed 05/08/2015
Route 24-1	From GPS 34 to Level 24-13	7.1	2	Completed 05/08/2015	Completed 05/08/2015
Route 24-2	From Level 24-13 to GPS 12	12.8	3	Completed 04/08/2015	Completed 04/08/2015
Route 25	From TBM 8 to Level 25-8	10.8	4	Completed 03/08/2015	Completed 03/08/2015

Route 26	From Level 25-8_9 to GPS 8	11.5	4	Completed 14/07/2015	Complete 30/07/2015
Route 27	From GPS 8 to GPS 7	4.0	4	Completed 16/07/2015	Completed 23/07/2015
Route 28	From GPS 7 to GPS 5	17.9	4	Completed 17/07/2015	Completed 18/08/2015
Route 29	From Level 1-1 to GPS A	2.6	1	Completed 04/08/2015	Completed 04/08/2015

Source: JICA Study Team

(4) Quality control

Quality control for leveling observation results was performed with the methods of 1) to 3) described below..

1) Check the difference between To and Fro observations between leveling points (i)
   Allowable tolerance: 5cm$\sqrt{S}$ (S = distance of leveling route)

2) Check the difference between To and Fro observation on each leveling route (ii)
   Allowable tolerance: 5cm$\sqrt{S}$ (S = distance of leveling route)

3) Comparison of intermediate fixed point elevation when elevation of a known point is connected with elevation of another known point (iii)

After the completion of To and Fro observation of each section or route, checking for leveling observation results was executed using the above-mentioned 1) and 2) methods. Leveling was performed again when difference between To and Fro observations was over the allowable error. Re-leveling was done until the difference between To and Fro for all sections and routes was within the allowable error. Finally, it was confirmed that the difference between the To and Fro of all leveling routes was within the allowable error.

Following is a brief description of the above-mentioned checking methods:

(i) Check the difference between To and Fro observations

For the checking of the accuracy of leveling at each section, the difference between To and Fro observation was calculated. Table 32 shows the checked samples of the difference between To and Fro observations. For example, the difference between To and Fro observation from the leveling point (Level 1-9) to leveling point (TBM 2) was -0.027 m, and the allowable error of this section was 0.066 m (Table 32). The leveling observation of this section was judged as “Good”. The differences between To and Fro observation of all sections were checked using this method. Finally, all leveling observation in all sections was judged as "Good".

Table 32 Sample of leveling results check (Difference of To and From observation)

1	Group 1: (Closure difference of all observation sections were in those tolerance.)												
2	Surveyor: Mr Kudakwashe Gwelo, Mr.Terrence Mujombiza, Mr.Billy Manwere, Mr.Aldrien Chironga												
3	NAME	BS	IS	FS		Σ BS	Σ FS	DIFF (go)	DIFF (back)	NAME	COMMENT	Error	
145	(go)	1.365		2						(back)			
146		1.594		1.34						1002			
147	Level 1-9	1.939		1.251		30.812	38.21	-7.398	7.420	1-8 to 1-9	complation	0.022	Ok
148		2.025		1.04									
149		2.095		0.949									
150		2.108		1.062									
151		1.815		1.115									
152		1.785		1.175									
153		2.125		1.085									
154		2.132		0.765									
155		2.231		0.93									
156		2.277		0.808									
157		2.163		0.907									
158		2.357		0.764									
159		2.250		0.924									
160		2.295		0.705	Page 8								
161		2.295		0.875									
162	(go)	2.075		0.761						(back)			
163		2.135		1.395						979			
164	TBM 2			2.03		36.102	17.29	18.812	-18.839	1-9 to TBM 2	completion	-0.027	Ok
165													
166	From TBM 2 to GPS 24 (INE 2)												
167	TBM 2	1.446											
168		1.050		1.845									
169	(go)	1.445		1.87									
170		1.045		1.972						(Back)			
171		1.148		1.85						902			
172	GPS 24			1.948		6.134	9.485	-3.351	3.371	TBM 2 to GPS 24	completion	0.02	Ok

Source: JICA Study Team

(ii) Check the difference between To and Fro observations at each leveling route

After confirming that there was no problem with the observation of each section, the difference in round-trip observation of each of the 36 routes was checked. It was confirmed that the difference in round-trip observation of each 36 routes was within the allowable range.

Table 33 Difference of To and From observation on each leveling route

Quality Control for 36 Levelling Lines (routes)								
Closure difference of all observation lines were in those tolerance.								
LINE		DIFFERENCE			DISCREPANCY	DISTANCE	TOLERANCE	Evaluation
		go	back	mean		(km)	(5cm√S)	
1	from TMB_1 to TBM_2	21.359	-21.320	21.340	0.0390	15.11	0.1944	ok
2/3	from TBM_2 to GPS_20	9.007	-8.993	9.000	0.0140	14.13	0.1879	ok
4	from GPS_20 to GPS_2	-136.430	136.506	-136.468	0.0760	7.82	0.1398	ok
5-1	from TBM_2 to BM_21M366	-5.247	5.269	-5.258	0.0220	3.32	0.0911	ok
5-2	from BM_21M366 to GPS_3	-35.584	35.630	-35.607	0.0460	13.70	0.1851	ok
6	from TBM_1 to TBM_3	6.416	-6.417	6.417	-0.0010	1.55	0.0622	ok
7	from TBM_3 to TBM_4	21.093	-21.028	21.061	0.0650	8.98	0.1498	ok
8	from TBM_4 to TBM_5	-129.360	129.372	-129.366	0.0120	10.31	0.1605	ok
9-1	from TBM_5 to BM_26/16	-30.362	30.360	-30.361	-0.0020	1.43	0.0598	ok
9-2	from BM_26/16 to GPS_18	-6.729	6.692	-6.711	-0.0370	3.85	0.0981	ok
10	from TBM_4 to GPS_23	13.566	-13.625	13.596	-0.0590	5.84	0.1208	ok
11-1/11-2	from GPS_23 to GPS_22	-18.849	18.894	-18.872	0.0450	11.82	0.1719	ok
12	from TBM_5 to GPS_1	-6.738	6.674	-6.706	-0.0640	15.66	0.1979	ok
13-1	from TBM_3 to BML_15	61.741	-61.770	61.756	-0.0290	13.22	0.1818	ok
13-2	from BML_15 to TBM_6	13.849	-13.908	13.878	-0.0591	7.90	0.1405	ok
14	from TBM_6 to TBM_7	1.083	-1.079	1.081	0.0040	0.23	0.0240	ok
15	from TBM_7 to GPS_16	35.730	-35.653	35.692	0.0770	7.06	0.1329	ok
16/17	from TBM_7 to GPS_17	-108.294	108.196	-108.245	-0.0980	14.67	0.1915	ok
18/19	from TBM_6 to Level 19-4	-16.376	16.471	-16.424	0.0950	7.67	0.1385	ok
20-1	from TBM_1 to BM_B2/1	-52.405	52.372	-52.389	-0.0330	8.40	0.1449	ok
20-2	from BM_B2/1 to GPS_27	-11.978	11.984	-11.981	0.0060	4.76	0.1091	ok
21-1	from GPS 27 to BM B2/10	-27.419	27.433	-27.426	0.0140	6.79	0.1303	ok
21-2	from BM_B2/10 to TBM 8	2.553	-2.557	2.555	-0.0040	0.69	0.0415	ok
22	from TBM_8 to GPS_10	27.529	-27.519	27.524	0.0100	4.85	0.1101	ok
23	from GPS_10 to GPS_34	-1.621	1.610	-1.616	-0.0110	7.92	0.1407	ok
24-1	from GPS_34 to Level 24-14	7.184	-7.179	7.181	0.0050	7.13	0.1335	ok
24-2	from Level 24-14 to GPS_12	49.772	-49.765	49.769	0.0070	12.84	0.1792	ok
25	from TBM_8 to Level 25-8	28.906	-28.955	28.931	-0.0490	10.80	0.1643	ok
26	from Level 25-8_9 to GPS_8	0.831	-0.804	0.818	0.0270	11.53	0.1698	ok
27/28	from GPS_8 to GPS_7	-39.544	39.547	-39.546	0.0030	21.91	0.2340	ok
29	from Level 1-1 to GPS_A	-11.908	11.926	-11.917	0.0180	2.58	0.0803	ok
						264.47	line km in total	

Source: JICA Study Team

(iii) Comparison of intermediate fixed point elevation when elevation known point is connected with another elevation known point

While checking the sections and routes by the 1) and 2) method in above, in order to find abnormalities that could not be found by the 1) and 2) method, inspections were also conducted by comparing the difference in height of the levelling points located on intermediate of the route when joining from the height known point to another height known point. As a result of this inspection, the section which was judged to be abnormal was re-observed and replaced with observation result with no abnormality.

(5) Adjustment computation

The elevation value of TBM-1, which is an intersection of three leveling routes, was determined by means of Y type net adjustment computation (weight using route length) based on the existing national bench mark (BM 21M366, BM 26/16 and BM B2/1).

Table 34 Adjustment computation

Route	Route Distance	Weight	Observed elevation at intersection (TBM-1)	Determined elevation at intersection (TBM-1)
From 21M366 to TBM-1	18.43	1.00	1473.977	1473.880
From 26/16 to TBM-1	22.33	0.82	1473.885	
From B2/1 to TMB1	8.4	2.19	1473.833	

Source: JICA Study Team

The elevation value assigned to the ground control points located on the three routes in Table 35 were corrected so that the elevation value for TBM 1 could be kept with the determined elevation value (1473.880m) in Table 35.

Regarding routes other than above, computation was performed by open route calculation method (correction based on the difference between To and Fro observations) from the existing national bench marks. Leveling routes and the location of the three existing national bench marks used for the computation is shown in
Figure 20.

(6) Determining elevations of ground control points

The elevations of the ground control points were determined using the leveling results based on MSL height from the result of existing national bench marks. The elevations of 20 ground control points among 37 points of ground control points in total were determined based on height obtained by the leveling. Concerning the 17 points of ground control points, which were not determined by levelling, were determined by GPS-derived orthometric height: adding geoid height (geoid undulation) from EGM 2008 geoid model and the correction amount for geoid model (-0.5m) determined by the GPS in-direct leveling to the ellipsoidal height determined by GPS survey.

The other 17 ground control points were determined using GPS observations not leveling based on the correction of geoid model EGM 2008, and the correction value obtained for geoid mode (-0.5m) by GPS leveling.

Table 35 Final elevations of ground control points

No.	Point Name	X	Y	Elevation (MSL)	Method to Determine Elevation *	Elevation (EGM2008)	Ellipsoid Height
1	GPS 1	314382.496	8047913.558	1,365.293	1	1,365.933	1,368.608
2	GPS 2	292850.960	8049112.091	1,362.471	0	1,362.971	1,366.211
3	GPS 3	273790.654	8042686.637	1,454.452	1	1,454.961	1,458.455
4	GPS 4	271549.365	8034909.896	1,425.714	0	1,426.214	1,429.866
5	GPS 5	263174.240	8026934.414	1,374.699	1	1,375.351	1,379.169
6	GPS 6	259084.375	8021876.360	1,352.805	0	1,353.305	1,357.206
7	GPS 7	262119.125	8014486.937	1,390.152	1	1,390.824	1,394.892
8	GPS 8	264692.906	8012654.544	1,414.238	1	1,415.014	1,419.112
9	GPS 9	274096.340	8009201.757	1,403.698	0	1,404.198	1,408.389

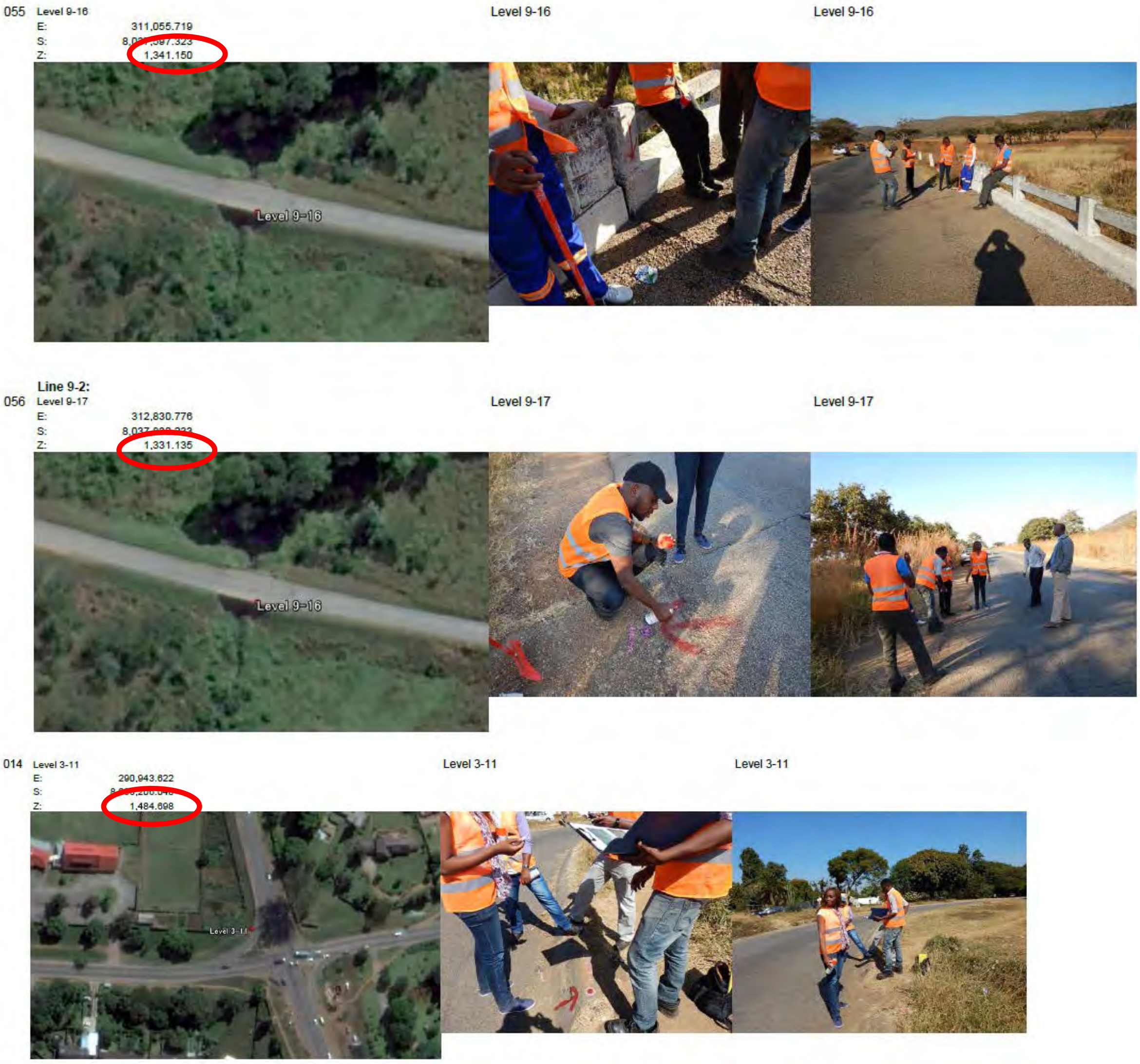
10	GPS 10	286071.705	8006843.034	1,412.025	1	1,412.519	1,416.735
11	GPS 11	287425.377	8004176.727	1,404.081	0	1,404.581	1,408.855
12	GPS 12	305847.806	8004236.142	1,467.359	1	1,467.958	1,472.165
13	GPS 13	307580.771	8011636.680	1,511.300	0	1,511.800	1,515.830
14	GPS 14	313821.915	8014518.069	1,543.561	0	1,544.061	1,547.962
15	GPS 15	311273.795	8017042.824	1,513.954	1	1,514.498	1,518.363
16	GPS 16	320035.173	8019516.288	1,593.203	1	1,593.765	1,597.400
17	GPS 17	321170.380	8029041.945	1,449.217	1	1,449.574	1,452.819
18	GPS 18	314658.254	8037675.006	1,334.924	1	1,335.050	1,338.125
19	GPS 19	310670.566	8042669.795	1,351.571	0	1,352.071	1,355.064
20	GPS 20	288274.784	8045239.571	1,497.943	1	1,498.609	1,502.073
21	GPS 21	271391.147	8029805.660	1,410.574	0	1,411.074	1,414.846
22	GPS 22	301248.495	8047811.639	1,496.099	1	1,497.073	1,500.200
23	GPS 23	298490.029	8037416.995	1,514.943	1	1,515.374	1,518.963
24	GPS 24	287828.275	8035193.366	1,491.944	1	1,492.479	1,496.233
25	GPS 25	283426.346	8022136.330	1,432.474	0	1,432.974	1,436.951
26	GPS 26	274134.504	8024757.423	1,413.686	0	1,414.186	1,418.069
27	GPS 27	286311.234	8017049.210	1,409.421	1	1,409.934	1,413.980
28	GPS 28	295125.318	8011971.506	1,435.055	0	1,435.555	1,439.662
29	GPS 29	299751.872	8032348.383	1,494.306	1	1,494.685	1,498.380
30	GPS 30	308927.662	8027343.098	1,580.001	0	1,580.501	1,584.121
31	GPS 31	269027.116	8020003.015	1,373.255	0	1,373.755	1,377.710
32	GPS 32	281383.374	8032398.197	1,445.774	0	1,446.274	1,450.063
33	GPS 33	319457.985	8024770.344	1,571.456	1	1,572.046	1,575.508
34	GPS 34	291763.273	8004255.777	1,410.403	1	1,410.578	1,414.858
35	GPS 35 (387/T)	291080.291	8025905.057	1,469.747	1	1,470.344	1,474.283
36	GPS 37 (175/S)	295456.010	8019913.237	1,505.732	0	1,506.232	1,510.223
37	GPS 38 (318/T)	303372.190	8019457.572	1,511.807	0	1,512.307	1,516.206

Note: * "1" means that the elevation was determined by direct leveling. "0" means that the elevation was determined by GPS indirect levelling. Source: JICA Study Team

(7) Preparation of description of ground control points

The description of ground control points and leveling points (pricking points) including the information of elevation (orthometric height above MSL), horizontal coordinates by GPS survey (available point only), point location as coordinate measured by handheld GPS, point location shown on satellite image, and site photograph was prepared for aerial triangulation process.

Furthermore, the information of ground control points and leveling points was prepared as GIS data in ESRI Shapefile and KML formats.



Source: JICA Study Team

Figure 20 Sample of description of leveling point (pricking point).

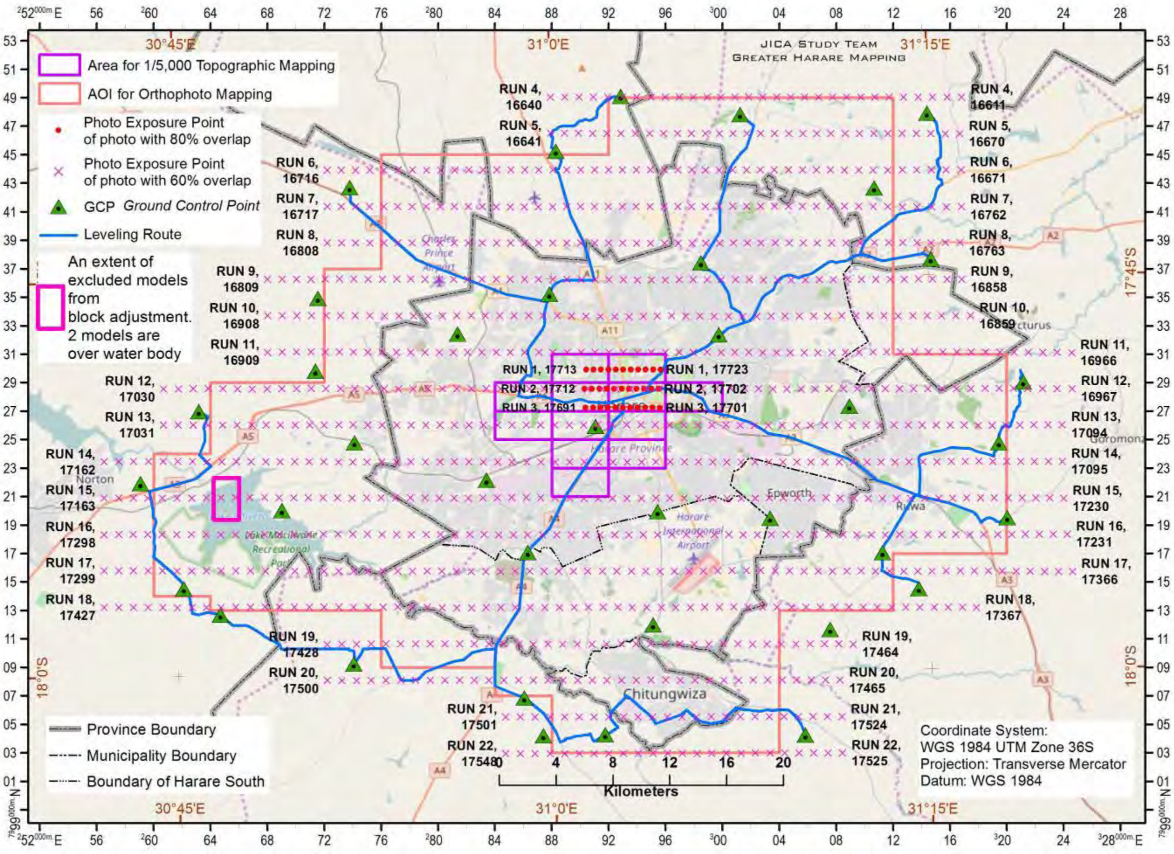
2.7 Aerial triangulation

Flowchart item [A-6]

Aerial triangulation was carried in order to determine the external orientation parameters (the position and triaxial attitude of each aerial photograph, where the aerial photograph was taken and the inclination and rotation) of the aerial photographs which were used for making the Digital Topographic map and the Digital Orthophoto. Aerial triangulation and block adjustment were performed based on aerial photo image data and ground control point survey results. The external orientation parameter of each aerial photograph, which constitutes 949 stereo models cover the aerial photography area with 1,824 km^2 was determined.

This work was performed during September 2015 in Japan. The overview of aerial triangulation is shown in

Figure 21.



Source: JICA Study Team

Figure 21 Overview of implementation of the aerial triangulation.

The aerial triangulation and block adjustment procedure was carried out as follows:

- Import external orientation parameters during aerial photography obtained by GPS/ IMU
- Measure photograph coordinate of tie points
  - ➢ Photo coordinate measurement of tie points (10 tie points/ a model for connection models in same strip, 1 tie point /model for connection model in model adjacent strips)
  - ➢ Inspection of tie point measurement result by block adjustment calculation using external orientation parameter obtained at aerial photography and re-measurement of tie point photo coordinate in case of error
- Photograph coordinate measurement of ground control point
- Performed block adjustment calculation with only one ground control point as control point, and other remaining ground control points (that was not used in the adjustment calculation) as the verification point
- Final block adjustment calculation.

The acceptable values of the accuracy in aerial triangulation and block adjustment calculation mentioned in the above procedure are shown in Table 36.

Table 36 Acceptable value in the accuracy control in the aerial triangulation and block adjustment result.

Residual difference in photo coordinates of tie points	Horizontal position:0.10mm
Residual of the ground control point by block adjustment result	Horizontal position: 0.6 m, Height: ± 1.2 m

In the block adjustment calculation results which were performed in the midway of the process for checking input data: the external orientation parameter during aerial photography, photograph coordinate of tie points, as for the tie points whose residuals do not fit within the allowable value, the re-measurement of photograph coordinate and re-calculation of aerial triangulation and block adjustment were repeated until the adjustment result fell within the allowable value.

It was confirmed by the above calculation in the midway of the process for checking that all necessary tie points required for final block adjustment were within the tolerance in finally.

However, for the two models over Lake Chivero, which is an “incomplete model” because most of the object in the aerial photograph were water surfaces, the adjustment calculation were not converged within the allowable value, so the 2 models were excluded from the target in subsequent block adjustment calculations　All land area in the 2 models was covered by another photographs in adjacent strips. For this reason, it was judged that even if these two models were excluded from adjustment calculation, there was no improper issue on Digital Orthophoto preparation.

Before the final block adjustment calculation, the photo coordinates of the ground control point were observed based on the description of the control point prepared by the ground control point survey team. The air marks for the all 37 ground control points marked in the ground control point survey were clearly visible on the aerial photographs. Subsequently, in order to see quality of the external orientation parameter acquired at the aerial photography, the result of the ground control point survey, the photo coordinates observation result on the ground control point, and block adjustment calculation was carried out using only one ground control point as a control point. The residuals of the remaining 36 ground control points were determined based on the adjustment calculation were all within the allowable limits. The quality of the external orientation parameter during the aerial photography, the ground control point survey results and the photo coordinates of the ground control points were confirmed to be normal.

The final block adjustment calculation was carried out with the following ground control points as control points:

- Thirty seven (37) ground control points were used as horizontal and vertical control, and
- Seventeen (17) leveling points at the leveling in ground control survey were used as vertical control

As a result of block adjustment calculation, the external orientation parameters of the aerial photograph were finalized. Table 37 shows the residuals of the ground control points when each photograph is oriented by the determined external orientation parameter.

Table 37 Residuals of the ground control points (37 GCPs and leveling points)

Index	GCP and Leveling Point Name	Point Name in Aerial Triangulation	Residuals of the ground control points		
			DX	DY	DZ
1	GPS-1	10000010	0.089	0.185	0.169
2	GPS-2	10000020	0.085	0.062	-0.273
3	GPS-3	10000030	0.011	-0.016	-0.184
4	GPS-4	10000040	0.017	0.011	0.099
5	GPS-5	10000050	-0.044	-0.028	0.039
6	GPS-6	10000060	-0.004	0.147	0.288
7	GPS-7	10000070	-0.027	0.033	0.186
8	GPS-8	10000080	0.064	-0.103	0.269
9	GPS-9	10000090	-0.036	-0.022	0.184
10	GPS-10	10000100	-0.016	0.007	0.133
11	GPS-11	10000110	0.003	-0.062	0.268
12	GPS-12	10000120	0.000	0.003	0.111
13	GPS-13	10000130	0.003	0.071	0.219
14	GPS-14	10000140	0.000	-0.021	0.115
15	GPS-15	10000150	-0.019	0.013	0.327
16	GPS-16	10000160	-0.064	0.038	0.287
17	GPS-17	10000170	0.167	-0.006	0.169
18	GPS-18	10000180	0.017	0.097	-0.158
19	GPS-19	10000190	0.071	0.032	-0.152
20	GPS-20	10000200	0.025	0.001	0.112
21	GPS-21	10000210	-0.008	-0.025	0.191
22	GPS-22	10000220	0.038	0.062	-0.041
23	GPS-23	10000230	-0.014	0.039	0.065
24	GPS-24	10000240	-0.066	0.026	0.154
25	GPS-25	10000250	0.020	0.002	0.184
26	GPS-26	10000260	0.002	0.007	0.131
27	GPS-27	10000270	-0.100	0.084	0.273
28	GPS-28	10000280	0.016	-0.019	0.300
29	GPS-29	10000290	-0.012	0.013	0.154
30	GPS-30	10000300	-0.020	0.042	0.178
31	GPS-31	10000310	0.014	-0.070	0.113
32	GPS-32	10000320	-0.020	0.004	0.080
33	GPS-33	10000330	0.018	0.045	0.120
34	GPS-34	10000340	-0.021	0.013	0.010
35	GPS-35	10000350	-0.028	0.134	0.307

36	GPS-37	10000370	-0.004	-0.004	0.148
37	GPS-38	10000380	0.074	-0.126	-0.090
38	3-13	20000010			0.214
39	11-7	20000020			0.062
40	12-4	20000030			-0.091
41	5-3	20000040			-0.014
42	8-9	20000050			0.037
43	TBM5	20000060			-0.071
44	1-7	20000070			0.134
45	TBM1	20000080			0.265
46	13-9	20000090			0.115
47	16-2	20000100			0.294
48	28-23	20000110			0.320
49	BM-B2_1	20000120			-0.219
50	19-4	20000130			-0.090
51	28-16	20000140			0.109
52	BM-B2_10	20000150			0.433
53	24-15	20000160			-0.007
54	25-7	20000170			0.155

Source: JICA Study Team

2.8 Field identification and field completion

Flowchart item [A-7]

Field identification was carried out in order to obtain place names and other information that could not be read and extracted from aerial photographs. In addition, features that could not be clearly identified during digital plotting and compilation were checked in the field. The final confirmation of place names and other annotation was executed as field completion.

(1) Implementation of field identification

Field identification was implemented from November to December 2015.

In order to obtain place names, feature names and administrative boundaries and other information to be represented on the 1:5,000 scale Digital Topographic maps and orthophoto maps, which could not be obtained from aerial photos, the existing documents, maps and etc. possessed by DSG and local administrative agencies were collected. GIS software was used to populate and edit data for the place names, road names and feature names in order to prepare annotation data. The main work of field identification was office works for the collection of the existing information and data. On the other hand, for the area that did not have existing data and information (mainly suburb areas) field survey for the collection of necessary information was conducted in field. This series of work was implemented by the staff of DSG as OJT program. Rapid mosaic of aerial photographs based were prepared and used as the base map for field identification.

With regard to administrative boundaries, some old small scale existing map showing administrative boundaries were found. However, there are no officially approved administrative boundaries on the map with 1:5,000 scale, which is the scale of the Project's Digital Topographic maps and orthophoto maps. In addition, with respect to administrative boundaries, assertions of Harare City and other organization surround Harare City are different. Therefore, it was decided that the administrative boundaries will not be shown on the 1:5,000 scale digital topographic and orthophotos maps for now.

Source: JICA Study Team

Photo 9 Collection of street names using photo mosaic

Source: JICA Study Team.

Figure 22 Annotation data arranged on photo mosaic (Yellow characters)

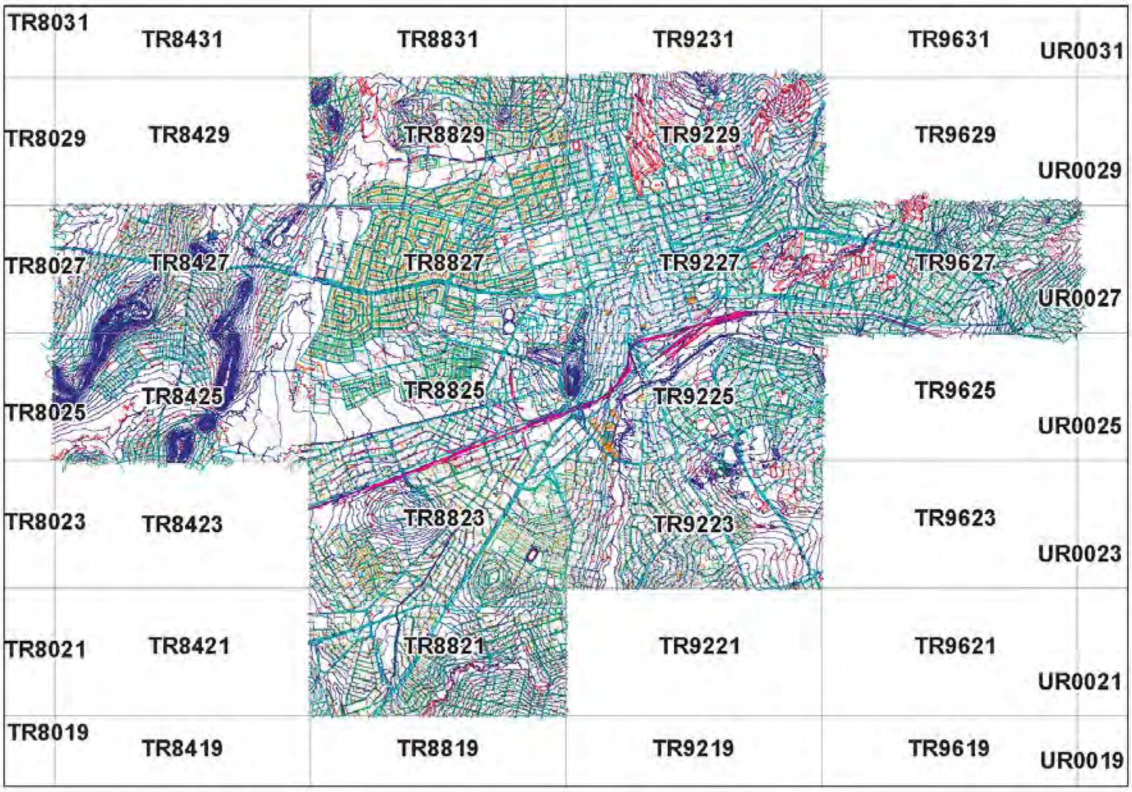
(2) Implementation of field completion

Field completion was implemented in August 2016 in order to verify unidentified or obscure features during digital plotting and compilation as well as confirm other supplementary information in the field. Field completion was implemented using the Digital Topographic maps derived from digital plotting and compilation as the base maps. The field completion area was the same as the digital topographic mapping area (96 km^2).

2.9 Digital plotting and digital compilation and integration of field completion result

Flowchart item [A-8]

Digital plotting and digital compilation were implemented as initial data acquisition and compilation process for the preparation of Digital Topographic maps. In addition, map compilation to integrate the completion results into the Digital Topographic maps was implemented after field completion survey. These works were executed in Japan. The 1:5,000 scale digital topographic mapping area is 96 km2 at the center of Harare city. During the implementation of each stage of work, such as digital plotting, digital compilation including integration of field completion result, quality control was executed to confirm the quality of products at each stage of work.



Mapping area: 96km^2, 12 map faces, 1 map face: 4 km x 2 km.

Source: JICA Study Team

Figure 23 1:5,000 scale digital topographic data obtained at the stage of digital plotting (Reduced scale)

2.10 Production of Digital Orthophotos

Flowchart item [A-9]

The following work was carried out in Japan in order to prepare Digital Orthophoto and contour line for the 1:5,000 scale orthophoto maps with contour lines. The details of the process the Digital Orthophoto production are as follows.

(1) Contour lines drawing and preparation of Digital Elevation Models (DEM)

The information of contour line, artificial structures and topographic features for break line to be reflected in Digital Elevation Models, which are necessary for the preparation of Digital Orthophotos, were obtained using a digital plotter. DEM which is necessary for orthogonal rectification, were prepared based on the contour lines and break lines data.

(2) Preparation of orthophotos

By the orthogonal rectification of digital aerial photo based on digital aerial photos and the corresponding orientation parameters and DEM, orthophoto (ortho rectified aerial photo) images were prepared.

(3) Preparation of orthophoto mosaics

Digital Orthophoto mosaic for each map sheet was prepared by following procedure.

In first, mosaicking Digital Orthophoto image correspond to each stereo model range into certain range.

Then, Clipping of Digital Orthophoto image according to orthophotos map sheet, and position information was added to each clipped image file. The 1:5,000 scale Digital Orthophotos map sheet was same as the 1:5,000 scale Digital Topographic maps sheet grid (4 km× 2km).

The master image data file of Digital Orthophoto is managed in 4 km×2 km by DSG, and the required range of data distributed from DSG to users will be clipped from the master data file and provided according to the needs of each user.

2.11 Map representation and map finishing

Flowchart item [A-11]

Map presentation was done in order to apply map symbols to the Digital Topographic map data, which was prepared from the digital plotting and compilation processes as well as from the supplementary field survey results. Map representation on each topographic map sheet was carried out. In addition, in order to prepare the output map image of the hard copy of the topographical map combined the map information which made cartographic representation and the marginal information, map finishing process was carried out.

Quality control was carried out to confirm whether there is the following trouble about the result of the map preparation and map finishing process;

- Display defects and missing information,
- Incorrect display position due to errors in the applicable coordinate system,
- Error in marginal information

2.12 Structuralization of Digital Data

Flowchart item [A-13]

Fundamental geospatial dataset was prepared from digital topographic data, which was derived from digital plotting and digital compilation procedures. Since the digital topographic data was in CAD format, it had to be converted to GIS format. Therefore, the digital topographic data was converted into GIS data, which can be easily used in GIS.

2.13 Preparation of data files

Flowchart item [A-14]

(1) Accuracy check of Digital Orthophotos

Accuracy check was performed for the Digital Orthophotos. The coordinate values were compared with the stereo model of aerial photographs that were orientated with the same external orientation factor (aerial triangulation result) and Digital Orthophoto. Verification was conducted at 20 places per one orthophoto map sheet extent, and it was confirmed that the position accuracy of Digital Orthophoto fits within the prescribed accuracy.

(2) Preparation of Orthophoto maps for plot-out

The Orthophoto maps were prepared as a final orthophoto mapping data. The marginal information and annotation on each sheet of 1:5,000 scale orthophoto maps were prepared. The Digital Orthophotos, contour lines data, annotation and marginal information of each sheet were combined, and PDF file for the final 1:5,000 scale orthophoto maps was prepared. Checking for the contents of marginal information, lack of data at the time of PDF file preparation and so on of each PDF file of the 1:5,000 scale orthophoto maps was executed.

(3) Data Storage

The 1:5,000 scale digital topographic data, Digital Orthophotos data, Digital Topographic maps (pdf files), orthophoto maps (pdf files), fundamental geospatial datasets, Street Map of Harare data, and digital aerial photos were stored in DVD or hard disc. Furthermore, metadata were attached to each digital data, and final check for digital data was executed to keep the quality of the final products of the Project.

3. Technical Transfer to staff of the DSG

Technical transfer to staff of the DSG has been implemented for the preparation and promotion of utilization of geospatial information database.

3.1 Objective of technology transfer and Current status of DSG's capability for preparation and utilization of Digital Topographic maps

3.1.1 Objectives of technical transfer

The objectives of the Project are; to prepare the 1:5,000 scale Digital Topographic maps (96km^2) and Digital Orthophotos (1,700km^2 in Harare City, the capital of Zimbabwe, and its surrounding area, and to strengthen the capability of the DSG to prepare and update geospatial information databases and to promote the utilization of Geospatial Information Databases.
In order to achieve the above-mentioned objectives, achievement of the following two items was indispensable.

- The DSG should be able to continue developing (preparing) Digital Topographic maps of Harare City and its surrounding area and updating the same after the end of the Project.
- The DSG should be able to provide the Digital Topographic maps, the Digital Orthophotos prepared by the Project, and the Digital Topographic maps which expected to be prepared by the DSG after completion of the Project in order that users properly use the Digital Topographic map and Digital Orthophoto for the planning, development and maintenance of the infrastructure in the project area.

For the purpose of achieving the above two, the technical transfer (including equipment) for the preparation of Digital Topographic maps and Digital Orthophotos, and promotion of utilization of geospatial information database to the DSG was implemented.

3.1.2 Current status of the DSG's capability for preparation and utilization of Digital Topographic maps

The current status and issues concerning with the DSG's topographic maps preparation and updating, and promotion of utilization of geospatial information database are recognized and understood by the JICA study team as follows.

The ideal situation for the DSG is that "The DSG should in future be able to prepare and update its geospatial related products and services by itself with the latest geospatial information and provide these data and information to users for solving user's problems".

However, at present, the DSG does not have the capability for preparing and updating the national topographic maps, as indicated by its most recent topographic maps of the 1:50,000 scale that were last updated more than 30 years ago. Similarly some of its 1:5,000 scale topographic maps for urban areas were updated from Aerial Photography of between the latter half of the 1950s to the latter half of the 1960s when the country was known as Rhodesia, while the others, like for the City of Harare were updated from Aerial Photography of between 1983 to 1987 after Zimbabwe became independent in 1980, and no new mapping was done since then, updated 15 or more years ago.

During that period analogue plotters and aerial films were used for the preparation and updating of topographic maps by the DSG until the first half of the 1990s. After the year 1995, preparation of topographic maps was generally executed by digital photogrammetry methods using digital aerial camera and 5 digital plotters that had been converted from analogue to semi-analytical (4 PG2s and 1 Plan-cart) running ADAM 3DD software on personal computers. However, DSG was not able to maintain the equipment as the maintenance contractors were foreign (Australian) and bringing them in time and again was expensive, thereby the capacity of the DSG for topographic mapping based on photogrammetry mapping technology was lost about 15 years ago.

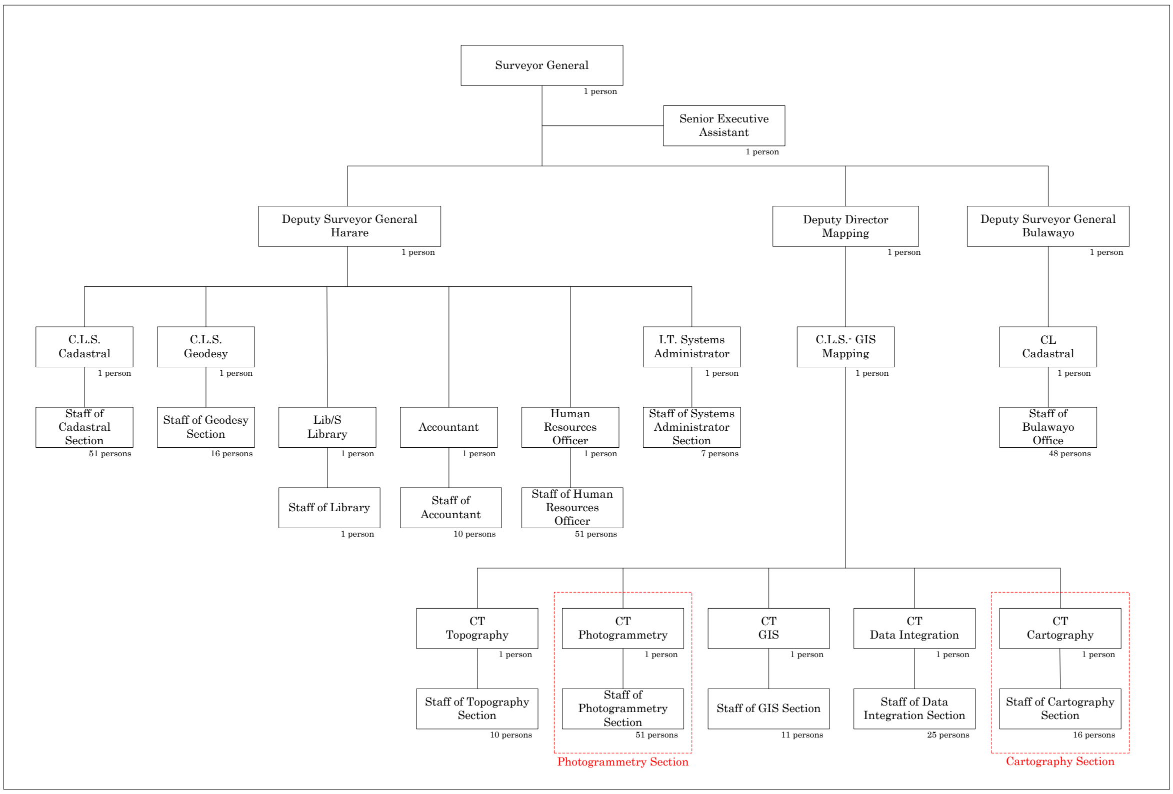
From the current situation analysis on the above, the JICA study team understands that the target issue on improving current situation of the DSG is to restore and strengthen the capability for developing and updating of Digital Topographic maps: technological competence, equipment, project operation ability, budget allocation and so on. Thus, the most important target issue is to strengthen the capability of digital photogrammetry which is the main means of data capturing in the photogrammetric mapping workflow.

3.1.3 Organization of DSG

The Department of the Surveyor-General (the DSG) is under the Ministry of Lands and Rural Resettlement (MLRR) of Zimbabwe. Figure 24 shows the organizational structure of the DSG.

The full staff complement at DSG should be 276 members in total. However, at the time of commencement of the Project in June 2015, the DSG had a staff complement of 124 members. That is 109 staff members at the Harare Main Office and 15 staff members at the Bulawayo Office.

It should be noted that more staff members were recruited under the EU/UNDP “MLRR Project”, which started form the middle of 2014. Therefore, the number of staff members at the DSG has increased.



Source: DSG

Figure 24 Organization chart of DSG

The main counterpart sections in the DSG for the Project are the Photogrammetry, the Cartography and the Reprographics sections of the Mapping Branch.

Currently, the Photogrammetry Section under the Mapping Branch at the DSG has 9 staff members. Several staff members have experience in analogue plotting and/or digital plotting using analytical plotter.

The Cartography Section and Reprographics Sections combined have 10 staff members at the present moment but only 8 were involved in the project. Up until the commencement of the EU/UNDP funded project, the Cartography Section was scanning and digitizing the existing topographic maps (printed paper maps). All staff members of the Cartography Section have experience in map digitizing.

3.1.4 Equipment of DSG

Currently, there are 5 four semi analytical plotters in the Photogrammetry Section of the Mapping Branch. However, of the semi analytical plotters are out of order and the other (PG-2, Swiss Kern) is still semi-functional.

As mentioned earlier, there has been no digital plotting system in the Photogrammetry Section for 15 or more years before the beginning of the JICA Project. However, one set of a digital plotting system, a Digital Photogrammetry Workstation (DPW) was introduced for technical transfer of digital plotting to the Photogrammetry Section during the implementation of the JICA Project.

To date, several vector graphic software (free hand) licenses were used for digital compilation in the Cartography Section.

However, this vector graphic software is not suitable for digital compilation of digital topographic data. This is because the data prepared using this software has no horizontal coordinates.

Several computers, GNSS equipment, GIS software and others were introduced to the DSG under the EU/UNDP-funded for the "MLRR Project". However, digital plotting system was not procured under this project.

The objective of "MLRR Project" is to support land reform policy of the Government of Zimbabwe and to strength the capability of the MLRR and the DSG for the preparation of land information by satellite image and remote sensing including permanent GPS stations.

3.1.5 Technical capacity of DSG

Three Photogrammetry Section staff members have experience in analogue plotting or digital plotting using analytical plotter. However, staff members have no experience in digital plotting using a digital plotting system.

Therefore, it is assumed that the remaining ten Photogrammetry Section staff members have little or no analogue plotting or digital plotting experience using analytical plotter.

However, the training for 3D measurement (height observation) using analytical plotter to staff of Photogrammetry Section is executed by staff having experience of photogrammetry.

All members of the Cartography Section have experience in digitizing from the existing paper maps using vector graphic software. However, it is assumed that the Cartography Section staff has no experience of map compilation for digital plotting data obtained directly from digital plotting system.

The map compilation technique has been already applied to the existing topographic maps (printed maps). Therefore, the map compilation knowledge and technique is not necessary for the production of digital topographic data if digitizing of the existing topographic maps (printed maps) is used.

However, the map compilation knowledge and technique according map scale are essential for the production of digital topographic data when data is derived from digital plotting system using aerial photos (digital plotting data).

Therefore, it is difficult to execute digital compilation of digital plotting data acquired by digital plotter only based on the knowledge and experience of digitizing off the existing topographic maps.

3.1.6 Budget of DSG

The breakdown of DSG's annual budget for FY 2014 and FY 2015 is shown in Table 38

Table 38 Budget of DSG during the 2014 and 2015 fiscal years

Items	Budget of 2014		Budget of 2015	
	Amount（US$）	Ratio (%)	Amount（US$）	Ratio (%)
Employment Cost	663,000	32.03	738,000	42.00
Goods & Services Cost	1,022,000	49.37	798,000	45.42
Maintenance Cost	225,000	10.87	91,000	5.18
Acquisition of Fixed Capital Assets	160,000	7.73	130,000	7.40
Total Amount	2,070,000	100.00	1,757,000	100.00

Source: DSG

Table 38 shows that “Employment Cost” which refers to staff salaries and allowances accounted for approximately 32 % and 42 % of the total budget in 2014 and 2015, respectively.

However, the “Goods & Service Cost” accounted for approximately 49.4 % and 45.4 % of the total budget in 2014 and 2015, respectively.

The "Maintenance Cost" (that is, equipment maintenance cost, office cleaning cost, fuel, oil and other additional costs) accounted for approximately 10.8 % and 5.1 % of the total budget in 2014 and 2015, respectively.

The "Acquisition of Fixed Capital Assets” (that is, the procurement or acquisition cost of equipment, mobile, furniture, land and so forth) accounted for approximately 7.7 % and 7.4 % of the total budget in 2014 and 2015, respectively .

Table 39 shows the total budget for "Good & Service Cost" and "Maintenance Cost”) in each Department during the 2014 fiscal year. The Mapping Department had a budget allocation of US$ 123,200, which is not enough for the production of new Digital Topographic maps as well as for updating digital topographic data.

Table 39 DSG Budget for each Department during the 2014 fiscal year

Section	Budget of 2014 (US$)	Ratio (%)
Cadastral Section	66,000	5.34
Geodesy Section	175,000	14.15
Mapping Section	123,200	9.96
IT Section	43,000	3.47

Administration Section	749,800	60.61
Human Affairs Section	47,000	3.80
Accountant	10,000	0.81
Library	23,000	1.86
Total Amount	1,237,000	100.00

Source: DSG

3.2 Technical transfer plan

Based on the objectives of technical transfer, the current status of the DSG and the issues of the DSG, a technical transfer plan was formulated as an implementation plan for technical transfer to staff of the DSG.

The technical transfer plan summarizes various indicators for baseline evaluation before technical transfer, the contents of technical transfer, target of technical transfer, and the degree of achievement evaluation.

In accordance with this technical transfer plan, technical transfer on various processes related to the preparation, updating, and utilization of Digital Topographic maps was implemented to staff of the DSG.

3.2.1 Points considered for technical transfer planning

In the technical transfer plan, the following were taken into consideration so that the DSG can independently prepare Digital Topographic maps and Digital Orthophotos from the digital aerial photos after the end of the Project.

- The training to staff of the DSG was implemented targeting the experience of actual work of Digital Topographic maps and Digital Orthophotos preparation to the staff of the DSG by OJT program.

- Aerial photography and 1:5,000 scale orthophoto maps with contour lines preparation were executed for the whole project area (approximately 1,700km^2) in the Project. However, 1:5,000 scale Digital Topographic maps preparation was executed for the central area of Harare City (96km^2) in the Project, and the 1:5,000 scale Digital Topographic maps for the remaining area (approximately 1,600km^2) is expected to be prepared by the DSG after completion of the Project. Therefore, the target of technical transfer for staff of the DSG was to strengthen the capabilities necessary for the preparation of Digital Topographic maps. To realize this target, not only technical transfer for Digital Topographic maps, but also lecture and practice for project planning and project management were executed.

- To be able to evaluate effectively the results of technical transfer to staff of the DSG, evaluation items, target of technical transfer, evaluation criteria was set, and hearing from staff of the DSG, questionnaire survey, skill tests were executed.

3.2.2 Technical transfer approach

The technical transfer for 1:5,000 scale Digital Topographic maps and Digital Orthophotos preparation by digital photogrammetry was executed by the combination of OJT and lectures on the theory necessary for implementation of actual works.

Furthermore, lectures and practice for project planning and project management to be able to plan and implement project for 1:5,000 scale Digital Topographic maps preparation at the remaining area where the aerial photograph has been already taken (approximately 1,600km^2) by the DSG themselves after completion of the Project.

The following two points were considered to be important technologies for achieving the objectives and much effort was input for this purpose.

- Introduction of digital photogrammetry technology to the DSG (technical transfer for digital plotting)
- Consultation and technical transfer for data distribution method, product development in order to promote the utilization of the geospatial information smoothly

The second item of the above was implemented as activities for the promotion of the utilization of geospatial information database. The details are described in Chapter 4.

3.2.3 Technical transfer plan for each technical field

Technical transfer plan for each technical field is described below, and the results of technical transfer are also mentioned at the end of each technical transfer plan.

Technical transfer plan: Planning and management of the preparation of Digital Topographic maps

Technical transfer plan for planning and management of the preparation of Digital Topographic maps is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

Technical transfer plan on Planning and management for preparation of Digital Topographic maps
Present status (baseline evaluation before technical transfer): • The role of the Mapping Branch of the DSG (Topographic Section, Photogrammetry Section, GIS Section, Data Integration Section Cartography Section and the Reprographics Section) is to produce various topographic maps at different scales. However, for more than 15 years the preparation and updating of topographic maps by photogrammetric method has not been carried out. Therefore, members of staff with experience of topographic maps preparation by photogrammetric method are limited to senior members only while the younger members of staff do not have experience of topographic maps preparation by photogrammetric method. • On the other hand, the DSG has a Cadastral Branch that is responsible for the cadastral survey. This Branch is continuously implementing projects. Personnel is continuously rotated between the Mapping Branch in which the work is stagnating and the Cadastral Branch that is continuously implementing project, in order to maintain experience and technology. However, in the Mapping Branch, it is necessary to strengthen the capabilities for planning and management of projects, due to the stagnation over many years. In the Project, the main target in implementing the technical transfer is to strengthen the photogrammetric mapping capabilities of the DSG for preparation of topographic maps. However, in order to obtain the required effect of technical transfer, it is also necessary to strengthen the capabilities of project planning and management. In order to realize this, it is necessary that the DSG has planning and management capabilities of geospatial information projects. So, technical transfer is implemented for planning and management of Digital Topographic maps and Digital Orthophoto preparation.
Targets: • Staff of the DSG will acquire knowledge regarding planning and management for Digital Topographic maps preparation project. • Staff of the DSG will understand the issues and problems for implementation of digital topographic mapping and orthophoto mapping, and will be able to take the necessary countermeasures for these.

Technology transfer items	Technology transfer method	Evaluation method (Index of baseline and achievement degree)
Planning and management of digital topographic mapping project	Lecture and practice for the DSG management staff	• Observation and hearing from staff of the DSG • Questionnaires
Results of Technical transfer: • Staff of the DSG understood the productivity of digital plotting which is the most important and basic information and critical pass for the planning and management of digital topographic mapping, and how to obtain this index. • It is necessary to determine the parameters for digital plotting productivity subject to the difference of topographic condition and land use by the DSG		

Technical transfer plan: Aerial photography

Technical transfer plan for aerial photography is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

Technical transfer plan
on Aerial photography

Present status (baseline evaluation before technical transfer):

- The DSG does not have experience of carrying out aerial photography using digital aerial camera (including outsourcing).
- However, the DSG has experience of aerial photography using a conventional film base aerial camera (outsourcing), and reproduction and sale of the aerial photos.
  - ➢ The last aerial photography by the DSG in Zimbabwe was taken in 1997.
  - ➢ The oldest aerial photos remaining in the DSG were taken in 1935.
  - ➢ Aerial photography known as "Blanket Photography" targeting whole country was periodically carried out during the era of Southern Rhodesia.
  - ➢ The old aerial films and photos which are high value historic assets are still stored in the DSG. The DSG used to reproduce the old aerial photos for sale at their store in the past, but is no longer doing so because of the following reasons:
    - ✧ There is no scanner in Zimbabwe to convert aerial films into digital images.
    - ✧ There are no capabilities of photo printing from aerial films in Zimbabwe any more.
    - ✧ There are no photographic materials in Zimbabwe and, coupled with cumbersome procurement procedures, it is impossible to make photo prints from aerial films.

Targets:

Acquisition of the knowledge and experience necessary for aerial photography using a digital aerial camera by outsourcing to an external aerial photography company.

Technology transfer items	Technology transfer method	Evaluation method (Index of baseline and achievement degree)
• Aerial photography planning and ground control points distribution planning • Difference between analogue aerial camera and digital aerial camera. • Difference between flight	• Explanation of the Project’s aerial photography plan Understanding of technical specifications of aerial photography for outsourcing • Explanation of the differences between the parameters of	• Observation and hearing from staff of the DSG

operation using GNSS/IMU system and conventional method.	digital aerial camera and analogue aerial camera, and points to be taken into consideration in aerial photography planning • Explanation of the differences from conventional ground control points plan by introduction of GNSS/IMU	
• Inspection method for aerial photography results	• Inspection of aerial photography results (actual work) • Sampling check of digital aerial photo images (actual work)	• Observation and hearing form staff of the DSG • Results of actual work
• Work process, quality control method	• Explanation of operation plan and specifications based on the sub-contract documents to sub-contractor • Explanation of aerial photography operation works and result using aerial photography report prepared by sub-contractor	• Observation and hearing from the staff of the DSG • Results of actual work
Results of Technical transfer: • Staff of the DSG obtained the knowledge and experience for sub-contracting of aerial photography using digital aerial camera to the external aerial photography company.		

Technical transfer plan: Ground control point survey

Technical transfer plan for ground control point survey is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

<table>
<tr><th colspan="3">Technical transfer plan
on Ground control point survey</th></tr>
<tr><td colspan="3">Present status (baseline evaluation before technical transfer):
• The DSG has no experience of wide-area GPS survey for the purpose of ground control point survey and also of leveling of long-distance routes. The contents of the usual DSG work is mainly surveying related to the cadastral survey, and there are not many opportunities for carrying out wide area survey.
• Staff of the DSG received professional education regarding surveying, and they have knowledge and a certain amount of work experience regarding GPS survey and levelling. Staff of the DSG actually involved in GPS survey and leveling (staff of Geodetic Survey Department of the DSG) has enough experience. Only one person from the Geodetic Branch participated in ground control point survey because the Geodetic Survey Branch was engaged in border survey at the time of ground control point survey. Many members of staff of the Cadastral Survey Branch participated in the ground control point survey. The Cadastral Survey Branch and Geodetic Survey Branch in the DSG cooperate in carrying out the cadastral survey on a routine basis. From the Photogrammetry Section in the DSG, the young members of staff participated in ground control point survey.</td></tr>
<tr><td colspan="3">Targets:
• To acquire the knowledge, skills, and experience necessary for the ground control point survey (GPS survey and leveling), selection of ground control point and air marking on ground control point.
• To get practical work experience of ground control point survey which is mainly performed in the field and which is the most critical process in digital topographic mapping process using aerial photogrammetry mapping method, through the practically mission for accomplishing the development of project deliverable: the Digital Topographic map and the Digital Orthophoto.</td></tr>
<tr><td>Technology transfer items</td><td>Technology transfer method</td><td>Evaluation method
(Index of baseline and achievement degree)</td></tr>
<tr><td>• Implementation of GPS survey and leveling</td><td>• Observation and calculation of GPS survey and leveling (actual work)
• Preparation of operation manual</td><td rowspan="2">• Observation and hearing from staff of the DSG
• Results of actual work</td></tr>
<tr><td>• Preparation of description of ground control points (method</td><td>• Preparation of description of ground control points (actual</td></tr>
</table>

of survey results transfer to next process , which is Aerial Triangulation)	work)	
• Planning of survey work, inspection and management of survey results	• Planning of observation, inspection of observation results (actual work)	
• Writing method of observation record and inspection method • Writing method of observation record and inspection method	• Actual observation work and writing method of observation record are instructed from JICA Study Team when necessary • Actual observation work and writing method of observation record are instructed from JICA Study Team when necessary	
• Accuracy control method	• Lecture and practice of accuracy and quality control of ground control point survey	

Results of Technical transfer:

- Staff of the DSG acquired the knowledge, skills, and experience necessary for the ground control point survey (GPS survey and leveling), selection of ground control point and air marking on ground control point.
- Staff of the DSG got experience of ground control point survey, including experience of implementation of large scale-survey project in the field.

Technical transfer plan: Aerial Triangulation

Technical transfer plan for Aerial Triangulation is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

Technical transfer on Aerial triangulation		
Present status (baseline evaluation before technical transfer): • Staffs of the DSG have no experience of Aerial Triangulation and Digital Photogrammetric Mapping using Digital Photogrammetry Workstation and digital aerial photo images. • Two staffs of the Photogrammetry Section of the DSG have experience in photogrammetric mapping using analogue plotters and aerial films. • The records of the past Aerial Triangulation results executed using analogue photogrammetry instruments were kept in the office of the DSG. • Two staffs of the Photogrammetry Section of the DSG have the knowledge and skills of data acquisition by semi analytical plotters using the existing Aerial Triangulation results and positive films. Therefore, it is evaluated that these two staff understand the basic principles of photogrammetric mapping from the fact that they can deal with analogue plotters. • The other members of staff in the Photogrammetry Section of the DSG do not have work experience of photogrammetric mapping. The other members of the Photogrammetry Section of the DSG received education of ground cadastral survey but their knowledge of photogrammetric mapping is not sufficient for practical levels. • The Photogrammetry Section of the DSG has one semi analytical plotter that is currently semi operating. Using this semi analytical plotter, the above-mentioned two staffs of the Photogrammetry Section of the DSG provide the training for spot height observation to the other staff of the section. Therefore, they are not completely unfamiliar with photogrammetry equipment. There are also several other dysfunctional old analog machines that provide an environment where the DSG staff can see analog photogrammetry instruments.		
Targets: • To be able to execute Aerial Triangulation and Block Adjustment using the Digital Photogrammetry Workstation introduced by the Project for technical transfer.		
Software used for technical transfer: Microsoft Windows (OS), ERDAS Imagine, Imagine Photogrammetry Suite, ORMIMA, CAP-A (photogrammetry, Aerial Triangulation, and block adjustment software)		
Technology transfer items	Technology transfer method	Evaluation method (Index of baseline and achievement degree)
• Understanding of the basic principles of photogrammetry and Aerial Triangulation • Explanation of the differences old and new Aerial Triangulation methods	• Lecture for basic theory of photogrammetry (Collinearity equation) • Outline of Aerial Triangulation (lecture) • Explanation of internal orientation, relative orientation and external orientation (lecture)	• Observation and hearing from staff of the DSG • Questionnaire

	• Explanation of block adjustment • Explanation of the differences between conventional Aerial Triangulation using analogue aerial camera, and Aerial Triangulation using DPW and digital aerial camera (lecture)	
• Implementation method of Aerial Triangulation and block adjustment using the DPW introduced by the Project • Explanation of the hardware and software of the DRW used. • Preparation work of Aerial Triangulation such as project setting and parameter setting in DPW software • Handling of data with large file such as digital aerial photo image data • Importing aerial photo image data into Aerial Triangulation project in DPW. • Importing method of camera calibration data and external orientation parameter obtained during aerial photography flight and so on. • Automatic and manual tie points observation • Observation method of ground control points • Evaluation method for accuracies of ground control points and tie points observation result before block adjustment • Re-observation of ground control points and tie points • Method of using the bundle block adjustment program • Evaluation method for the results of block adjustment	• Lectures regarding the functions and operation method of the DPW and the software used, and practical training of Aerial Triangulation using the software	• Observation and hearing from staff of the DSG • Questionnaires
• Process and accuracy control methods • Preparation of accuracy control sheets	• Preparation of accuracy control sheets based on the results of Aerial Triangulation executed by staff of the DSG themselves for the practical training of Aerial Triangulation	• Observation and hearing from staff of the DSG • Questionnaires • Contents of accuracy control sheets
Results of Technical transfer: Staff of the DSG became to be able to execute Aerial Triangulation and block adjustment using the DPW introduced by the Project.		

Technical transfer plan: Field identification and field completion

Technical transfer plan for field identification and field compilation is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

<table>
<tr><th colspan="3">Technical transfer plan
on Field identification and field completion</th></tr>
<tr><td colspan="3">Present status (baseline evaluation before technical transfer):

• Preparation of new topographic maps and updating of the existing topographic maps has not been executed for 15 years or more, in the DSG. Therefore, most of the current members of staff of the Photogrammetry Section in the DSG have no actual work experience for the preparation of topographic maps, and also have no actual work experience of field identification and field completion for preparation of 1/5,000 scale topographic maps.
• The field identification and field compilation was planned to be executed using GIS software. However, the majority of the members of staff of the DSG do not have experience in the use of GIS software in their actual work.</td></tr>
<tr><td colspan="3">Targets:
• To be able to execute field identification and field completion and arrangement of the results.
• To be able to use GIS software for the arrangement of field identification and field completion data. To be able to prepare simple GIS data by themselves.</td></tr>
<tr><td colspan="3">Software used for technical transfer:
Microsoft Windows (OS), Quantum GIS (GIS software)</td></tr>
<tr><td>Technology transfer items</td><td>Technology transfer method</td><td>Evaluation method
(Index of baseline and achievement degree)</td></tr>
<tr><td>• Determination of field identification items based on specifications of topographic maps, and preparation of work plan</td><td>The following points must be considered, and solutions found at the work planning stage
• Understanding the differences between topographic maps and thematic maps for special purpose to avoid collecting unnecessary data for</td><td>• Observation and hearing from staff of the DSG
• Results of actual work</td></tr>
</table>

	topographic maps. • Which organization possess the necessary data? • Whether the data to be collected can be used as information for topographic maps or not?	
• Implementation of field identification and field completion • Data collection in the office • Arrangement of survey results	• Instruction through actual work	
• Data input and checking • Data inspection methods	• Lecture and practical work for introduction of GIS software, data input and data edit • Instruction through actual work	
• Process and quality control methods	• Checking of spelling mistakes and violation of notation rules	

Results of Technical transfer:

- Staff of the DSG became to be able to execute field identification and field compilation, and also compile and organize the survey results of field identification and field compilation.
- Staff of the DSG became capable to use GIS software for the arrangement of survey results, and also to make simple GIS data by themselves.

Technical transfer plan: Digital plotting, digital compilation and integration of field completion results

Technical transfer plan for digital plotting, digital compilation and integration of field completion results is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

<table>
<tr><th colspan="3">Technical transfer
on Digital plotting, Digital compilation and integration of field completion data</th></tr>
<tr><td colspan="3">Present status (baseline evaluation before technical transfer):
• Preparation of new topographic maps and updating of the existing topographic maps by photogrammetric method has not been executed for 15 years or more, in the DSG. Therefore, the capability of preparation and updating of topographic maps by photogrammetric method including plotting was virtually been lost in the DSG.
• The main methods of data acquisition for preparation and updating of topographic maps is by plotting using aerial photos. Due to the loss of plotting capability, it was not able to prepare the necessary data for the Cartography Section thus the work of the Cartography Section also stopped.
• In the Cartography Section of the Mapping Branch of the DSG, digitizing of the existing maps using vector graphic software has been carried out, and they possess this ability at present. However, the contents of the cartography work from the digital plotting data that is the subject of technical transfer of the Project is not the same as the present work of the Cartography Section of the DSG.
• The preparation and updating of topographic maps had almost stopped in the DSG. Therefore, most of the young members of staff of the DSG have no work experience of preparation and updating of topographic maps and their understanding of topographic maps and preparation of topographic maps by photogrammetric method is insufficient.</td></tr>
<tr><td colspan="3">Targets:
• To obtain the basic knowledge of digital plotting and digital cartography: the process on the digital photogrammetric mapping method, through lectures on topographic maps and preparation of topographic maps by photogrammetric method.
• To be able to execute digital plotting using the function of DPW which will be introduced by the Project for technical transfer
(Support for transition to digital photogrammetry in the Photogrammetry Section of DSG).
• To be able to execute digital cartography work (error check and correction, data compilation) using CAD software and GIS software based on the digital plotting data which will be obtained by technical transfer of digital plotting.</td></tr>
<tr><td colspan="3">Software used for technical transfer:
Microsoft Windows (OS),
ERDAS Imagine, Imagine Photogrammetry Suite, PRO600 (photogrammetry and digital plotting software), Microstation (CAD software for recording and editing topographic map data), ArcGIS (GIS software for editing topographic map data)</td></tr>
<tr><td>Technology transfer items</td><td>Technology transfer method</td><td>Evaluation method
(Index of baseline and achievement degree)</td></tr>
</table>

• Basic knowledge of topographic maps preparation (digital plotting and digital compilation) • Basic knowledge regarding topographic maps • Workflow of topographic maps preparation • Basic knowledge regarding topography	• Lecture	• Observation and hearing from staff of the DSG • Questionnaires
• Practice of digital plotting using DPW • Determination of data acquisition standards and map feature codes • Setting of code numbers into DPW • Stereoscopic measurement and data acquisition by DPW	• Lecture regarding the basic theory • Lectures regarding workflow and data flow • Practical training using DPW	• Observation and hearing from staff of the DSG • Questionnaires • Skill test
• Inspection of digital plotting data (quality inspection within the digital plotting process)	• Practical training for inspection and correction of digital plotting data	• Observation and hearing from staff of the DSG • Questionnaires
• Data checking and data correction (digital plotting and digital compilation)	• Lectures regarding the contents of digital topographic data • Lectures and practice regarding data inspection and correction • Understanding the errors contained in digital plotting data, and countermeasure at the time of digital plotting	
• Data Integration (digital compilation and integration of field completion data)	• Practice of data integration between difference models, and different data files into one data file	
• Process and quality control methods	• Preparation of accuracy control sheets for data that they prepared by themselves, and to understand the issues, points to be improved and good points • Countermeasures for these issues and points to be improved • Sharing know-how regarding good results and bad results with other members	• Contents of quality control sheets
Results of Technical transfer: • Staff of the DSG acquired the basic knowledge of digital plotting and digital compilation necessary for the preparation of Digital Topographic maps through the lectures of topographic maps and topographic maps preparation. • Staff of the DSG became competent to execute digital plotting using DPW introduced by the Project for the technical transfer (Support for transition to digital photogrammetric mapping in the Photogrammetry Section of the DSG) • Staff of the DSG became to be able to execute digital compilation (error check and correction, data integration) of digital topographic data using CAD software and GIS software.		

Technical transfer plan: Preparation of Digital Orthophoto

Technical transfer plan for preparation of Digital Orthophoto is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

Technical transfer plan
on Preparation of Digital Orthophoto

Present status (baseline evaluation before technical transfer):

The DSG has no equipment for preparation of Digital Orthophoto, and also no experience of Digital Orthophoto preparation.

- The DSG prepared the orthophoto in past time.
- An analogue orthophoto projector remains in the DSG, although it does not work.
- In the 1990s, the Digital Photogrammetry Workstations of the semi analytical nature were introduced into the DSG by the support from foreign country, and Digital Orthophotos were prepared.

Targets:

- To enable the preparation of Digital Orthophoto using the function of DPW introduced by the Project for technical transfer.

Software used for technical transfer:

Microsoft Windows (OS), ERDAS Imagine, Imagine Photogrammetry Suite (Photogrammetry, DEM, Digital Orthophoto preparation and editing software)

Technology transfer items	Technology transfer method	Evaluation method (Index of baseline and achievement degree)
• Orthophoto preparation workflow and data flow	• Lecture	• Observation and hearing from staff off the DSG • Questionnaires
• Preparation and editing of digital terrain model • DEM preparation • DEM editing • DEM evaluation	• Lecture and practice	
• Preparation orthophoto images • Preparation of orthophoto (Ortho rectification process) • Evaluation of orthophoto	• Lecture and practice	
• Orthophoto mosaic preparation • Acquisition and editing of seam	• Lecture and practice	

lines • Mosaic processing • Color tone adjustment • Orthophoto mosaic evaluation		
• Process and accuracy control	• Quality control of the data prepared in the training, preparation of quality control sheets and	• Contents of accuracy control sheets
Results of Technical transfer: • Staff of the DSG became to be able to prepare Digital Orthophoto using DPW introduced by the Project for technical transfer.		

Technical transfer plan: Map representation and map finishing

Technical transfer plan for map representation and map finishing is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

Technical transfer plan
on Map representation and map finishing

Present status (baseline evaluation before technical transfer):

- The DSG has experience of digitizing of scanned topographic maps (smaller than 1:25,000 scale) using vector graphic software. A part of this workflow is the same as the map representation and map finishing process of the digital topographic mapping using DRW. Therefore, it is evaluated that the DSG has experience and knowledge of map representation and map finishing.
- The software for map representation and map finishing used in the Project is GIS software (ArcGIS). The operability is different between the vector graphic software and GIS software. However, the workflow and concept of map representation and map finishing is the same.
- The technical transfer of map representation and map finishing will be implemented for the different and additional parts between the vector graphic software and GIS software considering the present DSG's workflow of map representation and map finishing.

Targets:

- To enable map representation and map finishing for Digital Topographic maps using GIS software.

Software used for technical transfer:

Microsoft Windows (OS), ArcGIS (GIS software for map representation and map finishing)

Technology transfer items	Technology transfer method	Evaluation method (Index of baseline and achievement degree)
• Understanding of workflow of topographic map preparation, map representation and map finishing using software (understanding of the difference from the conventional analogue methods)	• Lecture	• Observation and hearing from staff of the DSG • Questionnaires

• Method of map expression using software (map representation and map finishing)	• Method of importing digital topographic data into ArcGIS (lecture and practice) • The representation function of ArcGIS (lecture and practice) • Method of preparation of marginal information using ArcGIS (lecture and practice) • Explanation of map representation and map finishing of Digital Topographic maps, orthophoto maps and the Harare Street Map prepared by the Project (lecture and practice)	• Observation and hearing from staff of the DSG • Questionnaires
• Process and quality control methods	• Preparation of accuracy control sheets for data obtained by the training •	• Contents of quality control sheets
Results of Technical transfer: • Staff of the DSG became to be able to execute map representation and map finishing using GIS software.		

Technical transfer plan: Data management and preparation of Fundamental geospatial dataset

Technical transfer plan for preparation of Fundamental geospatial dataset is described below, and the results of technical transfer are also mentioned at the end of technical transfer plan.

Technical transfer plan on Fundamental geospatial dataset, and preparation and management of data to be provided
Present status (baseline evaluation before technical transfer): • Preparation of new topographic maps and updating of the existing topographic maps including large scale Digital Topographic maps has not been executed for 15 years or more by the DSG. Preparation of new GIS data has also not been carried out by the DSG. Concerning the large scale topographic maps, the DSG has no experience of digitizing of the existing large scale topographic maps. The Data Integration Section of the DSG that develops GIS data from the existing data such as topographic maps, etc., exists on the organization chart of the DSG. However, at present this section is dormant. • The DSG has been digitizing scanned topographic maps (smaller than 1:25,000 scale) using vector graphic software and the result is not GIS data. Raster image data (TIFF or JPEG data) of these topographic maps are sold to the users, but vector data is not sold to the users up to present. Therefore, the DSG has no experience and know-how in the distribution of vector data to the users. • The existing printed topographic maps are scanned and archived by the DSG. The raster image data of the existing topographic maps are sold to the users by the DSG. • In the 1980s, cadastral data was digitized. GIS was introduced and used before the year 2000. The database and searching system of the index of cadastral information and control points prepared by the support by foreign country still exists in the DSG
Targets: • To enable preparation of Fundamental geospatial dataset from digital topographic data using GIS software. To acquire the knowledge and skills necessary for the preparation of Fundamental geospatial dataset. • To enable preparation of data to be supplied to the users using GIS software. To acquire the knowledge and skills necessary for this.
Software used for technical transfer: Microsoft Windows (OS), ArcGIS (GIS software for structuring, and searching and processing data to be supplied)

Technology transfer items	Technology transfer method	Evaluation method (Index of baseline and achievement degree)
• Understanding of Digital Topographic map data and Fundamental geospatial dataset	• Lecture and practice	• Observation and hearing from staff of the DSG • Questionnaires
• Preparation of Fundamental geospatial dataset based on digital topographic data	• Lecture and practice	
• Preparation and management of data to be supplied • Vector/raster conversion • File format conversion • Data searching and extraction operation by specific topics and specific ranges • Changing file record units (conversion from seamless to framework units, etc.) • Transformation of coordinates	• Lecture and practice	
• Process and quality control methods	• Preparation of quality control for the data prepared by the training	• Contents of quality control sheets
Results of Technical transfer: • Staff of the DSG acquired the necessary knowledge and skill for Fundamental geospatial dataset. Staff of the DSG became to be able to prepare Fundamental geospatial dataset based on digital topographic data (CAD data). • Staff of the DSG became to be able to prepare the data to be provided to the users, and also to acquire the knowledge and skill for preparation and provision of data to the users.		

3.3 Technical transfer of aerial photography

Flowchart item [B-3]

(1) Outline

Technical transfer for aerial photography was executed by a combination of On the Job Training (OJT), lectures and site visits. Table 40 shows the items and method of technical transfer for aerial photography.

Table 40 Items and methods of technical transfer for aerial photography

Items of technical transfer	Method
• Preparation of necessary document for permission of aerial photography and application to aviation authority	OJT
• Understanding of aerial photography specifications	Lecture
• Parameters of digital aerial camera (Difference between analogue and digital aerial camera)	Lecture
• Aerial photography plan	OJT and lecture
• Ground control points distribution plan	OJT and lecture
• Aerial photography equipment	Lecture and tour of inspection
• Aerial photography inspection method	OJT
• Process and quality control methods	Lecture
• Explanation of current technologies such as aerial photography using drone	Lecture

Source: JICA Survey Team

(2) Evaluation of technical understanding regarding aerial photography by obtaining flight permission

Preparation for aerial photography was started in June 2015 immediately after commencement of the Project. Since orthophoto is one of the important outcomes in the Project, it is desirable that aerial photograph used for the preparation of Digital Orthophotos is without clouds or haze. Normally, the dry season from May to July is the most fine (cloudless) weather season in Zimbabwe. From August onwards, there are many days with clouds, and also burring commences in the agricultural land. Therefore, aerial photography was necessary to start as soon as possible after commencement of the Project, failure of which the photography would have had to be postponed to the next appropriate window of the next season.

In order to prepare the necessary application documents for the flight permission, not only the understanding of complete process of aerial photography, but also the understanding of the specifications of aerial photography, aerial photography planning and ground control point survey plan are essential. The application for flight permission was submitted to the Authorities concerned in Zimbabwe by sub-contacted aerial photography company with assistance of DSG. Prior to the commencement of the Project, there were concerns that it would take time to obtain the flight permission from the Authority concerned. The necessary procedures and coordination within the Government of Zimbabwe for the flight permission were carried out by the DSG. As a result, the approval for flight permission was issued with exceptional speed (within only a few days after submission of the necessary application documents to the Authorities concerned.

Therefore, JICA study team concluded that the smooth coordination within the Government of Zimbabwe for the flight permission by the DSG is the evidence that DSG had a certain level of understanding for the specifications of aerial photography and photogrammetric mapping from the beginning.

(3) Planning of aerial photography and ground control points distribution, and site visit for aerial photography equipment

Prior to the application for the flight permission, explanations and lectures regarding aerial photography plan and ground control points distribution plan were executed by the JICA Study Team and a sub-contracted aerial photography company. The flight plan was prepared based on the type of digital aerial camera and airplane to be used by the sub-contracted aerial photography company through the discussion between JICA Study Team and the sub-contracted aerial photography company.

Source: JICA Study Team

Photo 10 Site visit within the aerial photography aircraft

(Explanation of positioning system of aircraft)

(4) Inspection of aerial photography results

The JICA study team and the DSG got explanation by the Sub-contracted aerial photography company the outline of aerial photography and the results based on the report prepared by sub-contracted company. The explanation included the observation situation of the direct positioning factor (external orientation parameter) captured by the GNSS / IMU and variation of the altitude and attitude of the aircraft during aerial photography. An explanation based on a familiar example was an opportunity for DSG to cognize and improve understanding about the newly introduced technology.

(5) Evaluation of technical transfer

Technical training for aerial photography was achieved through OJT programs. The contribution from DSG resulted in the smooth coordination within the Government of Zimbabwe for the flight permission. From these results, it is evaluated that the specific target of acquisition of the knowledge and experience necessary for outsourcing of aerial photography using the latest digital aerial camera was achieved.

What remains is for the DSG to create another opportunity for aerial photography for photogrammetry applications so that this experience gained by the trainees can be applied. A certain cost, however, is required for carrying out the aerial photography. Thus the DSG needs to secure the necessary budget for a similar project for the preparation and updating of Digital Topographic maps and geospatial information database. On the other hand, with the use of unmanned aircraft (drones) in recent years, there are cases that, depending on the intended end usage of mapping and size of the target area, it is not necessary to use an aircraft for aerial photography. Technical transfer was carried out in lecture form providing outline of aerial photography using drones and their possibility for photogrammetry, and it is evaluated that the ability of staff of the DSG to select and adopt aerial photography method suitable for the purpose have also been increased.

3.4 Technical transfer of ground control points survey

Flowchart item [B-4]

GPS survey and leveling were executed by the staff of the DSG as OJT technical transfer for ground control point survey.

The result of ground control point survey executed by the staff of the DSG by OJT was used for the preparation of Digital Topographic maps and Digital Orthophotos in the Project. Therefore, OJT for ground control point survey was executed as a part of actual work of Digital Topographic maps and Digital Orthophotos preparation in the Project.

(1) Technical transfer of Ground Control Point Survey (GPS survey)

GPS survey was executed by 8 members of the staff of the DSG under the instruction and supervision of JICA Study Team see Table 41 for the members of the staff of the DSG who participated in the OJT on the ground control point survey (GPS survey).

Table 41 Members of the staff of the DSG participated on the OJT for Ground Control Point Survey (GPS survey)

No.	Name	Affiliation	Position
1	Mr. Tangai Munyongani	Photogrammetry Section	Land Survey Technician
2	Mr. Nomore Arikoko	Photogrammetry Section	Land Survey Technician
3	Mr. Reward A. Munyeki	Photogrammetry Section	Land Survey Technician
4	Mr. Dennis. Machinga	Cadastral Branch	Land Survey Technician
5	Mr. Nicholas Mazvazva	Cadastral Branch	Land Survey Technician
6	Mr Tanyaradzwa Chitengu	Cadastral Section Branch	Land Survey Technician
7	Mr. John Taruvinga	Photogrammetry Section	Land Survey Technician
8	Ms. Florence Kurasha	Geodesy Branch	Land Survey Technician

Source: JICA Study Team

Source: JICA Study Team

Photo 11 Members of the staff of the DSG participated in the OJT on Ground Control Point Survey (GPS survey)

The GPS survey was executed using 4 sets of GPS equipment arranged in Japan and brought to Zimbabwe by JICA Study Team.

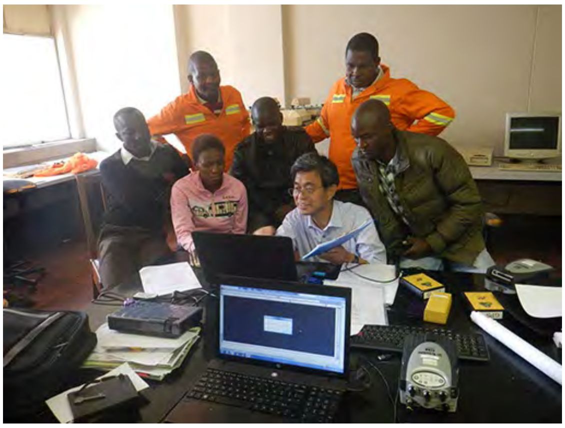
Under the supervision of JICA Study, the staff of the DSG executed the series of operations from selection of ground control points, marking of air-mark, GPS observation, calculation and accuracy control Team. The details of GPS survey for ground control survey are described in Section **2.6.3 Ground control point survey (GPS Survey)**, while the achievement evaluation of technical transfer is described in this Section. The technical transfer items are as follows:

- GPS survey
- Preparation of description of ground control points (hand over method survey results to the next process, which is Aerial Triangulation)
- Inspection and management of survey results
- Writing method on field notebook and inspection method of observation results
- Accuracy control method

Firstly, the staff of the DSG received lectures regarding the outline of the reference point survey and the ground control point survey in the office using slides. On the first day of site work, the staff of the DSG received the instruction regarding the actual work form the JICA Study. On the second day, the staff of the DSG executed the GPS observation by themselves with the support from JICA Study Team. On the third and subsequent days, the GPS observation was executed by the staff of the DSG by themselves. Also, meetings were held with all members for the purpose of confirmation of GPS observation method and the method of summarizing the observation records.

After the GPS observation, the staff of the DSG executed the calculation of GPS observation results completely by themselves in accordance with the manual prepared by JICA Study Team. The staff of the DSG executed all processes of the GPS survey (observation and calculation) by themselves.

Therefore, it was concluded that, by referring to the manual for points of doubt, the staff of the DSG will be able to execute the same work by themselves, including carrying out GPS survey planning, GPS observation, calculation processing after observation, establishment of photo signals have been achieved to the target level.

Source: JICA Study Team

Photo 12 Training on GPS observation and GPS calculation

(2) Technical transfer of ground control point survey (Leveling)

Leveling was executed by 8 members of the staff of the DSG under the instruction and supervision of JICA Study Team and the DSG experienced staff members. The members of staff of the DSG who participated in the OJT on ground control point survey (Leveling) are shown in .

Table 42 Staff of the DSG participated in the OJT on ground control point Survey (Leveling)

No.	Name	Affiliation	Position
1	Mr. Kudakwashe Gwelo	Photogrammetry Section	Land Survey Technician
2	Mr.Terrence Mujombiza	Cadastral, Drawing Office	Land Survey Technician
3	Mr.Billy Manuwere	Cadastral, Examination	Land surveyor
4	Mr.Aldrien Chironga	Cadastral, Examination	Land surveyor
5	Mr. Alexander Macheka	Photogrammetry Section	Land Survey Technician
6	Mr. Tobias Makuyo	Cadastral, Examination	Land Survey Technician
7	Mr. Ronald Chishiri	Cadastral, Examination	Land Survey Technician
8	Mrs. Pearmer Tanhara	Photogrammetry Section	Land Survey Technician
9	Mrs. Tendai Mungarevani	Cadastral, Examination	Land surveyor
10	Mr. Douglas Siwawa	Cadastral, Examination	Land Survey Technician
11	Mr.Bethwel Banda	Cadastral, Examination	Land surveyor
12	Mr. Lenard Mudzana	Photogrammetry Section	Land Survey Technician
13	Mr. Beruvin Gumbo	Cadastral, Examination	Land surveyor
14	Mr. Justice Zindoga	Cadastral, Examination	Land Survey Technician
15	Mr. Donald Molai	Cadastral, Examination	Land surveyor

Source: JICA Study Team

Photo 13 Members of the staff of the DSG participated in the OJT on ground control point survey (Levelling)

The leveling was executed using 4 sets of leveling instruments procured in Japan and brought to Zimbabwe by JICA Study Team.

The staff of the DSG executed the series of operations from reconnaissance survey, selection of leveling points, leveling observation, calculation of observation results and accuracy control under the supervision of JICA Study Team and the DSG veteran staff members. The details of leveling for ground control survey are described in Section **2.6.5 Ground control point survey (Leveling)** while the achievement and evaluation of technical transfer is described in this Section.

The technical transfer items are as follows:

- Selection of leveling routes, leveling points taking into consideration the aerial photography courses
- Methods of using the handy GPS for reconnaissance survey, etc.
- Implementation of leveling (total 520km of Go and Back observation)
- Preparation of ground control points description
- Preparation of leveling plan
- Writing method on field notebook and inspection method of observation results
- Accuracy control method

As a result of insufficient experience of actual leveling work by the staff of the DSG, resulting in frequent re-observation of some leveling, it was necessary to increase by 10 working days for the completion of leveling from the original scheduled. However, the staff of the DSG gradually became proficient in the skills, and finally the leveling covering 260km (520 km length leveling route Fro and 520 km route Back) was completed as OJT program within the accuracy prescribed by the staff of the DSG.

On the basis of this achievement, it was evaluated that the specific objective of "**the staff of the DSG being able to execute leveling for ground control point survey"** has been achieved.

On the basis of this achievement, it was evaluated that the specific object to be able to execute leveling for ground control point survey has been achieved.

In Zimbabwe, the national benchmark network has already been established. However, through this ground control point survey (leveling), it was found that most of the benchmarks in the project area had are no longer existing and could not be used, and the staff of the DSG recognized the importance of the benchmark network and that the establishment and maintenance of benchmark network is an important task for reasonable progress in the preparation of Digital Topographic maps in the future.

The implementation of approximately 520km length leveling (260km for Go and Back observation) was the important experience for basic technical skill of the staff of the DSG. It is expected that the staff of the DSG will continuously prepare the Digital Topographic maps by themselves based on the experience of this leveling works.

3.5 Technical transfer of Aerial Triangulation

Flowchart item [B-5]

The technical transfer for Aerial Triangulation was carried out over 38 days from 19 October 2016 to 24 November 2016, simultaneously with the technical transfer for Digital Orthophoto preparation.

The operation to obtain the position and inclination (external orientation parameters) of the aerial camera during the implementation of aerial photography that is the most important process for Digital Topographic maps and orthophoto preparation by photogrammetry is called Aerial Triangulation. This is an important process and technology to govern the horizontal and vertical accuracy of the Digital Topographic maps, Digital Orthophoto and Digital Elevation Models DEM as the final products. If the position and inclination of the aerial camera is not correctly obtained, required accuracy of Digital Topographic maps, Digital Orthophoto and DEM, which will be prepared in the subsequent process of photogrammetry, will not be obtained.

Therefore, the staff of the DSG should not only learn the simple software operation but also should understand the basic theory of photogrammetry and Aerial Triangulation so that the output results could be evaluated by themselves, otherwise it would be difficult for the DSG to prepare Digital Topographic maps by themselves in the future.

The technical transfer was implemented with the objective of not only learning the techniques of software operation, but also learning the technology of Aerial Triangulation, that is the basis for preparation of Digital Topographic maps by DSG themselves, through lectures in the theory of photogrammetry, practical training of Aerial Triangulation and training in accuracy control and evaluation.

(1) Implementation period

The technical transfer for Aerial Triangulation and orthophoto preparation was executed as follows:

- Preparation work (parameter setting, etc.): from 19 October 2016 to 21 October 2016
- Aerial triangulation: from 24 October 2016 to 8 November 2016
- DEM and ortho image preparation: from 9 October 2016 to 17 October 2016
- Follow up: from 18 November 2016 to 25 November 2016

(2) Counterpart

The members of the staff of the DSG who participated in the technical transfer for Aerial Triangulation, DEM and orthophoto preparation are shown in Table 43.

Table 43 Members of the staff of the DSG participated in the technical transfer of Aerial Triangulation

No.	Name	Affiliation	Note
1.	Mr. Enias Chinjekure	Photogrammetry section	Chief of Photogrammetry Section Having experience of analogue plotting
2.	Mr. Mudzana Lenard	Photogrammetry section	Having technical training of ground survey, no experience of photogrammetry
3.	Mr. Alexander Macheka	Photogrammetry section	Same as above
4.	Mr. Nomore Arikoko	Photogrammetry section	Same as above Participated in lecture

Source: JICA Study Team

(3) Baseline survey for the degree of understanding regarding the basic knowledge of Aerial Triangulation

A baseline survey was carried out by questionnaire with the 3 person who participated in during the whole period of technical transfer. The evaluation in accordance with a 5 points method ("1" is a low degree of understanding, "5" is a high degree of understanding) and the results are shown in Table 44.

Table 44 Baseline survey results

No.	Questionnaire contents	Counterpart answers		
		1	2	3
1	Do you know the work procedure of the digital topographical mapping?	4	1	3
2	Do you know the work procedure of the digital topographical mapping?	3	1	2
3	Do you know that Leica Photogrammetry Suite (hereinafter LPS)* have stereoscopic ability?	3	1	4
4	Do you know that stereovision is effective for the measurement and interpretation of the feature?	4	1	4
5	Do you know about initial setting of LPS*?	4	1	2
6	Do you know minimum number of the GCPs of Aerial Triangulation by POS/IMU**?	3	2	2
7	Do you know measurement principle for ground control points and tie points?	4	2	2

8 Do you know operation for the bundle block adjustment computation using CAP-A (ORIMA)?	3	1	1
9 Do you know the accuracy management and quality control for the Aerial Triangulation?	3	2	3
Minimum value	3	1	1
Maximum value	3	2	4
Average value	3.44	1.33	2.56
Average value of 3 counterparts	2.44		

* "Leica Photogrammetry Suite (LPS)" is previous name of "Imagine Photogrammetry" from ERDAS
**"POS/IMU" is another word for GPS (GNSS) /IMU

Source: JICA Study Team

The content of the questionnaire was questions to determine the degree of understanding of the basic knowledge of photogrammetry, Aerial Triangulation and the functions of the software used. The results showed that the maximum average value by the 3 members of the staff of the DSG was 3.44, the minimum average value was 1.33, and the overall average value was 2.44, indicating an overall low level of knowledge and experience.

It also showed that there was a difference of 2.11 points in the degree of understanding between the staff with experience in photogrammetry and the staff with no experience.

(4) Content of technical transfer

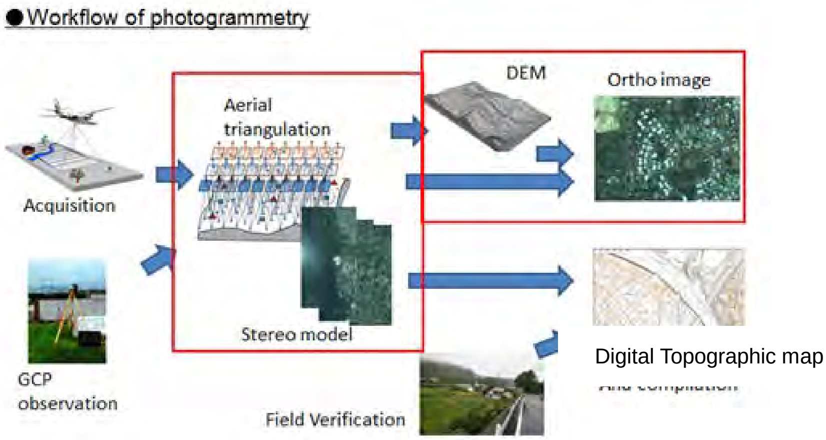
The following 4 items of training were executed as the technical transfer for Aerial Triangulation

- Lecture for outline of photogrammetry
- Lecture for outline of Aerial Triangulation
- Practice of Aerial Triangulation using software
- Practice of accuracy control

(5) Outline of photogrammetry

Aerial triangulation is a technology that constitutes one of the basic principles of photogrammetry, and in order to understand Aerial Triangulation, it is essential to understand photogrammetry. The position and inclination of the aerial camera at the time of taking aerial photos that are used for the preparation of Digital Topographic maps and Digital Orthophoto in subsequent processes are obtained by Aerial Triangulation. This is an important process for photogrammetry, and the horizontal and vertical accuracies of Digital Topographic maps and orthophoto are governed by the results of Aerial Triangulation.

Before the lectures on Aerial Triangulation, lectures on the principles of photogrammetry, the workflow of topographic map preparation by photogrammetry and the role of Aerial Triangulation in the flow for preparation of Digital Topographic maps and Digital Orthophoto were executed by JICA Study Team.

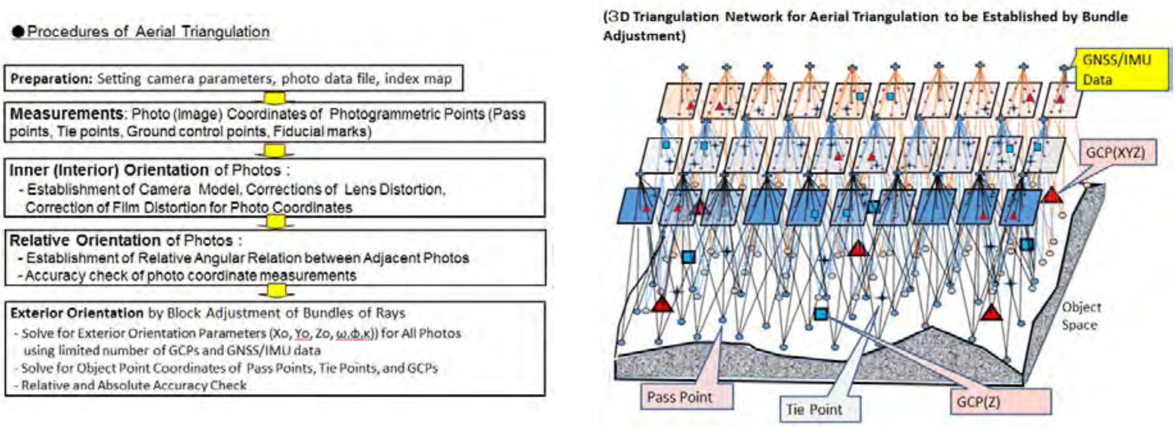


Source: JICA Study Team

Figure 25 Outline workflow for the preparation of topographic maps, DEM and orthophoto by photogrammetry

(6) Outline of Aerial Triangulation

In the outline of Aerial Triangulation, the objectives of Aerial Triangulation, the principles, the implementation procedures (parameters setting, tie points and ground control points measurement, internal orientation, relative orientation and external orientation by bundle block adjustment) were explained in order to understand the practical training using software which is to be implemented in next step.



Source: JICA Study Team

Figure 26 Flow of Aerial Triangulation (left) and conceptual diagram of bundle adjustment calculation (right)

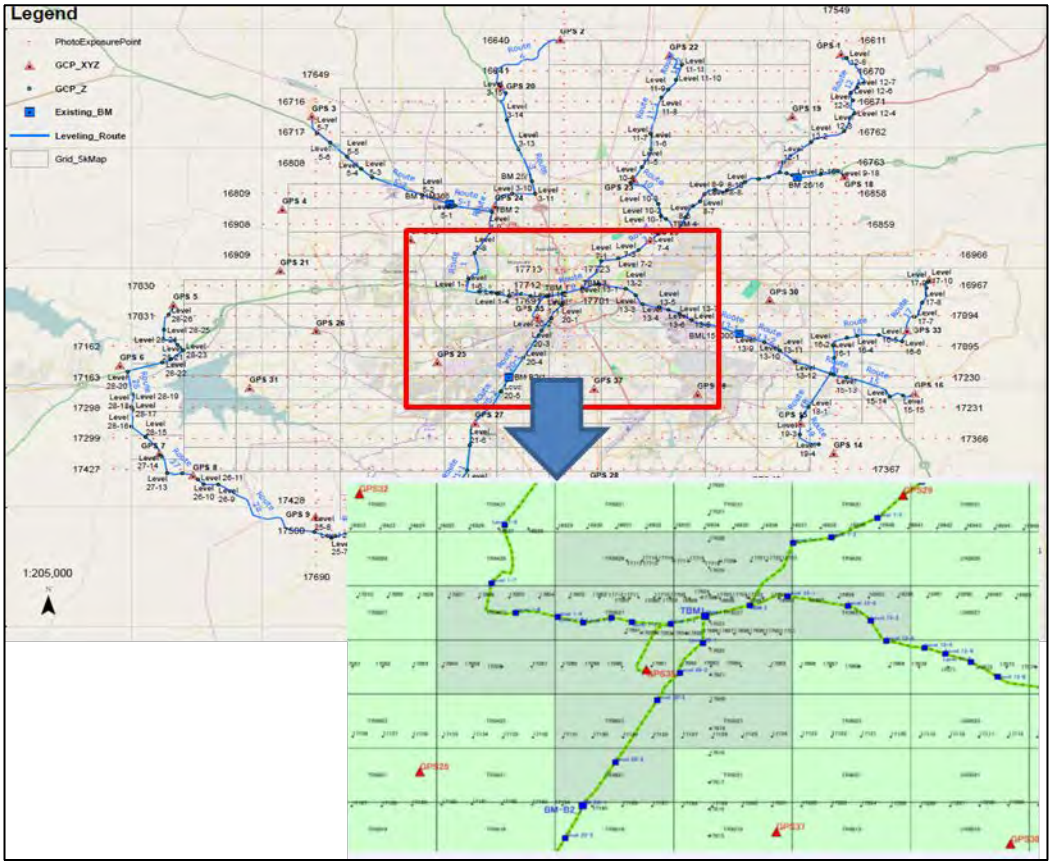
(7) Practice of Aerial Triangulation

Practical training of Aerial Triangulation was executed using the software introduced by the Project, namely ERDAS IMAGINE, IMAGINE Photogrammetry and ORIMA from Hexagon AB, and CAP-A.

1) Method of initial setting of software

2) Method of preparation of project definition file
3) Setting of camera calibration parameter file
4) Importing external orientation parameters recorded by GPS/IMU at aerial photography to software
5) Preparation of pyramid image file (reduced image for high-speed display)
6) Implementation of internal orientation
7) Methods of observation and re-observation of tie points using ORIMA
8) Methods of observation and re-observation of ground control points
9) Bundle block adjustment using CAP-A
10) Evaluation of block adjustment results

The practice area for Aerial Triangulation was the area within the red lines within the project area shown in the Figure 4. This area includes the 1:5,000 scale Digital Topographic maps preparation area of the Project. This area also includes 117 aerial photos, 6 horizontal and vertical ground control points and 27 leveling points which are necessary and sufficient for the practice of Aerial Triangulation.



Source: JICA Study Team

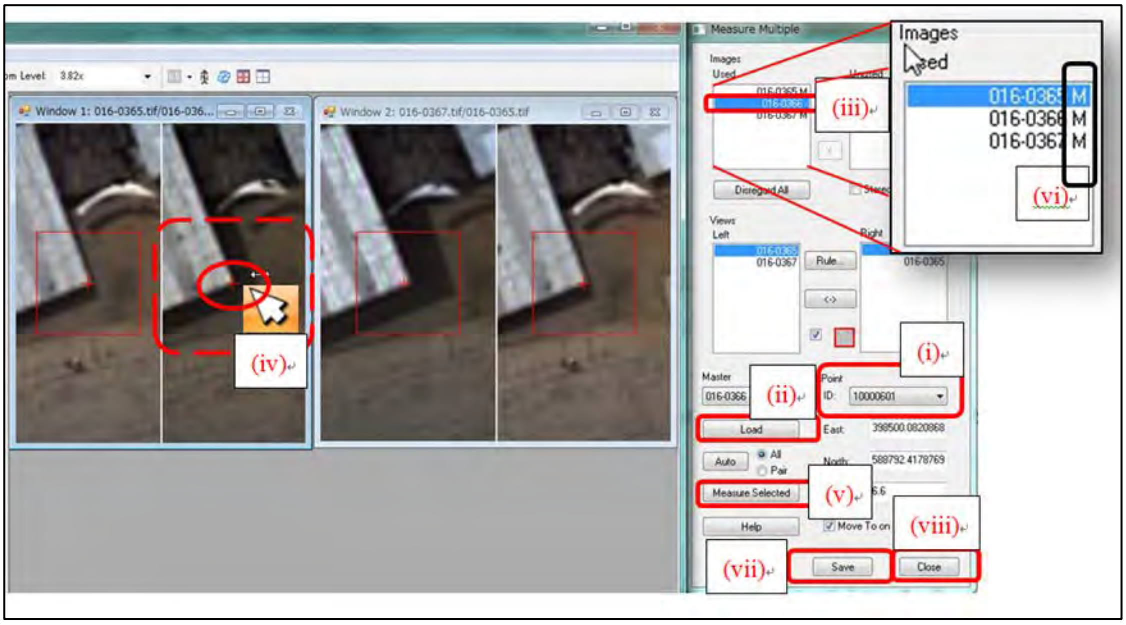
Figure 27 Aerial triangulation practice area

Figure 28 shows a screen capture image of the software operation showing tie points measurement, which is a process of Aerial Triangulation. This figure is a diagram in the operation manual used in the training.

Tie point measurement consists of the following processes;

- Finding out same location on multiple photographs in which a certain percentage of objects overlap between adjacent photograph with the objective of putting connecting points on adjacent stereo models,
- Measuring the photograph coordinates of the connecting points (tie points).

Figure 28 shows the measurement of the photograph coordinates of the same locations (corner of building) on four photographs.



Source: JICA Study Team

Figure 28 Observation of tie points in Aerial Triangulation

(8) Practice of accuracy control

The practice of accuracy control for Aerial Triangulation was executed by the preparation of accuracy control sheets by summarizing the results of the Aerial Triangulation practice. The accuracy control method and standards for Aerial Triangulation in Japan were used for accuracy control of Aerial Triangulation practice. Through this work, it was confirmed that the results of Aerial Triangulation practice executed by all participants in the practice were within the prescribed accuracy. Therefore, it was concluded that the staff of the DSG obtained the knowledge of Aerial Triangulation, skill of observation (observation of each point with good accuracy, etc.), and all processes of Aerial Triangulation were executed precisely by the staff of the DSG.

One of the DSG staff, Mr. Chinjekure, who had experience of analogue photogrammetry, produced extremely good results with no one-sided errors. The JICA study team recommends and expects continuous training of the DSG staff carried out for the purpose of them to gain experience on the observation and improvement of observation skills results in order to reduce errors and variation in the observed values, so high quality results can be obtained ultimately.

(9) Check for degree of understanding of the contents of the practice and review

In order to check the degree of understanding of the contents of the practice, Aerial Triangulation was executed again in a different practice area. Regarding points of doubt that arose during this practice, the staff of the DSG was encouraged to resolve their own problems by themselves by reference to the operation manual. By this practice, each staff of the DSG was able to clearly determine their own weak points. Also, each staff of the DSG prepared their own operation manual by adding the processes by which they resolved their own points of difficulty to the operation manual.

(10) Survey for degree of understanding after completion of training

A questionnaire survey to measure the degree of understanding of the contents of training was executed by the 5 points method ("1" is low degree of understanding, "5" is a high degree of understanding), the same as for the baseline survey. Table 45 shows the results of questionnaire survey.

Table 45 Results of understanding degree of Aerial Triangulation after completion of training

No.	Questionnaire contents	Counterpart answers		
		1	2	3
1	Did you know the work procedure of the digital topographical mapping?	5	4	3
2	Did you know the work procedure of the Aerial Triangulation?	5	3	3
3	Did you know that Leica Photogrammetry Suite (hereinafter LPS)* have stereoscopic ability?	5	5	4
4	Did you know that stereovision is effective for the measurement and interpretation of the feature?	5	5	4
5	Did you know about initial setting of LPS*?	5	4	4
6	Did you know minimum number of the GCPs of Aerial Triangulation by POS/IMU**?	5	3	3
7	Did you know measurement principle for ground control points and tie points?	5	5	4
8	Did you know operation for the bundle block adjustment computation using CAP-A (ORIMA)?	4	4	4
9	Did you know the accuracy management and quality control for the Aerial Triangulation?	4	4	4
	Minimum value	4	3	3
	Maximum value	5	5	4
	Average value	4.78	4.11	3.78
	Average value of 3 counterparts	4.22		

* "Leica Photogrammetry Suite (LPS)" is previous name of "Imagine Photogrammetry" from ERDAS

**"POS/IMU" is another word for GPS (GNSS) /IMU

Source: JICA Study Team

The average value prior to training was 2.44 points. Overall the level of knowledge and experience was low, and there were large differences in the degree of understanding among the members of the staff of the DSG. However, after training, the average was 4.22 points, so it is evaluated that overall the knowledge and experience of each staff of the DSG had improved.

It is concluded that the objective of the training, which was **"to introduce the basic technologies to the DSG for preparation of topographic maps in the future"**, has been achieved.

3.6 Technical transfer of field identification and field completion

Flowchart item [B-6]

(1) Technical transfer of field identification and field completion

The technical transfer for field identification and field compilation was executed from November 2015 to December 2015 and from August to September 2016 for the collection of place names and road names necessary information for Digital Topographic maps and orthophoto maps. The actual work of field identification and field compilation was executed by the staff of the DSG as OJT program.

The main items of technical transfer are as follows:

- Understanding the contents of the specifications and standards of topographic maps (Difference of information shown on topographic maps and thematic maps) and preparation of work plan
- Checking the organizations that possess the information of place names and road names, and collection of information regarding place names and road names
- Arrangement and editing the information of place names and road names using GIS software
- Process and quality control methods

The collection and arrangement of place names and road names, and data input and editing of the collected information using GIS software was executed mainly by the young members of the staff of the DSG under the instruction of experienced members of the staff of the DSG. The members of the staff of the DSG who participated in field identification are shown in Table 46.

Table 46 Members of the staff of the DSG participated in field identification

No.	Name	Affiliation	Position
1	Mr. Enias Chinjekure	Photogrammetry Section	Chief of Photogrammetry Section
2	Mr. Tangai Munyongani	Photogrammetry Section	Land surveyor
3	Mr. Nomore Arikoko	Photogrammetry Section	Land surveyor
4	Mr. Reward A. Munyeki	Photogrammetry Section	Land survey Technician

5	Mr. Kudakwashe Gwelo	Photogrammetry Section	Land survey Technician
6	Mr. Alexander Macheka	Photogrammetry Section	Land survey Technician
7	Mrs. Pearmer Tanhara	Photogrammetry Section	Land survey Technician
8	Mr. Lenard Mudzana	Photogrammetry Section	Land survey Technician

Source: JICA Study Team

Through this technical transfer, the methods and experience of annotation data preparation using GIS software (free software) were introduced into the DSG. Training for installation method of free GIS software from internet, preparation of GIS data file, inputting and editing of GIS data was executed.

For most of the members of the staff of the DSG, this was the first time that they prepared data using GIS software. After the initial training, the work of annotation data preparation using GIS software was executed continuously by the staff of the DSG until April 2016, after JICA Study Team returned to Japan at the end of December 2015. During this period, JICA Study Team checked the contents of data transmitted from DSG using the internet at appropriate times, and the necessary advice was given and the progress was checked.

Through this work, the place names and road names information to be shown on the Digital Topographic maps and orthophoto maps was obtained.

The staff of the DSG executed the actual work of field identification, including at times when JICA Study Team is not in Zimbabwe, by using the GIS software that was first introduced.

From this result, it was evaluated that technical level of the DSG in field identification has reached the target level (to be able to execute field identification and to arrange the collected data) through the technical transfer.

3.7 Technical transfer of digital plotting, digital compilation and integration of field compilation results

Flowchart item [B-7]

Training for digital plotting, digital compilation and integration of field compilation results was carried out from August 2016 to September 2016 (1st phase) and also from February 2017 to March 2017 (2nd phase).

The training was executed by way of lectures and practicals, and the outline of training is described in Section 3.8.2.

During the 1st phase, training of digital plotting using digital plotter introduced by the Project, the process of data acquisition from aerial photos, was executed. Through this training, the staff of the DSG executed the digital plotting using digital plotter for the first time. The staff of the DSG obtained the digital plotting data (2km^2) at the center of Chitungwiza during the period of approximately one month.

After the first phase and before the second phase, staff of the DSG continued the digital plotting work targeting Chitungwiza area as self-training.

3.7.1 Outline of technical transfer of digital plotting, digital compilation and integration of field compilation results

The technical transfer for digital plotting, digital compilation and integration of field compilation results was executed through lectures and practice. The main content of technical transfer was as follows:

- Digital compilation (participants is young staff and the staff with no experience of Topographic Mapping of the DSG)
  - The workflow of topographic mapping and basic knowledge of Digital Topographic maps preparation
  - Outline of topographic maps (What is topographic maps?)
  - Topography (knowledge of topography necessary for topographic maps preparation)

- Practice of digital plotting using digital plotter
  The training of digital plotting using digital plotter was planned targeting 2 members of the staff of the Photogrammetry Section of the Mapping Department of the DSG who had experience in photogrammetry, as concentrated practice to support the transition from analogue photogrammetry using conventional analogue plotter and aerial films to digital photogrammetry using digital plotter and digital aerial photo images.
  In fact, the training was carried out for a total of 3 persons, the 2 persons who had experience in photogrammetry, and 1 person who has no experience in photogrammetry.

  - Operation method of the DPW introduced for the technical transfer
  - Practical training of digital plotting (data acquisition)
  - Determination of data acquisition standard and map feature codes including adding and correcting the data acquisition standard and map feature codes as necessary, which is frequently occurred during the operation of digital plotting
  - Process, approach, technique of setup and configuration of the digital plotter
    - Setting of map feature-codes, preparation of symbols and so on into DPW
  - Inspection method for errors of digital plotting data obtained
  - Correction of errors of digital plotting data using DPW

In order to deal with the parallel implementation of the above-mentioned several training programs, a 2 persons instruction system was used consisting of "Digital plotting, digital compilation, integration of field data, map finishing 1" and "Digital plotting 2".

3.7.2 Lecture of basis of map compilation and topographic mapping

Lecture for the basis of map compilation and topographic mapping was implemented to the staff of the DSG.

(1) Participants

The following members of the staff of the DSG participated in the lecture on the basis of map compilation and topographic mapping:

	Name
1	Mr. Alex Macheka
2	Mr. Pearmer Tanhara
3	Mr. Kudakwashe Gwelo
4	Mr. Leonard Mudzana
5	Ms. Angela Muzondo
6	Mr. Farai Mudara
7	Ms. Esnath Makanganya
8	Mr. Osten Magunise

(2) Schedule

The following is the schedule for the lecture on the basis of map compilation and topographic mapping:

	Date
1st time	2 September 2016
2nd time	5 September 2016
3rd time	7 September 2016
4th time	9 September 2016
5th time	21 September 2016
6th time	23 September 2016

(3) Contents of lectures

The content of the lecture of basis of map compilation and topographic mapping are as follows:

i) Outline of map compilation
- Difference between middle and large scale map
- Type of data
- Transposition
- Elimination
- Intermittence
- Pattering and fill
- Generalization
- Delineation rule
- Rotation
- Contour line and spot heights
- Etc.

ii) Introduction of topography
- Textbook

3.7.3 Practice of digital plotting using digital plotter

Instruction and practice of digital plotting was executed using the digital plotter introduced by the Project. Two of the 3 members of the staff of the Photogrammetry Section of the Mapping Branch of the DSG participated in practical training on digital plotting using digital the plotter, and 1 member had very little experience of photogrammetry.

(1) Objective

This practice program was planned that the 2 members of the staff of the DSG, who have experience of analogue photogrammetry could use the digital plotter introduced in the Project. And one beginner of photogrammetry was added at implementation of the training.

(2) Implementation period, contents and schedule

This practice program was implemented during August and September 2016.

Outline of the practice program for digital plotting and the schedule are show in Table 47.

Table 47 Technical transfer schedule of digital plotting

Contents of technical transfer/Month	August 2016		September 2016	
System assembly, and operation checking and inspection				
Baseline survey				
Preparation work for digital plotting				
Explanation of data acquisition method and practice of data acquisition (digital plotting)				
Practice in data acquisition (digital plotting)				
Quality control and evaluation of achievement degree of technology transfer				

Source: JICA Study Team

(3) Equipment used

A digital Photogrammetry Workstation (DPW) introduced in the Project has a Digital Plotting function and it was used for training on digital plotting. The DPW used in the Project is a personal computer based system, which is currently the mainstream, and runs on Microsoft Windows Operating System. It is a high spec computer that can handle large capacity digital aerial photo image files, and includes the hardware for stereoscopic observation which is essential for photogrammetry. It was configured from the following parts:

- Hardware: High spec PC unit, high spec graphics board, 3D monitor,
  3D glasses and mouse for 3D observation
- Software: Digital photogrammetry software (supporting all the functions of Aerial Triangulation, digital plotting, preparation of DEMs, preparation of orthophotos, and digital compilation), and CAD software for drawing topographic map data

(4) Basic operations of digital plotting

The main functions of the DPW as a digital plotter are as follows:

- The function of 3D display of stereo pairs of aerial photos and measuring mark
- The function of data acquisition and data recording (recording as figure data in CAD data or GIS data)

Source: JICA Study Team

Photo 14 Practice of digital plotting using digital plotter

The above image (Photo 14) shows the scene of digital plotting using a digital plotter.

The eyeglass shaped item that the operator is wearing (person in the background on the left) are 3D glasses with an LCD shutter. A 3-dimensional model image is seen when the image on the left side of the stereo pair of aerial photos is seen with the left eye, and the image on the right side is seen with the right eye. Plotting is carried out while measuring and recording the shape (position) of objects in the 3D image as topography (coordinates).

The acquired data is indicated with the 3D model image on digital plotting software displayed in the left side of 3D LCD monitor. In addition, the acquired data is also indicated on CAD software displayed in the 2D LCD monitor on the right side.

Figure 29 shows a screen capture image of digital stereo plotter. Digital stereo plotter displays two aerial photographs constituting a stereo pair side by side to enable stereoscopic viewing for operator. A red cross cursors indicated over the both aerial photograph images are measuring marker.

Image captured on the screen of the digital plotter:
[This image appears to be 3-dimensional when viewed stereoscopically with the naked eye]

Source: JICA Study Team

Figure 29 Stereo pair of aerial photos and measuring marker of digital plotter (+ lines in the center)

Basic operations of digital plotting are as follows:

- While stereoscopically viewing the 3D model of the stereo pair of aerial photos, the plain position of the measuring marker on the 3D model screen is moved to the target position using a 3D mouse.
- By rotating a disk on the 3D mouse, the vertical position of the measuring marker is adjusted to the vertical level of the object being measured.
- When both the plain and vertical position of the measuring mark is placed on the object being measured, the button of the 3D mouse is clicked by digital plotting operator. The position is recorded in the CAD software as figure data having coordinates in a 3 dimensional space.

Furthermore, the classification according to the subject attribute of the object is distinguished and recorded by the following method.

- First, as a preparatory work for digital plotting, register the feature code of the digital mapping defined for each feature type classifying the object with the subject attribute and the drawing setting of the graphic corresponding thereto in the CAD software. The details are as follows.
    - CAD software commands to draw geometry corresponding to the geometry type (distinction of point, line, face, text) defined for each feature code,
    - Layer name in CAD file to draw figure
    - Symbol attribute (color / line type / line width) of figure to be drawn

In the Digital Topographic map, the subject of the map information which is content is classified by combining the above information

- The digital plotting operator compares the subject attribute of the object on the stereo model according to the agreed acquisition standard;
- And uses the drawing command corresponding to the defined feature code to draw and record figures that make up the map in the CAD data file of the digital terrain map data while classifying it as feature type. The Topographic map is produced by repeating these operations.

(5) Staff of the DSG

Table 48 shows the members of the staff of the DSG who participated in the practice of digital plotting, all of them coming from the Photogrammetry Section of the Mapping Branch of the DSG. Two of these have more than 10 years’ experience with analytical plotters (Analytical plotter is not digital plotter, but old type of digital plotter).

Table 48 Members of the staff of the DSG who participated in the technical transfer on digital plotting

Name	Photogrammetric mapping experience (years)	Age (years)	Note
Mr. Enias Chinjekure	28	55	Acting Chief of Photogrammetry Section
Mr. John Taruvinga	12	43	Land Survey Technician
Mr. Reward Munyeki	1	27	Land Survey Technician

Source: JICA Study Team

The Photogrammetry Section of the DSG has one analytical plotter in operation. From 2015, 2 members of the staff of the Photogrammetry Section, who have experience in photogrammetry, provided training of stereoscopic measurement using the analytical plotter to another member of the staff who has no experience of photogrammetry.

The other member of the staff of the DSG with experience of less than 1 year, who also participated in the practical training on digital plotting, also received the training of stereo measurement using the semi analytical plotter. Therefore, all members of the staff of the DSG who participated in practical training on digital plotting had some level of experience on analogue photogrammetry, but no experience on digital photogrammetry.

(6) Baseline survey for the degree of understanding of the basic knowledge and skills for digital plotting

A baseline survey was implemented by interviews and skill tests. The survey was carried out in the following steps.

a. Interview survey and its results

The interview survey method is as follows:

The content of the questions was designed to measure the degree of understanding of digital plotting, photogrammetry, preparation of topographic maps, quality and accuracy control. The member of JICA Study Team conducted the interviews and questionnaire survey with the 3 members of the staff of the DSG.

The members of the staff of the DSG answered the questions from the member of JICA Study Team regarding their own knowledge and skill level in a self-evaluation in 6 levels (from "0" to "5"). The results were converted into an index by allocating a score.

In the answer to the questionnaire, the two staffs with analog photogrammetry experience had a score of 0 for the questions that asked for preliminary knowledge about digital plotter introduced in the project. But the two experienced staffs had three or more evaluation points for the question about the existence of basic knowledge on topographic mapping by photogrammetry which is a question other than the preliminary knowledge of the digital plotter introduces in the Project. As expected from the beginning, the two experienced staffs have been evaluated as having expertise in data capturing with stereo plotters and photogrammetry.

For the one staff of the DSG who had little experience of photogrammetry, the score in the question asking whether there is basic knowledge of topographic mapping by photogrammetry was lower than that of the other two experienced staffs. However, for the following three questions, although the evaluation was self-evaluation, evaluation score was 4 points.

- Knowledge of stereoscopic view of aerial photographs
- Possibility of interpretation and measurement of field features in stereovision
- Classification of topography and features by 3 dimensional interpretation (skill level)

This was evaluated that it was the result of the training using the analytical plotter, which was carried out within the DSG Photogrammetry Section that described in one section before: the section “(5) Staff of the DSG”.

b. Skills test and its results

A skill test was executed in measurement of elevation by stereoscopic view, which is a basic skill in digital plotting and photogrammetry.

In a test area prepared by the member of JICA Study Team, the values of elevation point measure by the member of JICA Study Team were taken to be the most probable values. The members of the staff of the DSG participated for technical training measured the heights of the same points by the digital plotter. These two values were compared, and the differences among the measured values were evaluated. The variation in the measurements was evaluated by the standard deviation of the differences of multiple measurements. Also, the time required for measurement was evaluated.

Also, an elevation measurement test was executed by both the elevation measurement by the naked eye stereoscopic view and the stereoscopic view using the stereoscopic view function of the digital plotter.

From the results of the elevation measurement test, it was found that the elevations measured by the 2 experienced staff of the DSG had vertical accuracy within 0.6m from beginning. The 0.6m is the value considered that can be measured from stereo model derived from aerial photographs with 20cm resolution on ground. The elevation observed by the staff of the DSG who was a beginner in photogrammetry was close to the limiting value at the beginning. However, it was confirmed that as the training progresses, this staff of the DSG became able to measure elevation with accurately equal to the other 2 experienced members of the staff of the DSG.

(7) Setting of technical transfer targets

From the results of the baseline survey, it was evaluated that the 2 experienced members of the staff of the DSG had a certain amount of the basics of digital plotting from the beginning. In accordance with the initial plan, the main theme of the training was to support the transition to using the digital plotter introduced by the Project.

Based on the baseline survey results, achievement targets for technical training for the 3 members of the staff of the DSG were set as numerical targets.

Table 49 Baseline and technical transfer target setting

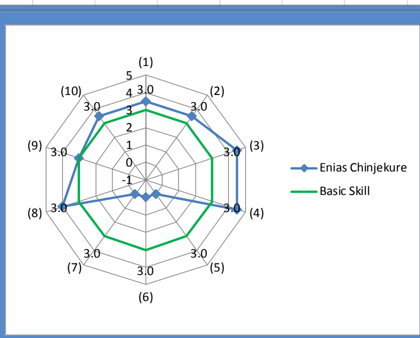
Technical level survey of the DSG staff

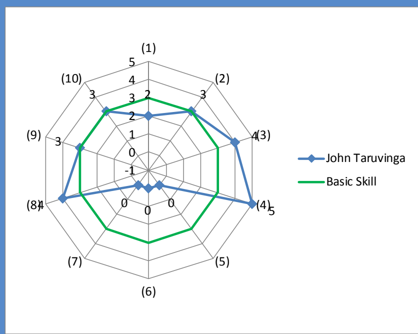
11-Aug

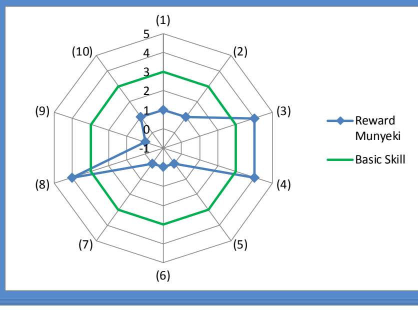
Item No,	Research item	Enias Chinjekure	John Taruvinga	Reward Munyeki			
		Technical skills before training (Present situation level) 11/08/2016					
(1)	Knowledge of the work production process of the digital topographic map	3.5	2	1			
(2)	Knowledge of the work production process of the Aerial triangulation	3.5	3	1			
(3)	Knowledge of stereoscopic view of aerial photographs	4.5	4	4			
(4)	Possibility of interpretation and measurement of field features in stereovision	4.5	5	4			
(5)	Initial setting of the LPS is possible：Input of the exterior orientation,camera, Aerial photography image	0	0	0			
(6)	Knowledge of environment setting of Pro-600 (Project file settings,tolerance etc.)	0	0	0			
(7)	Knowledge of Pro-600 library setting	0	0	0			
(8)	Classification of topography and features by 3 dimensional interpretation (skill level)	4	4	4			
(9)	Experience of topographic map correction using aerial photographs	3	3	0			
(10)	Knowledge of quality control and quality control	3.5	3	1			

:Current skills — Unaware | Know the basics | Well known

0 1 2 3 4 5







Source: JICA Study Team

(8) Practice area

For the technical transfer practice area, an area of 2.0km^2 that was 1/4 of the 8.0km^2 area of map number TR9207 was selected. This is an area where 1:5,000 scale Digital Topographic maps had not been prepared in the Project, and is in the center of Chitungwiza Municipality where low rise buildings are densely built. This practice area was selected with the objective of preparing a sample 1:5,000 scale Digital Topographic map for Chitungwiza area, which is expected to be prepared by the DSG in the future.

The colored part in the center of the overall project area on the left side of the figure is the center of Harare city, that is the range over which Digital Topographic maps were prepared in this project (Area 96km^2, 12 sheets)

(Source: JICA Study Team)

Figure 30 Practice area of digital plotting (enclosed in red), East-West 1km × North-South 2km

(9) Implementation of digital plotting practice

Practice in data acquisition using digital plotter was implemented from 19 August 2016 to 23 September 2016. The numbers of actual working days in this period was about 26 days. As a result of this data acquisition practice, 2km^2 digital plotting data was acquired by the members of the staff of the DSG. Photo 15 to Photo 18 shows the scenes of digital plotting practice.

Table 50 Contents and schedule of digital plotting practice

Category	Training contents	Date
Preparation of training programme	Preparation of training	10 Aug
Practical training of preparation work of digital plotting	• Basic setup and configuration of a digital plotter, and baseline analysis survey for setting of technical transfer target	11 Aug
	• Design and register of map symbol and custom line style in Bentley Map (Microstation), [Lecture]	11 Aug
	• Design and register of map symbols and custom line styles in Bentley Map (Microstation) [Practical training]	12 Aug
	• Data structure of Digital Topographic map data, • Outline of way of data capture: data acquisition order in feature category for efficient data capture in topographic mapping. [Lecture]	15 Aug

	• Setup and configuration library catalog (digital mapping feature code and assigning data capture command) in PRO600 and Bentley Map (Microstation). • Setup and configuration digitizer devise (3D mouse (Topo mouse)) in PRO600 and Bentley Map and operation of Topo mouse. [Lecture and Practical training]	16 Aug
	• Setup photogrammetry work and data capturing project in LPS, PRO600 and Bentley Map (Microstation) • Setup aerial photograph image data, camera data, ground control point, external orientation parameter, mapping datum (referenced ellipsoid, map projection) • Assign strip or block layout and external orientation parameter for aerial photographs • Configure data capture environment in PRO600 and Bentley Map • Setup and load CAD file (Microstation (Bentley Map) design file (DGN file) • Loading stereo pair model in PRO600	17 Aug
	• Setup and configuration library catalog (digital mapping feature code and assigning data capture command) in PRO600 and Bentley Map. [Practical training]	18 Aug
Lecture and practical training on data acquisition way	• Explanation data capturing order in feature categories for efficient data capture in topographic mapping.	19 Aug
	• Data capture (Road related features), [Lecture and preliminary practical training]	22 Aug.
	• Data capture on Railway related features, [Lecture and preliminary practical training for subsequent earnest drill]	23 Aug.
	• Data capture on Shore line and Water course related features, [Lecture and preliminary practical training for subsequent earnest drill]	24 Aug.
	• Data capture on Building , misc. structure, wall and other related feature [Lecture and preliminary practical training for subsequent earnest drill]	25 Aug.
	• Data capture on slope, retaining wall, [Lecture and preliminary practical training for subsequent earnest drill]	26 Aug.
	• Data capture on topography related features: spot height and contour line, [Lecture and preliminary practical training for subsequent earnest drill]	29 Aug.
Earnest drill of data capturing in digital plotting	• Data capture on road and related feature	30 Aug. /1 Sep.
	• Data capture on road related feature and river related feature	2 Sep.
	• Data capture on road related feature and building, misc. structures related feature	5 Sep.
	• Data capture on building, misc. structures related feature	6-9 Sep.
	• Data capture on building, misc. structures related feature and wall, fence related feature	12 Sep.
	• Data capture on wall and fence related feature	13-14 Sep.
	• Data capture on wall and fence related feature and vegetation limit and related feature	15 Sep.
	• Data capture on vegetation limit and related feature	16 Sep.

	• Data capture on vegetation limit, vegetation symbol, other point symbols for marking land cover and land use feature	19 Sep.
	• Data capture on spot height and contour line	20 -23 Sep.
Practice of quality control and wrap up of training	• Quality control of digital plotting data	26 -28 Sep.
	• Quality control of digital plotting data、 • Evaluation of achievement degree on result of the training	29 Sep.

Source: JICA Study Team

Source: JICA Study Team

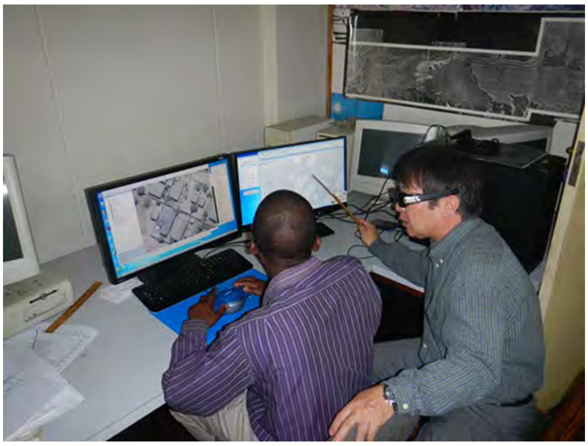
Photo 15 Lecture of digital plotting work process

Source: JICA Study Team

Photo 16 Practice in setting the map feature codes

Source: JICA Study Team

Photo 17 Practice in setting map feature codes



Source: JICA Study Team

Photo 18 Practice of 3D digital plotting

(10) Errors of digital plotting data

This was the first experience of digital plotting for the members of the staff of the DSG. Therefore, many errors included in the digital plotting data acquired by the members of the staff of the DSG.

JICA Study Team inspected the plotting data acquired by the 3 members of the staff of the DSG. Based on the inspection results, JICA Study Team explained the examples of errors in digital plotting data, what acquisition method produced the error, how to acquire the data without errors, and what was done incorrectly during the digital plotting, etc.

Source: JICA Study Team

Photo 19 Discussion between members of JICA Study Team and the staff of the DSG concerning digital plotting errors

As example of errors, the following items were found in the digital plotting data.

- Lack of data acquisition by careless mistake
- Duplicate data (house, etc.)
- The fence or wall between houses that were actually connected was drawn as unconnected, and a house and fence or wall that was not actually un-connected was drawn connected.
- The indicating point of tree symbol should be placed at the root of tree; however, it was placed at the center of tree crown. Therefore in the topographic map data, some tree symbol is located in

the road area, and those tree symbols on map suggested that there are trees in the center of the road.

- There was lacking or duplication of data at the digital plotting boundary between the different members of the DSG staff.
- Selection error of map feature codes at data acquisition or photo interpretation mistake
- Contour lines and water courses are zigzag intersecting

Instruction was given to the members of the staff of the DSG on these issues one by one. JICA Study Team explained how the data should have been acquired and the data acquisition standards, etc. in order to deepen their understanding.

(11) Technical transfer of quality control

As technical transfer for quality control, each member of the staff of the DSG check the quality off their own acquired data in the training, and summarized as accuracy control sheets. Table 51 shows the example of quality control sheet.

Table 51 Quality control sheet of digital plotting

Sample quality control sheet

Digital plotting data Quality control sheets

Checked Date :

Project Name	Sheet Name/No.	Mapping Scale	Volume	Executive Organization	Chief Engineer	Checked by
TRAINING	TR9207	1/ 5000	0,66 Km²	JOHN TARUVINGA		

Item	Missing	Error
Geodetic points		
Classification		
Value		
Contour Lines		
Form		
Value		
Roads		
Classification		
Form	HHT I	HHT
Road institutions		
Embankment		
Underpass		
Over bridge		
Distance marker		
Bridge / Culvert	I	III
Foot bridge		
Road divider		
Railways		
Classification		
Form		

Item	Missing	Error
Railway institutions		
Over bridge		
Platform		
Administrative Boundaries		
Classification		
Form		
Public facilities		
Classification		
Position		
Buildings		
Classification	III	I
Form	HHT HHT II	HHT
Fences		
Form	IIII	II
Building symbols		
Classification		
Position		
Accessory objects		
Classification of symbols		
Position of symbols		
Form of lines		

Item	Missing	Error
Water features		
Classification of symbol items		
Position of symbol items		
Form of line items		HHT II
Traffic		
Classification		
Position		
Vegetation		
Form of boundary		
Classification of symbol		
Natural features		
Classification		
Form		
Flow direction		
Annotation		
Administration name		
Road name		
Road institution name		
Railway name		
Railway station name		
Building name		

Item	Missing	Error
Water name		
Place ground name		
Marginal information		
Sheet Name/No.		
District name		
Neat & Grid Line		
Coordinates Value,etc.		
Scale Bar/Map symbol		
Sheet index		
Sheet History		
Planning / Executing Org.		
Others		
Connection between adjacent sheets		

Source: JICA Study Team

As results of inspection, 416 errors and lack of data were found in the digital plotting data acquired by the members of staff of the DSG. The results of inspection were recorded on accuracy control sheets, and the digital plotting data was corrected and additional data acquisition was executed.

(12) Technical transfer results and evaluation

As a result of the practice in digital plotting executed over the 26 days, by the end of September 2016, the members of the staff of the DSG had prepared the digital plotting data using the digital plotter introduced in the Project for the 2km^2 area shown in Figure 31.

The following is the outline of evaluation of the digital plotting data developed by trainees from DSG in the training.

- Regarding the simple rectangle geographic features such as building, the horizontal and vertical accuracies of the digital plotting data was good, and satisfied the required horizontal and vertical accuracy for 1:5,000 scale Digital Topographic maps. On the other hand, the height accuracy was insufficient for geographic features that have a certain liner or area extent such as roads edges and vegetation boundaries.

➢ A countermeasure against this problem is to catch an entire image of the shape of a feature to be captured and to select location to put vertices and to measure accurately horizontal and vertical location of every vertices of the shape, in capturing liner or area feature.

- In the acquisition of contours in undulating terrain, there were cases where the precision of the contour height was insufficient. In training on capturing contour line, the following techniques were instructed. By appropriately switching the display range of the monitor in order to catch a wide range of the situation and tendency of topography, it is possible to predict extending contour line beyond the range displayed on the monitor screen of the digital mapping machine. However, the trainees were not yet able to master and practice the instructed techniques.

➢ A countermeasure against this problem is to practice so that the above mentioned guidance contents can be surely done. In addition, understanding on topography that was lectured in the class on basis of map compilation and topographic mapping is also effective. It is also important to be familiar with the operation of switching the display range (display magnification) of the digital plotter and instantaneously grasp information of the necessary range in a very quick way during data capturing.

- In areas with a flat topography, in comparison with contour lines that were drawn by three trainees, elevation (shape) of contour was largely different)

- As a countermeasure against this, the content of countermeasures for capturing contour lines in undulating terrain area described in the immediately preceding paragraph is effective.

- Also, when capturing contour lines in a flat terrain, the following method is can be applied. First, DEM is created by the stereo matching method. Next, rough contour lines are generated in automatically using software program from the DEM, and displayed the contour lines on screen. Then, contour lines to be captured by stereo plotting operator with referring to the rough contour line derived from DEM displayed on the screen for catching tendency of terrain undulation.

  Procedures for generating DEM by stereo matching method and procedures for automatically generating contour lines from the DEM were trained in the training: the preparation of Digital Orthophoto image conducted in November 2016. One of the challenges is to be able to utilize this method for contour plotting.

- It was observed that measurement accuracy of contours deteriorated at places where the ground was covered by buildings, trees, walls, etc. and cannot be directly seen.

- The countermeasure against this problem is as follows.
  - In where ground elevation cannot be directly observed by the covered by object, it is to estimate terrain undulation and shape of contour line correspond to the estimated terrain undulation t based on the following information.
  - Situation of ground surface and captured contour lines for surrounding area where can be directly observed,
  - Estimated cause and developing process of the topography of the place,
  - Principle of terrain undulation and shape of contour line
  - And to draw contour line based on above estimation.

- To this end, the following issues are to be addressed
  - Understanding topography and principle of correspondence between topography and shapes of contour lines
  - Familiarize with the display switching operation to obtain the necessary information in the digital graphing machine.

- The accuracy of the measuring elevation on single point was within the tolerance. It was evaluated that the basic technique concerning height measurement was fully understood.

Training on digital plotting has only just begun, so it is necessary for further proficiency in the technique. Further continuous improvement is desirable in the future, bearing in mind the issues raised in this training.

Note: mapping area: 2km^2 (East and West: 1km× North and South: 2km)

Source: JICA Study Team

Figure 31 View of practice training area

(The Left: orthophoto, the right: digital plotting data by the staff of the DSG)

(13) Evaluation of technical transfer

After completion of the digital plotting training lectures, an evaluation of the degree of achievement of technical transfer for digital plotting was executed by a questionnaire survey and a skills test, the same as the beeline survey.

Table 52 shows the results of evaluation, and descriptions of the evaluation on each item are stated in paragraphs.

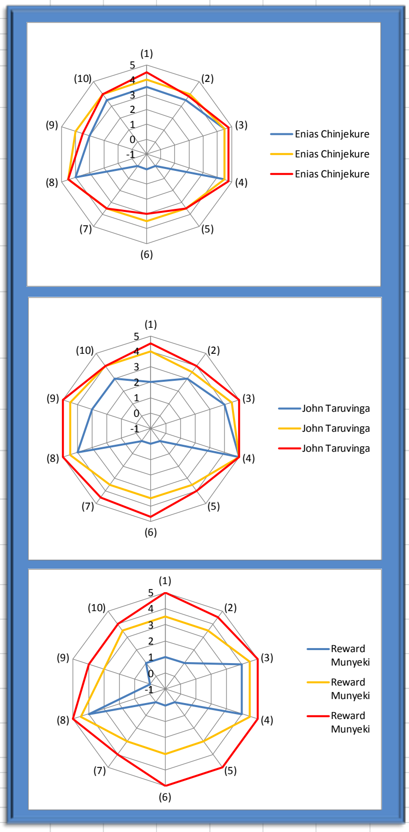
Table 52 Evaluation results of digital plotting after completion of technical transfer

Technical level survey of the DSG staff

30-Sep-16

Item No,	Research item	Technical skills before training (Present situation level) 11/8/2016			Target value of skill up (The later level)			Examination **after** the trainig (The later level)29/9/2016		
		Enias Chinjekure	John Taruvinga	Reward Munyeki	Enias Chinjekure	John Taruvinga	Reward Munyeki	Enias Chinjekure	John Taruvinga	Reward Munyeki
(1)	Knowledge of the work production process of the digital topographic map	3.5	2	1	4.0	4.0	3.5	4.5	4.5	5.0
(2)	Knowledge of the work production process of the Aerial triangulation	3.5	3	1	4.0	3.5	3.5	3.8	4.0	4.5
(3)	Knowledge of stereoscopic view of aerial photographs	4.5	4	4	4.5	4.5	4.5	4.8	5.0	5.0
(4)	Possibility of interpretation and measurement of field features in stereovision	4.5	5	4	4.5	5.0	4.5	4.8	5.0	5.0
(5)	Initial setting of the LPS is possible：Input of the exterior orientation,camera, Aerial photography image	0	0	0	3.5	3.5	3.0	3.5	4.0	5.0
(6)	Knowledge of environment setting of Pro-600（Project file settings,tolerance etc.）	0	0	0	3.5	3.5	3.0	3.0	4.7	5.0
(7)	Knowledge of Pro-600 library setting	0	0	0	3.5	3.5	3.0	3.5	4.5	4.0
(8)	Classification of topography and features by 3 dimensional interpretation (skill level)	4	4	4	4.5	4.5	4.5	4.5	5.0	5.0
(9)	Experience of topographic map correction using aerial photographs	3	3	0	4.0	4.5	3.0	3.5	5.0	4.0
(10)	Knowledge of quality control and quality control	3.5	3	1	4.0	4.0	3.5	4.0	4.0	4.0

:Current skills — Unaware … Know the basics … Well known
:Target skills — 0 1 2 3 4 5
:After skills



Source: JICA Study Team

a. Overall evaluation

Regarding the degree of technical proficiency in the digital plotting training, an average of 2.2 points was improved over all the evaluation items　This was the average + 0.5 points relative to the target points set in the baseline survey, so it can be seen that the targets were appropriately set prior to implementing the training.

b. Understanding of theory [questionnaire items (1), (2)]

It was confirmed that as a result of the lectures in the theory of the technology, the improvement in the technical level was an average of 0.7 to 2.5 points, but it was not possible to achieve the target value for evaluation item (2).

This item included questions regarding understanding of the theory and the process of photogrammetry. Although not a direct factor, one reason may be the characteristic problem of the digital plotter that all the processing is done electronically by software in a form that is difficult to be confirmed visually.

The operator operates the machine in accordance with the theory, and it is easy to understand because this operation is reproduced physically on the machine and operator can see how the tilt of the picture is physically reproduced on the machine as a result of his / her operation. On the other hand, with digital plotters in which everything is carried out within a computer, it is difficult to visually reproduce the theory.

However, there is no difference in the fact that the theory is reproduced in the program even in the digital plotter, and operation deviates from the theory leads to the following result, for example, a stereoscopic image is not displayed, the program stops due to an error, the program output an abnormal result.

Understanding the basic theory is essential in order not to be embarrassed without knowing what the cause is in case the intended result cannot be obtained.

As a measure to encourage understanding of the basic theory of photogrammetry while using a digital plotter for a person who has experience of using a conventional mechanical stereo plotter, it is necessary to explain with the following in order to help understanding the operation on the software in the digital plotter and the description of the contents of the corresponding theory. Explanation of operations that had been performed using various conventional photogrammetry instruments such as analog mechanical plotter and commentary on the physical movement of the machine with respect to the operation is necessary.

c. Confirmation of basic techniques and skills [Questionnaire item (3)]

As was clear from the baseline survey results, 2 members of the DSG has experience in analog plotting, so there was no problem with their knowledge and skill regarding stereoscopic observation, which is the basic skill. In the technology transfer, lectures were provided on the contents to be added to the digital plotting, such as the mechanisms that enable stereoscopic viewing in digital plotters and the necessary hardware thereof. It was concluded that the participants understood the contents, and the target of supporting the transition to digital plotting has been achieved.

d. Understanding of digital plotting and digital plotters [Questionnaire items (4) -(7)]

These were questions regarding knowledge and understanding of interpretation of topographic and geographic features by stereoscopic viewing, and understanding the functions and methods of operating the digital plotter software.

There is no particular problem with the knowledge in interpretation of topographic and geographic features, because of their experience with analog plotting.

In the training, understanding of the data structure of Digital Topographic maps and understanding of the operation of the digital plotting system required more time than envisaged.

The score on the final questionnaire was an average of 4.1 points, so it was judged that their understanding of digital plotters has advanced. The target of supporting the transition to digital plotting has been achieved for the 2 experienced members.

e. Improvement in 3D measurement techniques [Questionnaire items (8), (9)]

Regarding acquisition of contour line data, training was provided in the method of plotting directly with the mouse while carrying out stereoscopic observation. The preparation of contour line data that two experienced people had done so far was the grid point method, mainly to measure the elevation points as grid points. From this background there was no experience of direct plotting of contour lines, but by repeating the actual skills training they became capable of direct plotting of contour lines to a certain level.

The DPW that was introduced in the Project has the function of generating contour lines from single points measured by the grid point method. Also, by obtaining DEMs by automatic stereo matching, it is also possible to edit the DEMs and plot contour lines. It is expected that in the future they will try plotting contour lines using this function.

In addition, as can be easily seen from the "Skills Test Results" which are described later, three-dimensional data could be measured faster and with better accuracy after the training than before the training. In terms of proficiency from practice, accuracy was improved in the range of 7 to 24cm standard deviation for the naked eye stereoscopic measurement, and 16 to 46cm standard deviation for the 3D glasses stereoscopic measurement.

Note that as a result of the training, the average was an improvement of 1.5 points, and the target was achieved. From the above it has been confirmed that measurement accuracy and operational speed improved with practice. However, a satisfactory level has still not been achieved for the production level of the general digital plotting work. Even after the completion of this project, it is necessary to digital plotting work by practical work and practical training continuously, and aiming to be able to make accurate observation while shortening measurement time.

f. Improvement in quality control techniques [Questionnaire item (10)]

As a result of the training there was an improvement in technical level of an average of 1.5 points, and an improvement in understanding of quality control was seen, so the set target values have been achieved.

g. Improvement in work efficiency [skills test results]

The three-dimensional measurement skills test that was carried out at the time of the baseline survey was also carried out after completion of the training. Table 53 and Table 54 show the measured accuracy in the skills tests before and after the training. In addition, Figure 32 shows a comparison of the measurement accuracy and time before and after training. The time is the time taken to measure 20 elevation points.

At the time of the baseline survey the 2 experienced persons did not have a problem with measurement accuracy, but they were unfamiliar with operations such as the mouse of the digital plotter, so it was evaluated that they had scope for improvement in measurement speed with the accumulation of skills training.

After completion of the training they became familiar with the 3D mouse operations, etc., and an improvement in their measurement speed was seen.

Table 53 Comparison of skill test results for measurement of spot elevation between before and after training

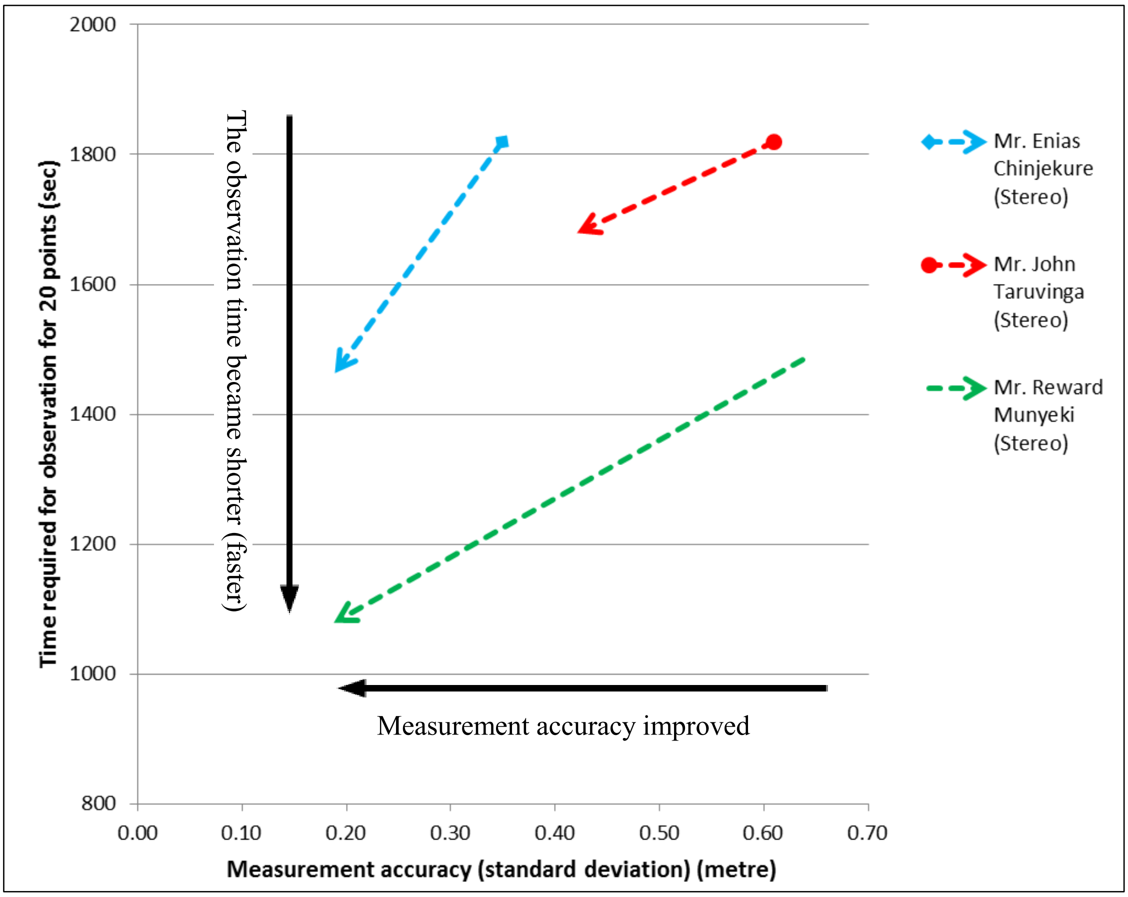
Measurement of spot elevations				
Name	Naked eye stereoscopic measurement		Measurement using 3D glasses	
	Difference before training (m)	Difference after training (m)	Difference before training (m)	Difference after training (m)
Mr. Enias Chinjekure	0.41	0.34	0.35	0.19
Mr. John Taruvinga	0.61	0.42	0.23	0.13
Mr. Reward Munyeki	0.58	0.35	0.64	0.19
* Values are the standard deviation (SD) of the difference in elevation (Dz)				

Source: JICA Study Team

Table 54 Comparison skill test results for line feature measurement between before and after training

Measurement of liner feature				
Name	Naked eye stereoscopic measurement		Measurement using 3D glasses	
	Difference before training (m)	Difference after training (m)	Difference before training (m)	Difference after training (m)
Mr. Enias Chinjekure	0.966	0.653	0.767	0.208
Mr. John Taruvinga	1.108	0.833	0.439	0.239
Mr. Reward Munyeki	1.116	0.901	0.864	0.307
* Values are the standard deviation (SD) in three-dimensional space (Dx, Dy, Dz)				

Source: JICA Study Team



Source: JICA Study Team

Figure 32 Results of skill test for spot height observation between before and after training

(14) Continuing implementation of digital plotting practice and feedback regarding error analysis results

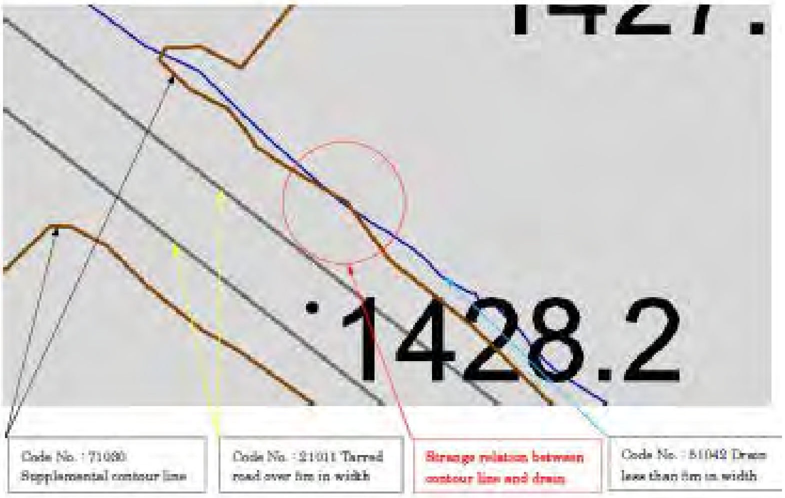
The members of staff of the DSG continued the practice of digital plotting after JICA Study Team returned to Japan. The training area was the area adjacent to the training area until the end of September 2016 in Chitungwiza. The members of the staff of the DSG transmitted the digital plotting data to JICA Study Team in Japan at appropriate time intervals, and the JICA Study Team evaluated and checked the digital plotting data while in Japan. Also, when there were questions from the members of the staff of the DSG regarding points about the method of operation, problems with the digital plotter, etc., JICA Study Team responded to those questions.

JICA Study Team analyzed the issues in the digital plotting data completed by November 2016, and summarized them in a manual as shown in Figure 33.

As a result of analysis of the digital plotting data, the issues were summarized into the following categories. Analysis of the causes of the issues and countermeasures were incorporated into a manual for the technical transfer from February to March 2017.

1) Wrong code number
2) Overlapping
3) Undershoot
4) Overshoot
5) Wrong line shape
6) Wrong connecting point
7) Lack of data
8) Double/triple data
9) Not closed
10) Ambiguous data
11) Wrong point location
12) Etc.

Based on this, in the technical transfer for digital plotting and digital compilation executed between February and March 2017, lectures are executed to the staff of the DSG.



Observations
At the location indicated by red color circle, the contour line crosses the line of "Drain" from left side to right side and left side again.

In theory of contour line, the contour line never crosses the water lines such as river, drain and so on as shown above image.

Assumed reasons for errors
1) Insufficient general knowledge of map compilation and production
2) Insufficient capability of contour line drawing during digital plotting.

Error proofing
1) Insufficient capability for contour lines drawing by digital plotting.
2) Special attention will be necessary when the contour lines crosses the water line such as river, drain and so on during the digital plotting.

Corrected data
Following image is the corrected data based on the observations above.

Source: JICA Study Team

Figure 33 Samples of digital plotting error and countermeasures

3.8 Technical transfer of Digital Orthophoto preparation

Flowchart item [B-8]

Technical transfer for Digital Orthophoto, and DEM preparation which is necessary for the process of orthophoto preparation was executed by OJT program.

Technical transfer was executed over a period of 38 days simultaneously with the technical transfer for Aerial Triangulation.

(1) Implementation period

Technical transfer program for Aerial Triangulation and its implementation period were as follows:

- Parameters setting to software: 19 October 2016 to 21 October 2016
- Aerial Triangulation: 24 October 2016 to 8 November 2016
- Preparation of DEM and Digital Orthophoto images: 9 November 2016 to 17 November 2016
- Follow up: 18 November 2016 to 25 November 2016

(2) Staff of the DSG

The members of staff of the DSG participated in Digital Orthophoto and DEM preparations are shown in Table 55.

Table 55 Members of staff of the DSG participated in the technical transfer of Digital Orthophoto and DEM preparation

No.	Name	Affiliation	Note
1	Mr. Enias Chinjekure	Photogrammetry Section	Chief of Photogrammetry Section Having experience of analogue plotting
2	Mr. Mudzana Lenard	Photogrammetry Section	Having technical training of ground survey, no experience of photogrammetry
3	Mr. Alexander Macheka	Photogrammetry Section	Same as above
4	Mr. Nomore Arikoko	Photogrammetry Section	Same as above (participated in lecture)

Source: JICA Study Team

(3) Baseline survey for the degree of understanding regarding the basic knowledge for Aerial Triangulation

A baseline survey was carried out by questionnaire with the 5 points method ("1" is low degree of understanding, "5" is a high degree of understanding) with the 3 members of the staff participated in all training. The results are shown in Table 56.

Table 56 Baseline survey results for Digital Orthophoto and DEM preparation

No.	Questionnaire contents	Counterparts answers		
		1	2	3
1	Do you know the work procedure of the DEM/ Ortho image?	1	1	3
2	Do you know creation and editing method of DEM by LPS*?	2	1	2
3	Do you know creation method of the ortho image by LPS*?	1	1	2
4	Do you know how to operate (setting and editing) the line for connecting the ortho image in LPS*?	1	2	1
5	Do you know color adjustment method of the ortho image?	1	2	1
6	Do you know the accuracy management and quality control for the DEM/Ortho image?	1	2	1
	Minimum value	1	1	1
	Maximum value	2	2	3
	Average value	1.33	1.50	1.67

* "Leica Photogrammetry Suite (LPS)" is previous name of "Imagine Photogrammetry" from ERDAS

Source: JICA Study Team

The content of the questionnaire objected to determine the degree of understanding regarding the basic knowledge of Digital Orthophoto and DEM, and the functions of the software used. The maximum value of the average value for the 3 members of staff of the DSG was 1.67, the minimum value of the average value was 1.33, and the average value was 1.50.

Therefore, the members of staff of the DSG with experience in analogue photogrammetry had very few knowledge and experience of Digital Orthophoto and DEM preparation using digital aerial photo images, so, it is evaluated that all the members were beginners.

(4) Contents of technical training

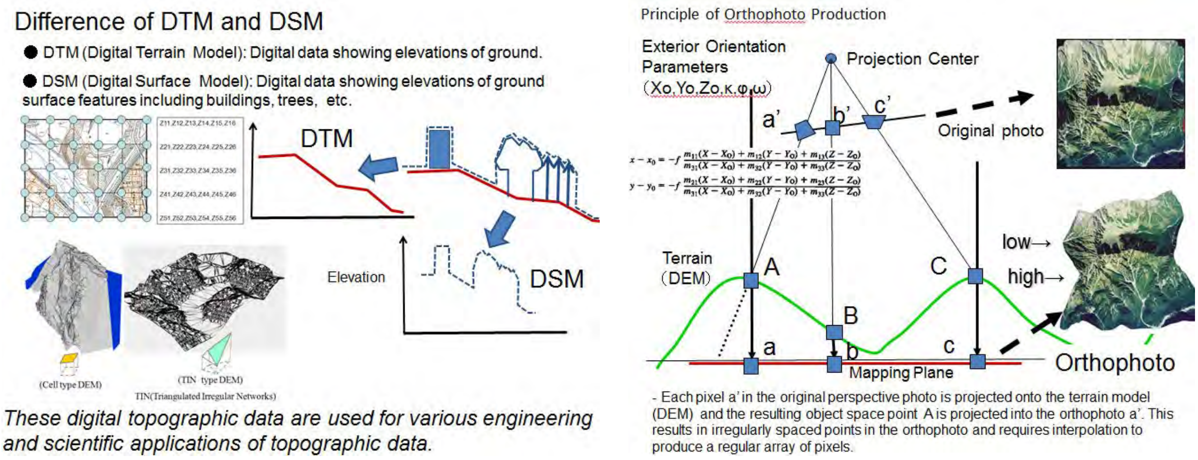
Following items of training were executed by OJT and lectures.

- Lecture for outline of Digital Orthophoto and DEM preparation
- Practice on preparation of Digital Orthophoto and DEM using software
- Practice of accuracy control

(5) Outline of Digital Orthophoto and DEM preparation

Outline of Digital Orthophoto and DEM preparation, the workflow, principles, and contents of data were explained to be able to understand the practice using software.

Figure 34 shows the difference between DTM and DEM (left) and the principles of orthophoto (ortho rectified aerial photo image) (right), a part of lecture material.



Source: JICA Study Team

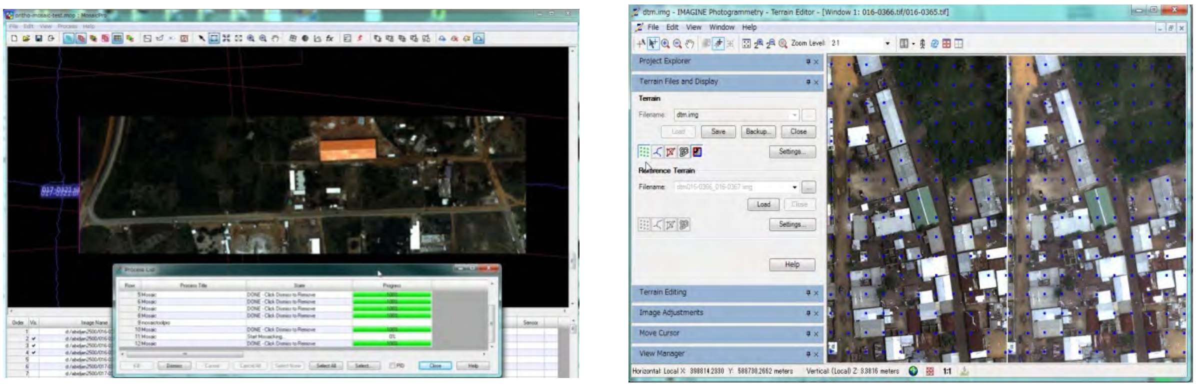
Figure 34 Definition of DEM (left) and Principle of orthophoto (right)

(6) Practice of orthophoto and DEM using software

The practice on the preparation of orthophotos and DEM was executed using Hexagon ERDAS IMAGINE and IMAGINE Photogrammetry, the equipment that was introduced for the technical transfer in the Project.

1) Parameters setting for DEM preparation
2) Editing method of DEM data
3) Evaluation of DEM data
4) Parameters setting for orthophoto preparation
5) Orthophoto mosaicking
6) Color tone adjustment
7) Evaluation of Digital Orthophotos

Figure 35 shows the screen of software used for training, and Photo 3.8-1 shows the scene of training to the staff of the DSG.



Source: JICA Study Team

Figure 35 DEM data editing interface (left) and mosaicked orthophoto image (right)

Source: JICA Study Team

Photo 20 DEM editing training

(7) Accuracy control

The accuracy of orthophoto and DEM can be evaluated by comparison of the results of products with the most probable value, which is considered to be the closest to the actual value in the real world.

The most probable value, which is considered to be closest to the actual value, is the survey result obtained by GPS in field, etc. However, obtaining the most probable value by surveying many verification points in site are not practical from the time and cost points of view. Therefore, comparison with the coordinates values measured (plotted) on the stereo model after Aerial Triangulation is effective method.

According to the survey standards in Japan, accuracy control for Digital Orthophoto is carried out by comparison between the coordinate values of the stereo model oriented the same orientation parameters (results of simultaneous adjustment in Aerial Triangulation) and the coordinate values of DEM and Digital Orthophoto.

Accuracy control was implemented for orthophoto prepared by each member of staff of the DSG in the training. The Digital Orthophoto prepared by the each member of staff of the DSG was inspected based on the standard in Japan mentioned in above. The inspection results were compiled in accuracy control sheets.

By the accuracy control sheet preparation, the members of staff of the DSG participated in the training understood how to evaluate the accuracy of Digital Orthophoto and DEM and inspection workflow. The contents of the accuracy control sheets showed that the members of staff of the DSG participated in the training understand the concept of accuracy control well and there was no issues with the horizontal accuracy of Digital Orthophoto and DEM prepared in the training.

(8) Survey of understanding degree after completion of technical training

A questionnaire survey for measuring the degree of understanding of the contents of the training was carried out by the 5 points method ("1" is low degree of understanding, "5" is a high degree of understanding), the same as for the baseline survey.

The average of evaluation prior to the training was 1.50 points, indicating the members of staff of the DSG did not have knowledge and experience. However, after training, the maximum value of the average value was 5.00, the minimum value of the average value was 3.83, and the average value was 4.33 points, so sufficient degree of understanding has been obtained.

Therefore, it is evaluated that the targets of the training which were to enable the members of staff of the DSG to acquire the basic technologies for preparation of Digital Orthophoto and DEM have been achieved.

Table 57 Survey results of understanding degree of Digital Orthophoto and DEM preparation after completion of training

No.	Questionnaire contents	Counterparts answers		
		1	2	3
1	Did you know the work procedure of the DEM/ Ortho image?	5	4	4
2	Did you know creation and editing method of DEM by LPS*?	5	5	5
3	Did you know creation method of the ortho image by LPS*?	5	4	4
4	Did you know how to operate (setting and editing) the line for connecting the ortho image in LPS*?	5	4	4
5	Did you know color adjustment method of the ortho image?	5	4	3
6	Did you know the accuracy management and quality control for the DEM/Ortho image?	5	4	3
	Minimum value	5	4	1
	Maximum value	5	5	3
	Average value	5.00	4.17	3.83

* “Leica Photogrammetry Suite (LPS)” is previous name of “Imagine Photogrammetry” from ERDAS

Source: JICA Study Team

3.9 Training in Japan

Flowchart item [B-14]

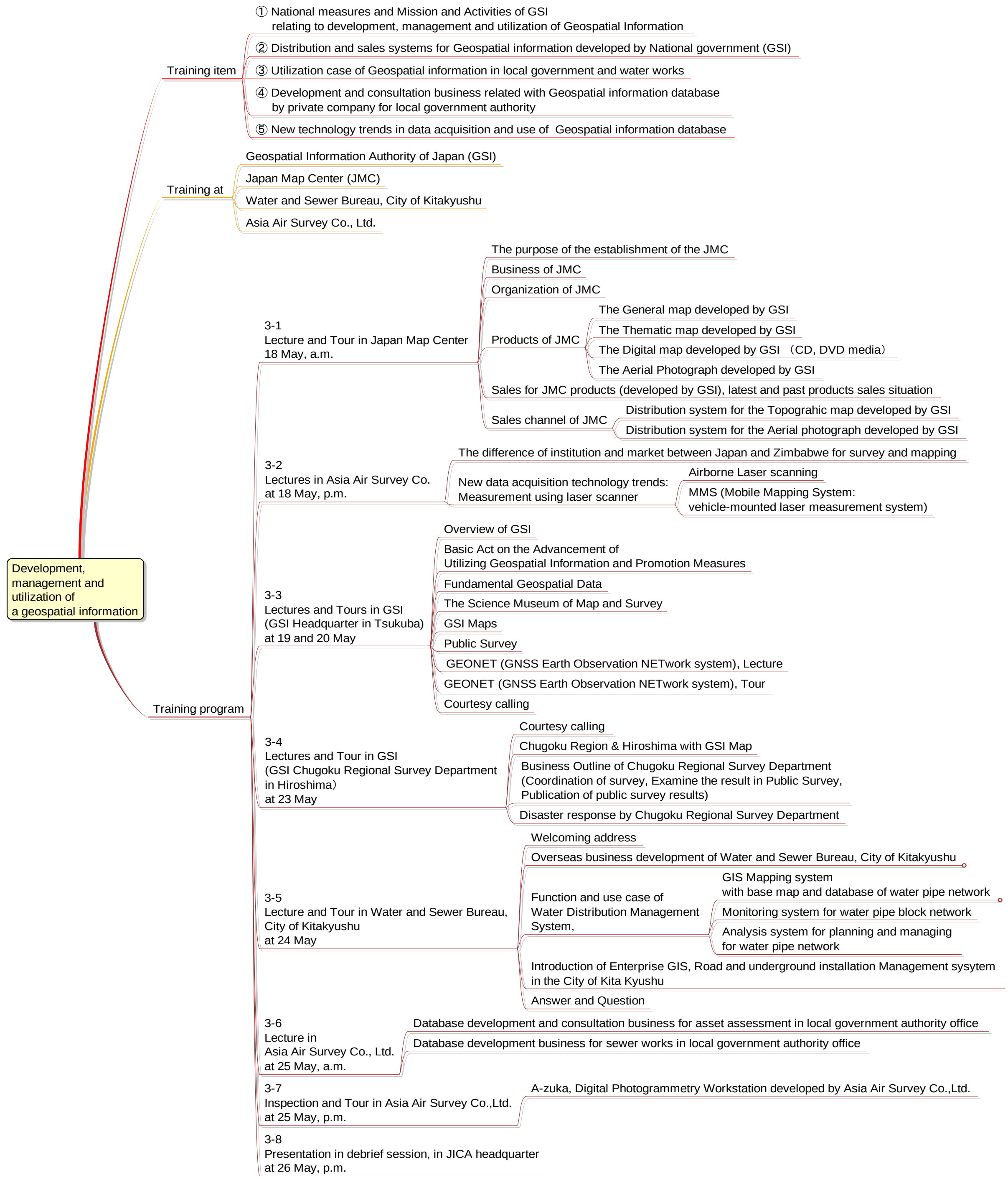
The Training in Japan was implemented for two weeks in May 2016. A total of four persons from the DSG including the Surveyor General participated in training (two executive staff, two general staff)

The themes of the training were to develop geospatial information databases and promote the utilization of them, which is the main objective of this project, and related examples, the current status, current issues, etc. from Japan, were introduced to the DSG.

In order to learn about the maintenance and management of various spatial data not only Digital Topographic map, and Digital Orthophotos, but also the spatial data applying latest measurement technology, example of utilization of geospatial data, and example of sales and distribution of geospatial data in Japan, the training was conducted with visiting Geospatial Information Authority of Japan: the national mapping agency of Japan, public-service corporation distributing the map prepared by the Geographical Information Authority of Japan, municipalities and private surveying companies that are using advanced geospatial information.

In addition, an inspection by the DSG was conducted to grasp the state of preparation of the Digital Topographic map under developing in Japan.

An overall conceptual diagram of training is shown in Figure 36 Conceptual diagram of the training in Japan



Source: JICA Study Team

Figure 36 Conceptual diagram of the training in Japan

Regarding Development, management and utilization of the geospatial information, the principle responsible for roles are different in Zimbabwe and Japan.

For example, in Zimbabwe, the DSG uses a system where it develops 1: 5,000 scale Digital Topographic maps themselves.

On the other hand, in Japan, 1: 2,500 and 1: 5,000 scale Digital Topographic maps are developed by local government rather than the Geospatial Information Authority of Japan which is the organization that develops national maps. However, while local governments bear the cost of development, the actual data preparation work is performed by a private survey company, etc. that is subcontracted to do this work.

It is necessary to understand that there are these differences in development, management and utilization of geospatial information in Zimbabwe and Japan, and that there are differences in the systems and operation in order to facilitate understanding of the training content.

Specific examples of geospatial information development, management and utilization in Japan were compiled in Table 58 with the objective of explaining the above differences, and the party responsible for the respective role (taking initiative) is shown.

Table 58 Examples of development, management, and utilization of geospatial information in Japan (Classified according to organization)

Doer	Development	Management of Legal system, Standardization, Regulation, Infrastructure	Utilization
Citizen	• Participate in Web-based mapping		• Web-based map • Map
Private enterprise	• Geospatial data development business commissioned from National and local government		• Web based map • Map • GIS
Local government, Public enterprise	• Large scaled topographic map for covering the local authority • Utility database with large scaled map or location data • Commission to private survey and mapping company • Open data policy		• Map, Drawing, Geospatial database for infrastructure management • GIS • Integrated GIS (Enterprise GIS) • Open data policy
National Government and public-service corporation	• National topographic map (series for entirety of Japan with middle of small scaled • "GSI map" • "Observation data from GNSS Earth Observation Network System (GEONET) • Open data policy • "Fundamental Geospatial database (FGD)"	• Standardization of survey and mapping specification • "Public survey" • Geodetic control points network including GNSS-based control station • Distribution of map by Japan Map Center • Legislation • NSDI • Satellite positioning • "Fundamental Geospatial database (FGD)"	• GIS • Integrated GIS (Enterprise GIS) • Open data policy

Technology	• Trend of new data acquisition technology • GNSS-based control station • Visualization of geospatial data	• Satellite positioning • "Fundamental Geospatial database (FGD)"	• Web-based GIS • GIS

Source: JICA Study Team

Although this may duplicate the previous explanation, in Japan, geospatial information that is used by the national and local governments and lifeline providers is created by the respective national and local governments, a water supply and sewage provider and other lifeline providers that actually use the information. However, the majority of the actual development work is performed by a private sector company such as a survey company subcontracted by the national and local governments and lifeline providers. Scale 1:5,000 scale topographic maps are created by private sector survey companies subcontracted by local governments.

Geospatial information that is developed as explained above is utilized for work that is performed by national and local governments, a water supply and sewage provider, and other lifeline providers.

The Geospatial Information Authority of Japan which is the same type of national map development agency as the DSG develops 1:25,000 and smaller scale topographic maps that cover the entire country. The maps are in both analogue and electronic form. Electronic maps are released on the internet free of charge. The topographic maps that are developed by the Geospatial Information Authority of Japan are duplicated and sold by a public-service corporation.

In addition, regarding the geospatial information development infrastructure, the Geospatial Information Authority of Japan develops control point networks including electronic control points and related legal system, and plans and implements policies to promote utilization on the same.

The training program including the training content and training destinations shown in Table 59 was planned and implemented in order to introduce examples of geospatial information development, management and utilization in Japan with the structure described above.

Table 59 Training items, contents and locations

Training items	Training contents	Training site
Case of Development of Geospatial information	Introduction of use case of Digital Orthophoto	Asia Air Survey Co., Ltd. (Private aerial survey and mapping company)
	Confirmation by the DSG for the developing situation of the project products	
	Introduction of developing geospatial information for government and public enterprise services: water, sewer, asset tax management, road management, with aerial survey and mapping technology by private company	
	Introduction of developing geospatial information such	

	as 3D modeling with airborne LiDAR, and Mobile laser mapping system	
Case of Utilization of Geospatial information	Introduction of practical use example of Geospatial information database in water, sewer, asset tax assessment, road management in local government and public enterprise	Water and Sewer Bureau, City of Kitakyushu (local government)
Case of Promotion and dissemination of Geospatial information	Measure for development and utilization of Geospatial information by Japanese government	Geospatial Information Authority of Japan (Government agency)
	Mission of Geospatial Information Authority of Japan	
	Collecting information about management, distribution, and pricing of map and the geospatial information product developed by GSI	Japan Map Center (Public-service corporation)

Source: JICA Study Team

(1) Training curriculum

The training curriculum described below was established.

Aim of the training

- To obtain the technology and knowhow of Japan by visits to organizations involved in the development, management, distribution, and utilization of geospatial information, such as the Geospatial Information Authority of Japan, local governments, etc.
- In particular, to understand how the national policy regarding geospatial information is implemented in Japan, by learning from the history, organization system, functions, and work examples of the Geospatial Information Authority of Japan, which is the organization responsible for preparation of national survey maps in Japan.
- To determine the issues in Zimbabwe and the DSG, through an understanding of the points of difference between Japan and Zimbabwe.

It is expected that the training results will serve as reference for developing policies to facilitate development, management and utilization of geospatial information conducted by the DSG in the future.

Training items

1. The National measures and Missions and Activities of GSI relating to development, management and utilization of Geospatial Information

2. The distribution and sales systems for the Geospatial information developed by the government of Japan through GSI and JMC

3. The Utilization case of the Geospatial information in local government and water works

4. The Development and consultation business related with the Geospatial information database by private company for local government authority

5. New technology trends in data acquisition and use of Geospatial information database

(2) Implementation of training in Japan

Training was conducted according to the above-mentioned training curriculum. The training schedule is shown in Table 60.

Table 60 Training implementation schedule

Date and hour		Training site	Trip and Training programme
14 Sat.	p.m.	Harare	Outbound from Zimbabwe / Depart from Harare, via Johannesburg, to Hong Kong
15 Sun.	a.m. p.m.	 Narita Airport	From Johannesburg to Hong Kong From Hong Kong to Narita, Entry to Japan.
16 Mon.	a.m.	JICA Tokyo	Briefing session
	p.m.	JICA Headquarters	Courtesy call to JICA headquarters Visit to the Observatory of Tokyo Metropolitan City Hall
17 Tue.		JICA Tokyo	General Orientation: Learning Japanese politics, culture, and society to assist better understanding of training program • Program description • Greeting from director of JICA Tokyo • Lecture: Economy • Lecture: Politics / administration
18 Wed.	a.m.	Japanese Map Center (JMC) JMC Asaka Facility (At Asaka)	Learning the case in Japan: government system and measures of the development, distribution method, pricing for the map and geospatial database product through the GSI and JMC. • Lecture, Overview of JMC: The past and present situation of the distribution and sales of the map and geospatial data developed by GSI. • Tour inspection of the map transit warehouse of JMC
		Asia Air Survey Co., Ltd. Shinyuri-head Office (At Kawasaki)	Learning the case in Japan: practical business and services related to Geospatial information performed by private survey and mapping company, • Lecture, Introduction of the latest technology trends in the data development of Geospatial information with the laser measurement system: Mobile Mapping System (MMS): the vehicle mounted laser measurement system, and airborne laser, visualization of geospatial information acquired with laser technology: 3D point clouds data and the Red Relief Image Map
19 Thu.	All day	Geospatial Information Authority of Japan (GSI) Head office (at Tsukuba)	Learning the measure of GSI for development and management of geospatial information database (Lecture and tour) Day-1 • Overview of GSI • Basic Act on the Advancement of Utilizing Geospatial Information and Promotion Measures • Fundamental Geospatial Data (FGD) • The Science Museum of Map and Survey

20 Fri.	All day	Geographical Survey Institute Head office (at Tsukuba)	Learning the measure of GSI for development and management of geospatial information database (Lecture and tour) Day-2 • GSI Maps • Public Survey • GEONET (GNSS Earth Observation network system), Lecture • GEONET (GNSS Earth Observation network system), Tour • Courtesy calling
21 Sat.	All day	Rest day	
22 Sun.	a.m.	Tokaido - Sanyo Shinkansen	Move from Tokyo to Hiroshima with the Shinkansen bullet train,(the Tokaido –Sanyo Shinkansen line)
22 Sun.	p.m.	Rest day	
23 Mon.	a.m.	Geospatial Information Authority of Japan Chugoku Regional Survey Department (at Hiroshima)	Learning the measure of GSI for development and management of geospatial information database (Lecture and tour) Day-3 • Courtesy calling • Chugoku Region & Hiroshima with GSI Map • Business Outline of Chugoku Regional Survey Department (Coordination of survey, Examine the result in Public Survey in GSI's Regional Survey Department), • Publication of public survey results) • Disaster response by Chugoku Regional Survey Department
	p.m.	Hiroshima City	Move to Kokura with the Shinkansen bullet train,(the Sanyo Shinkansen line)
24 Tue.	a.m.	Kitakyuushuu city water and sewage bureau	Learning utilization case of Geospatial information such as topographic map and GIS in water works and local government office (Lecture and tour) • Welcoming address • Overseas business development of Water and Sewer Bureau, City of Kitakyushu • Function and use case of Water Distribution Management System(GIS mapping system based water pipe network management system and monitoring system)
	p.m.	Kitakyuushuu city water and sewage bureau (at Kitakyushu City)	• Monitoring system for water pipe blocks network • Analysis system for planning and managing for water pipe network • Introduction of Enterprise GIS, Road and underground installation Management system in the City of Kita Kyushu • Answer and Question Move to Tokyo by Air (From Kitakyushu airport to Tokyo/Haneda Airport)
25 Wed.	a.m.	Asia Air Survey Co., Ltd. Shinyuri-head Office (At Kawasaki)	Learning example of development and utilization of Geospatial information, development of Geospatial database and application for utility management, asset tax assessment in business for local government and public enterprise
	p.m.		Inspection by the DSG for developing status of the project deliverables developing by Asia Air Survey (visit) Introduction of Digital Photogrammetry Workstation (DPW) developed by Asia Air Survey and experience of DPW by trainees.
26 Thu.	a.m.	JICA Tokyo	Preparation of the preparation material for training debriefing
	p.m.	The JICA headquarters	Training debriefing meeting, Presentation from trainees
27 Fri.	p.m.	Narita Airport	Depart from Japan, Tokyo/Narita – Hong Kong - Johannesburg
28 Sat.	a.m.		Hong Kong – Johannesburg – Harare
	p.m.	Harare	Arrival at Harare from Johannesburg Return to Zimbabwe

Source: JICA Study Team

A part of the state of the training is shown as Photo 21 and Photo 22.

Source: JICA Study Team

Photo 21 Training at the Geospatial Information Authority of Japan

Source: JICA Study Team

Photo 22 Training at Kitakyushu City Water and Sewer Bureau

(3) Methods of utilization of training results

At the training report meeting held as the final program of the training, the trainees made passionate presentations based on the knowledge learned from the training in Japan and the methods of utilizing it.

The trainees discussed the measures for development, management, operation, and utilization of geospatial information in Zimbabwe in the future by the DSG, in particular the necessity for the DSG to update the 1: 5,000 topographic maps of each city within Zimbabwe, and the necessity of strengthening the capabilities of the DSG in order to realize this.

In the presentations, the following were specifically mentioned as methods of utilizing the training results.

- There is a desire to develop high-resolution geospatial information for the whole country of Zimbabwe, utilizing the latest geospatial information technology and successful examples from around the world including the examples learned on this occasion in Japan.
- There is a desire to construct a network of electronic control points covering the whole land of Zimbabwe.
- Construction of an NSDI for sharing data
- Development of staff members through actual practice in the management of geospatial information, capable of responding to changes in technologies
  In Japan, by actively sharing geospatial information, the utilization of geospatial information for

sustainable socioeconomic development is advanced. In order to realize the same thing in Zimbabwe, there is a desire to continue the cooperative relationship with the Japanese government for capacity building by personnel development and sharing of experience.

Also, in the questionnaire responses by the trainees, the following was stated in response to the question "from what you learned in the training in Japan, what knowledge or technology could contribute to solving tasks in your country?"

- Construction of a network of electronic control points for disaster monitoring and examples of their utilization (GeoNet by the Geospatial Information Authority of Japan).
- Examples of use of map information by GIS (use of maps and GIS for managing water works at the Kitakyushu City Water and Sewer Bureau)
- There is a desire for the DSG engineers to realize the technologies for preparation of Digital Topographic maps applying digital technologies.
- The reason is because the following has been understood regarding technologies for preparation of Digital Topographic maps applying digital technologies.
- Government organizations and research organizations can share geospatial information with each other.
- This will strengthen the quality and distribution of geospatial information.
- It will enable maintenance of urban utilities and urban planning to be carried out better
- There is a possibility that the "GSI Map" system by the Geospatial Information Authority of Japan can be applied in Zimbabwe to various services related to geospatial information.
- Investment in digital technologies provides convenient, efficient, and effective solutions for distribution of geospatial information to the public.
- The current problem at the DSG is that they only have paper maps prepared by the analog method, and it is recognized that it is necessary for the DSG to transition to the digital method.

Finally, in the questionnaire responses, the trainees expressed that they recognize the issues that are obstacles to utilization of the training results in the Zimbabwe government or in the DSG.

- In order to realize in Zimbabwe examples of the use of geospatial information utilizing electronic control points and ICT, as learned in this training, the biggest issue will be how to solve the allocation of the necessary funds. If the funding problems can be solved, then technically it can be realized.
- The technologies learned in this training can also be applied in Zimbabwe, but for the DSG has a difficulty in the development and maintenance of infrastructure, which is a precondition of the management of electronic control points and ICT systems, and the construction and operation of

the system.

The trainees held reporting meetings after their return home with the intention to widely share within the DSG the information and knowledge gathered during the training in Japan.

3.10 Technical transfer of map representation and map finishing

Flowchart item [B-9]

Technical transfer regarding the editing of map representation and map finishing, and procedure of preparation of data for output image of Digital Topographic map was implemented.

In the Project, a method utilizing the map representation function provided in the GIS software and GIS database was adopted as a method for map representation and map finishing of the topographic map and the Harare Street Map output figure data. This is adopted a new technology trend by comparison with map symbolization using drawing software (also called vector graphics editor) which was the mainstream of the past, and also used in the DSG.

The special area of drawing software is to draw and edit the figure of the vector, and the use of drawing software has become popular also in map representation in order to draw and edit a map which is a diagram: collection of lines, symbols, and filled figures. In the data flow for topographic mapping, after completion of preparation of the topographic map data file by using CAD or GIS software in digital plotting and compilation process, the topographic map data file is converted into a file format compatible with drawing software, especially in the process of map representation and map printing, the final output image data of the printed map was prepared with using the drawing software.

However, since drawing software is not software intended to handle maps and geospatial information themselves like GIS and CAD; it has no functions related to handling spatial reference or map projection. There was the following problem in the map representation performed by drawing software and the created map information with drawing software (output image of the map).

- The map drawn with drawing software is not geospatial information with spatial reference; it is, so to speak, an ordinary picture or diagram.
- It will be drawing and editing the vector figure as it is in the map representation. For example, when editing a dislocation as a map representation, the position of the target figure on the data file is moved. In case of interruption, the figure is divided. When omitted, the figure is deleted or hidden. Information is complicated by being edited for dislocation or interruption as a map representation. The figure is moved from its original position. Continuity and connectivity of graphics are also lost, and those figures are difficult to be used as GIS data.

- There is difficulty in map data with map representation, in importing into GIS or CAD, re-editing, and analyzing in GIS or CAD.

For this reason, in the data flow for topographic mapping, independent file was created for handling with drawing software as the final image of print / plot out map with map representation. The data flow was a so-called one-way data flow toward the post process in the work flow. It was used only for preparing data of output image of map and delivery purpose to output process. Upon updating the map information, it is common to update the original topographic map data again with GIS or CAD data, convert the updated information to file, deliver it to drawing software, and perform map representation editing again there were. It was not common to return the edited information to GIS or CAD with drawing software.

When the process has progressed to the map representation, updating the topographic map data using GIS or CAD and map representation with drawing software will be required if integration of the results of field verification or updating of information by secular changes are required data updating work was necessary. It was common to perform update tasks targeting two files separately. The troublesome management of update contents and management of data files became a problem.

On the other hand, in order to solve the problem of the data flow of topographic map creation with using the drawing software, Functions related to map representation editing and map portrayal method application were implemented in GIS software and GIS database. As a result, in the GIS database, a method of editing the map representation with geospatial information with spatial reference was realized.

This method is realized by implementing the following functions in the GIS database.

- Information on one figure (point, line, area, and text string) constituting the map information is recorded as one record in the GIS database.
- At this time, the unit of figures recorded as one record constitutes the data of the Digital Topographic map before map representation such as transposition, interruption, omission of figures to realize the map representation, and map symbol before it is applied.
- Information on the appearance of the figure to which the map expression is applied is recorded in the database as one of the various attribute information stored in the record of the database corresponding to each figure.
- In map representation editing, edit to realize map representation such as dislocation / interruption / omission of a figure, do not change the position and shape of the figure itself constituting the map information. The change is made to the drawing rule of the figure realizing the map representation.

This realized storing multiple appearances in one database. That is, a plurality of map representations (results of map representation editing) can be stored in the database for one digital terrain map data. It is possible to create maps of different expressions from one Digital Topographic map data by portraying different map with different map representation according to the subject theme and scale of the target map.

Also, before applying the map representation, the digital plotting data acquired by digital plotting retains the position close to the true position when it was captured into a state without editing such as dislocation, interruption, or omission of the figure being added, it can be stored with spatial reference.

Advantages of data flow by adopting map symbolization using GIS database are as follows.

1. It is possible to give and store multiple map representation in a database of one Digital Topographic map and GIS database according to the scale and application of the map. Depending on the application, map representation can be invoked and applied as a portrayal method.

2. It is possible to make a completely different maps from one database by applying different map projection and coordinate transformation into maps with map representation with functions of GIS software and GIS database.

3. By being able to give spatial reference information to data, even map data with map representation, it is possible to create completely different maps by applying different map projections and coordinate systems depending on the change of map projections method and coordinate transformation function in GIS software and database. As a result, it will be more flexible than drawing software.

4. Since the contents of the map information before and after the application of map representation editing can be held in the same database, the updating work of the previous data and the applied data can be performed with a map representation at a time. As with the data flow using drawing software, there is no need to update and manage multiple data files when updating the topographic map.

By introducing map symbolization editing using GIS into the DSG, it can be expected that updating information that does not require data capturing from new aerial photograph will be able to update the map partly in a relatively short cycle in the department in map editing and compilation process. Further, it can be expected that another map can be created from the updated map data.

Technology transfer was carried out in lectures and practical training forms on the following three tasks with the aim of supporting the introduction of map representation technology using GIS into the DSG.

- Import Digital Topographic map data (CAD format) into GIS database (geodatabase format) using GIS software. This process is called as data integration process in the DSG.

- Perform map representation editing on Digital Topographic map data which is GIS data in the geodatabase format with using GIS software.
- Add marginal Information to the Digital Topographic map data with map representation, and create output image data of topographic map (PDF format).

(1) Baseline and issues for consider regarding in implementation of the training

As an observation from the start of the Project, DSG uses Aldus FreeHand (later Macromedia FreeHand), one of the drawing software, for map representation of the Harare Street Map and the scale 1: 25,000 or smaller scale map. In this process, since DSG is conducting the same editing as the content of the technology transfer this time, it was evaluated that DSG already has experience and knowledge of map representation editing with drawing software.

The main issues with consideration is that, focusing on differences in data flow, workflow, and software operability of map representation editing between using ArcGIS and Aldus FreeHand, To make it possible to smoothly transition map representation with using Aldus FreeHand to ArcGIS.

(2) Implementation of training

ArcGIS Desktop 10.4 was used for training. On the following tasks of map representation, training was conducted with lectures and practical training on the work method using ArcGIS 10.4 and its basic knowledge.

- Overview of map representation (workflow and data flow)
- About map representation using the functions of ArcGIS software and geodatabases, explanation on software editing function and database function
- Explanation of the difference with map representation by Aldus FreeHand which was done conventionally by the DSG
- Practice of map representation using ArcGIS
- Creation of map symbols
- Apply map representation
- How to create a marginal Information of topographic map using ArcGIS
- How to create PDF data for topographic map output image

(3) Evaluation of technical transfer

As a result of the training, the counterpart has become able to do the following work using GIS software.

- Import Digital Topographic map data (CAD format) into GIS database,
- Map representation edit
- Creation of marginal information and integration with map symbolization data
- Create output put image data of topographic map

Based on the above results, it was evaluated that it reached the goal of being able to perform the map representation of Digital Topographic map data using GIS software

3.11 Technical transfer of structuralization of Digital Data

Flowchart item [B-10]

Regarding process of importing Digital Topographic map data into GIS database, and creating GIS database as fundamental geospatial dataset, and preparing GIS database for provision to the users, the technology transfer on necessary knowledge and technology was carried out. Technology transfer was conducted in lectures and practical forms.

(1) Outline of training

For the handling of the GIS database, the following training was conducted.

ArcGIS Desktop software was used to conduct the training.

The aim of training was to introduce following issues handing GIS databases.

- Design and build geodatabase of ArcGIS
- Convert data from CAD data file to GIS database
- (Digital terrain map data in CAD data format is converted to GIS database to create Digital Topographic map in GIS data format and fundamental geospatial dataset)
- Management method of GIS database and method of preparation data for distribution

(2) Baseline survey

For the purpose of grasping the baseline, survey was conducted by questionnaire for counterparts.

The content of the questionnaire was to ask about the following matters.

- About experience with GIS and database management
- Recognition to GIS
- Expectations for GIS database training

From the analysis of the response contents of the questionnaire, the following results were found for trainees.

- Having basic knowledge of computer, basic skills and information systems
- Having experience in using database language (query language) and queries with spreadsheet software
- Having basic knowledge about relational databases and geodatabases
- Having experience using CAD software and drawing software (Aldus Free Hand)
- Having knowledge of the basic concept of GIS, received introductory training on ArcGIS Desktop software

In order to improve the ability of the DSG to manage GIS database, training on GIS database management, raster image data handling, handling map projection, coordinate system, topology and web-GIS is necessary.

(3) Implementation of training

Training on the following issues has been carried out.

1) Issues related to the handling of ArcGIS geodatabase model

- Design of a simple geodatabase logical model
- Building a geodatabase
- Creating feature datasets and feature classes
- Create subtype
- Populating data into geodatabase and converting data from CAD data to GIS database
- Import raster image data to geodatabase
- Build topology

2) Issues related to coordinate transformation

- Map projection method
- Coordinate transformation

3) Issues on handling raster images for data distribution

- Assign position information to raster image data (existing cadastral map image)
  - Spiriting and clipping of Digital Orthophoto images

4) Issues related to data sharing

- Demonstrate data sharing using GIS data sharing web service

(4) Evaluation of technical transfer

As a result of the training, the counterpart evaluated that it was able to do the following work using GIS software.

- Design and build geodatabase of ArcGIS
- Convert data from CAD data file to GIS database

  (Digital Topographic map data in CAD data format is converted to GIS database to create Digital Topographic map data in GIS format and fundamental geospatial dataset)
- Management method of GIS database and method of preparation data for distribution to user

From the above results, it was evaluated that the two goals of technology transfer have been reached.

- To enable preparation of Fundamental geospatial dataset from digital topographic data using GIS software. To acquire the knowledge and skills necessary for the preparation of Fundamental geospatial dataset.
- To enable preparation of data to be supplied to the users using GIS software. To acquire the knowledge and skills necessary for this.

3.12 Lecture and practice of project planning and project management

It is expected that the DSG will produce 1:5,000 scale Digital Topographic maps using the digital aerial photo images taken by the Project after completion of the Project. For this purpose, the lectures and practice of project planning and project management were implemented. The participants in the lectures and practice of project planning and project management were assembled of the management staff of the DSG and the members of staff of the DSG who participated in the training of the digital plotting in the technical transfer programme.

3.12.1 Objectives of lecture and practice

Lecture and practice for project planning and project management were implemented so that the DSG would be able to execute 1:5,000 scale Digital Topographic maps (in particular, preparation of 1:5,000 scale Digital Topographic maps for the remaining are of 1,604km^2 in the Greater Harare) by themselves in the future.

The lecture and practice focus that how to collect and use the productivity index in digital plotting process for project planning and management for production of Digital Topographic map. Particularly digital plotting process using digital plotter usually becomes the most critical path in digital topographic mapping production. Therefore, the productivity of digital plotting process is an indispensable basic quantitative index for project planning and management of digital topographic mapping project.

In the DSG, creating and updating topographical map with photogrammetry using analog plotter was performed before 2000, but there is no experience of creating a Digital Topographic map using digital plotter. Therefore, the DSG does not have indices based on practical experiences such as productivity of the digital plotting, error rate of digital plotting, and know-how of collecting those indices; and recognition that how an error in digital plotting made an influence on the production of Digital Topographic map.

Since those issues are essential knowledge for the DSG, in the planning, implementation, and management of digital topographic mapping project in the future will be executed by the DSG. The lecture and practice were carried out so that administrative position and trainees of the digital plotting training in the DSG understand them.

Implementation of lectures and practice was divided into two periods: First period (September 2016) and Second period (February to March 2017).

3.12.2 Participants and schedule for the lecture and practice

The members of staff of the DSG participated in the first and second period lectures and practice and schedule are described as follows:

(1) Participants and schedule of the first-period lecture and practice

1) Subjects for the first-period lectures and participants are described below.

i)	Mr. Robert Mupondi	Deputy Director of Mapping, (Mapping Branch)
ii)	Ms. Chipo Chanetsa	Data Integration Section, (Mapping Branch)
iii)	Mr. Pondai Mupambawashe	Cartography Section, (Mapping Branch)
iv)	Mr. Enias Chinjekure	Photogrammetry Section, (Mapping Branch)

2) Schedule of the first period lectures and practice

The schedule for the first period lectures and practice is as follows:

1st Time	September 1, 2016
2nd Time	September 2, 2016
3rd Time	September 6, 2016
4th Time	September 7, 2016

5th Time September 9, 2016
6th Time September 21, 2016
7th Time September 23, 2016

3) Outline of the first-period lecture and practice

Outline of the first-period lectures and practice is as follows:

i) Outline of Digital Topographic map preparation
ii) Number of digital plotter and simulation of work time for the preparation of 1:5,000 scale Digital Topographic maps for the remaining area for 1,604km^2 of Greater Harare.
iii) Project management for Digital Topographic maps preparation

- Important points for the management of Digital Topographic maps preparation
- Outline of EVM as monitoring technique
- Introduction of Digital Topographic maps preparation project (Problems that occurred during 1:25,000 scale Digital Topographic maps preparation by the Survey of Bangladesh)

(2) Participants and schedule of the second-period lectures

The main topics of the second period lecture was simulation of the required number of digital plotters and the work time for the production of the 1:5,000 scale Digital Topographic maps for the remaining area (1,604km2) : the aerial photographs had been taken by the Project in the Greater Harare (1,604km2), including estimation of the error rate and productivity in the topographic mapping process, especially digital plotting (data capturing) process based on the result record and the result (digital topographic map) which had been prepared by the staff of the DSG at the technical transfer for digital plotting.

Therefore, the participants of in the second-period lecture was assembled of not only the management staff but also the staff of the DSG who participated in the technical transfer of the digital plotting.

1) Participants of the second-period lectures

The members of staff of the DSG participated in lectures are as follows:

i) Mr. Cannan Ndambakuwa Chief Land Surveyor, (Mapping Branch)
ii) Mr. Pondai Mupambawashe Cartography Section, (Mapping Branch)
iii) Mr. Enias Chinjekure Acting Chief Photogrammetrist, (Mapping Branch)
iv) Mr. John Taruvinga Photogrammetry Section, (Mapping Branch)
v) Mr. Reward Munyeki Photogrammetry Section, (Mapping Branch)

2) Schedule of the second period lectures

The schedule for the second period lectures is as follows:

1st Time	February 27, 2017
2nd Time	February 28, 2017
3rd Time	March 1, 2017
4th Time	March 2, 2017
5th Time	March 3, 2017
6th Time	March 13, 2017
7th Time	March 14, 2017

3) Outline of the second-period lectures

Lectures in the second period consisted of the following content based on the 1:5,000 scale digital plotting data acquired by the staff of the DSG during the technical transfer for digital plotting that could not be implemented during lectures and practice in the first period.

i) Calculation and evaluation of types or errors and the number of errors in 1:5,000 scale digital plotting data acquired by the staff of the DSG
ii) Calculation and evaluation of average number of node points per 1km^2 in 1:5,000 scale digital plotting data acquired by the staff of the DSG during the technical transfer for digital plotting
iii) Calculation and evaluation of error rate in 1:5,000 scale digital plotting data acquired by the staff of the DSG during the technical transfer for digital plotting
iv) Explanation of impact on Digital Topographic maps preparation when error rate of digital plotting data is high using examples for the Survey of Bangladesh
v) Estimation of 1:5,000 scale digital plotting productivity by staff of the DSG in the future

Outline of the topics in the lecture is described in the following section.

3.12.3 Calculation and evaluation of error types and number of errors in 1/5,000 scale digital plotting data acquired by the staff of the DSG

Due to the fact that some error of digital plotting data cannot be found by a logical check, all 1:5,000 scale digital plotting data acquired by the staff of the DSG during the technical transfer for digital plotting was visually checked. The types of errors and number of errors found by the visual inspection are shown in Table 61.

Table 61 Types and numbers of errors in 1:5,000 scale digital plotting data obtained by the staff of the DSG during the technical transfer of digital plotting

Types of Error	No. of errors	Error Description
Wrong code number	146	The code of data is wrong.
Overlapping	47	Two line data are crossing each other.
Undershoot	19	The line does not reach to other line.
Overshoot	21	The line crosses over other line.
Wrong line shape	41	The shape of line is not correct.
Wrong connecting point	40	Line data does not connect to the proper point.
Lack of data	19	Necessary data is not obtained during digital plotting.
Double/triple data	18	Double/triple data is found.
Not closed	5	The line was not connected.
Ambiguous data	5	Meaningless data is found.
Wrong point location	14	Point data locates at improper location.
Etc.	41	The contour line crosses water line incorrectly、etc.
Total	416	

Note: 1:5,000 scale digital plotting area is 2km^2

Source: JICA Study Team

It was found that the following were the main reasons for almost all errors of digital plotting data as described in Table 61 Types and numbers of errors in 1:5,000 scale digital plotting data obtained by the staff of the DSG during the technical transfer of digital plotting.

1) Appropriate code number was not selected when data was acquired.
2) Appropriate snap function was not used when data was acquired.

These errors are fundamentally caused by carelessness when digital plotting data is acquired, and also the insufficient experience of actual work. It is considered that almost all errors can be eliminated if staff of the DSG is very careful at the time of data acquisition.

3.12.4 Calculation and evaluation of average number of node points per 1km2 in 1:5,000 scale digital plotting data obtained by the staff of the DSG

1:5,000 scale digital plotting data for a total area of 2km^2 was acquired by three members of staff of the DSG (0.66km^2 per person) during technical transfer for digital plotting.

This digital plotting data was used to calculate the number of node points per $1km^2$ in the 1:5,000 scale digital plotting data for the surrounding area of Harare City (residential area), and the results is shown in Table 62.

The number of node points per $1km^2$ in the 1:5,000 scale digital plotting data for the surrounding area of Harare City (residential area) was calculated as approximately 24,500 points/km^2.

Table 62 Number of node points per $1km^2$ in the 1:5,000 scale digital plotting data acquired by the staff of the DSG during technical transfer

Name	No. of node points	Plotting data area	No. of node points per $1km^2$
Mr. Enias Chinjekure	17,132	0.66	25,957
Mr. John Taruvinga	19,450	0.66	20,469
Mr. Reward Munyeki	17.962	0.66	27,215
Total	54,544		
Average			24,547

Source: JICA Study Team

3.12.5 Calculation and evaluation of error rate in 1:5,000 scale digital plotting data acquired by the staff of the DSG during technical transfer of digital plotting

The error rate in the 1:5,000 scale digital plotting data was calculated from the number of node points and the number of errors in the 1:5,000 scale digital plotting data by the staff of the DSG.

The error ratio of the digital plotting data was calculated with the formula described below.

Digital plotting data error rate calculation formula:

(Total number of errors in digital plotting data)÷(Total number of node points in digital plotting data)

= digital plotting error rate

The error rate (for $2km^2$ portion) for the 1:5,000 scale digital plotting data acquired by the staff of the DSG during technical transfer for digital plotting was calculated as "0.0076". This means that there was one error for approximately 140 node points.

However, due to the fact that this 1:5,000 scale digital plotting work was virtually the first time data acquired by the staff of the DSG using a digital plotter. Therefore, the error rate cannot be simply compared to the error rate for 1:5,000 scale digital plotting in Japan.

As an optimum material for comparison of the error rate in the digital plotting data, the JICA study team brought the record and experience in "Bangladesh Digital Mapping Assistance Project (BDMAP)" implemented by JICA from 2008 to 2012.

The explanation for evaluation of error rate of digital plotting was executed based on the data of error rate obtained during the implementation of this project to the staff of the DSG.

In BDMAP project, technical training for 1:25,000 scale and 1:5,000 scale digital plotting was executed for the staff of Survey of Bangladesh (SOB), national survey and mapping organization in Bangladesh.

The error rate of 1:25,000 scale and 1:5,000 scale digital plotting was calculated during the technical training and actual works of digital plotting.

This is the data to show the change of error rate quantitatively according to the progress of training and actual work of digital plotting of the staff of Survey of Bangladesh.

The error rate for digital plotting during the first time and second time for 1:25,000 scale and 1:5,000 scale digital plotting by the staff of Survey of Bangladesh was compared with the error rate for 1:5,000 scale digital plotting by the staff of the DSG, and the results are shown in Table 63.

Table 63 Comparison of digital plotting data error rates between DSG and SOB

Organization	1/5,000 digital plotting data		1:25,000 digital plotting data	
	The 1st time	The 2nd time	The 1st time	The 2nd time
DSG	0.00763	-----------	-----------	------------
SOB	0.01587	0.00169	0.01127	0.00386

Source: JICA Study Team

As shown in Table 63, the error rate by the staff of the DSG for 1:5,000 scale digital plotting was lower than the error rate for 1:5,000 scale digital plotting by the staff of SOB during the first time, but higher than the error rate for 1:5,000 scale digital plotting during the second time.

The 1:5,000 scale digital plotting error rate by the staff of SOB during the second time (0.00169: 1 error for approximately 591 mode points) and 1:25,000 scale digital plotting error rate (0.00386: 1 error for approximately 259 node points) are high values from the respective productivity for smooth implementation of Digital Topographic maps preparation. Therefore, the digital plotting error rate needs to be reduced to a value of "0.001 of less" (one error for several thousand node points).

For SOB, the digital plotting error rate was reduced to "0.001 or less" during the third time digital plotting was performed. It is expected that the same process will be taken for the preparation of 1:5,000 scale Digital Topographic maps preparation by the DSG.

3.12.6 Calculation and evaluation of 1:5,000 scale digital plotting productivity based on 1:5,000 scale digital plotting data acquired by the staff of the DSG during technical transfer of digital plotting

Digital plotting productivity refers to digital plotting area (km^2), which will be obtained by one day with one digital plotting system and one digital plotting operator.

The other important data for the estimation of the 1:5,000 scale digital plotting productivity is "an average time for one node point data acquisition by digital plotting system".

Digital plotting data for a total area of $2km^2$ was acquired by three members of the staff of the DSG ($0.66km^2$ per person) during technical transfer for digital plotting, and the “Number of node points acquired per hour” or “Time (seconds) needed to acquire one node point” by the staff of the DSG during the technical transfer for digital plotting can be calculated from the hours required for digital plotting and total number of node points of digital plotting data.

The total number of node points and time spent for digital plotting can be used to calculate "the average number of node points per one working hour" or "the average time necessary for one node point data acquisition by digital plotting system".

The average number of node points per one working hour was 371 points/hour, while the average time necessary for one node point data acquisition by digital plotting system was approximately 10 seconds/point during the technical transfer.

Table 64 Number of node points per one working hour and the time for one node point by the photogrammetry section staff of the DSG

Name	Number of node points *(a)*	Operation time (hour) *(b)*	Number of node points per 1 hour *(c=a ÷b)*	Time for 1 node point (second) *(3600 ÷c)*
Mr. Enias Chinjekure	17,132	49	349	10.3
Mr. John Taruvinga	19,450	49	396	9.1
Mr. Reward Munyeki	17,962	49	366	9.7
Average	18,181	49	371	9.7

Source: JICA Study Team

The average time (10 seconds/point) necessary for one node point data acquisition by digital plotting system is considered as time taken for data acquisition in terms of digital topographic mapping production.

However, this was the first digital plotting work done by the Photogrammetry Section staff during the technical transfer.

Therefore, this average time for one node point data acquisition by digital plotting system is expected to improve and become better than 10 seconds/point during the implementation of digital plotting by the Photogrammetry Section staff.

Since the following three data which are necessary to calculate digital plotting productivity were available, the productivity of 1:5,000 scale digital plotting by staff of the DSG during technical transfer was calculated.

i) Average working hours per day (calculated at 5 hours, excluding lunch break, time necessary for preparation, meeting and so on)
ii) Average number of note points per 1km^2 in 1:5,000 scale digital plotting data
iii) Time required for one node point data

Calculation Formula

Average working hours per day (second)÷Time required to acquire one node point÷Average number of node points per 1km^2 in 1:5,000 scale digital plotting data

= Productivity of 1:5,000 scale digital plotting

These results indicated that productivity on 1:5,000 scale digital plotting by three members of the staff of the DSG participated in technical transfer for digital plotting was approximately 0.09km^2/day/equipment.

Considering the fact that this was the first experience for the members of staff of the DSG in performing 1:5,000 scale digital plotting using digital plotter, the calculated productivity per day of 0.09km^2/day/equipment is low. However, it can be assured that higher digital plotting productivity per day can be achieved as the members of staff of the DSG become more proficient in digital plotting using digital plotter in the future.

The productivity of 1:5,000 scale digital plotting at city area and its surrounding area is considered as approximately 0.22km^2/day/equipment. The productivity on 1:5,000 scale digital plotting was improved as approximately 0.2km^2/day/equipment at the third time digital plotting in other country.

Therefore, it is considered that the target value of the productivity of 1:5,000 scale digital plotting of DSG is $0.2km^2$/day/equipment, and the training to staff of the DSG is necessary to achieve this target value for the Digital Topographic maps production in the future.

3.12.7 Results of lectures and practice for project planning and project management

A questionnaire survey was conducted for the participants in order to evaluate the results of the lectures and practice on project planning and project management for staff of the DSG.

Since almost all the staff of the DSG had no knowledge regarding the average node points per $1km^2$ in 1:5,000 scale digital plotting data, error rate of digital plotting data, the productivity of 1:5,000 scale digital plotting, questionnaire was answered by "Yes" or "No".

The content of questionnaire and its reasons are as follows:

(1) Questions regarding errors of digital plotting data (3 questions)

The content of the questionnaire was questioned to the error types, causes of errors, reduction method of errors that are basic knowledge for quality control of Digital Topographic maps

(2) Question regarding the average number of node points per $1km^2$ in 1:5,000 scale digital plotting data (1 question)

The content of the questionnaire was pointed to the average number of node points per $1km^2$ in 1:5,000 scale digital plotting data that is the basic information for planning and management of Digital Topographic maps preparation.

(3) Questions regarding the error rate in digital plotting data (2 questions)

The content of the questionnaire was pointed to the error rate in digital plotting data in 1:5,000 scale digital plotting data that is the main issues occurred during the implementation of Digital Topographic map preparation

(4) Questions regarding the productivity of 1:5,000 scale digital plotting (3 questions)

The content of the questionnaire was questioned to the productivity of 1:5,000 scale digital plotting that is the basic information for the planning and implementation of 1:5,000 scale Digital Topographic maps preparation by the DSG in the future.

This is the most important item in this questionnaire. The most important target of the lectures is to understand how to estimate the productivity of digital plotting, and how to make a work schedule of Digital Topographic maps preparation based on the productivity of digital plotting by staff of the DSG.

The result of questionnaire survey is shown in Table 65, and analysis of the results of questionnaire survey is described below:

(1) Questions regarding errors of digital plotting data (3 questions)

Three (3) out of 5 members of staff of the DSG answered that they has knowledge of errors of digital plotting data prior the lecture.

These 3 members of staff of the DSG participated in technical transfer of digital plotting and explanation of the digital plotting errors was already executed during the technical transfer of digital plotting. Therefore, this is an expected result.

After completion of lectures, all members of staff of the DSG answered "Yes". Therefore, it is concluded that the members of staff of the DSG obtained the knowledge regarding errors of digital plotting.

(2) Question regarding the average number of node points per 1km^2 in 1:5,000 scale digital plotting data (1 question)

All 5 members of staff of the DSG answered that they do not have the knowledge of the average number of node points per 1km^2 in 1:5,000 scale digital plotting data.

After completion of lectures, all members of staff of the DSG answered "Yes". Therefore, it is concluded that the members of the staff of the DSG obtained the knowledge regarding the average numbers of node point per 1km^2 in 1:5,000 scale digital plotting data.

(3) Questions regarding the error rate in digital plotting data (2 questions)

4 members among the 5 members of staff of the DSG answered that they do not have the knowledge of error rate of 1:5,000 scale digital plotting data.

After completion of lectures, all members of staff of the DSG answered "Yes". Therefore, it is concluded that the members of staff of the DSG obtained the knowledge regarding the error rate of 1:5,000 scale digital plotting data.

(4) Questions regarding the productivity of 1:5,000 scale digital plotting (3 questions)

All 5 members of staff of the DSG answered that they do not have the knowledge of the productivity of 1:5,000 scale digital plotting data.

After completion of lectures, all members of staff of the DSG answered "Yes". Therefore, it is concluded that the members of staff of the DSG obtained the knowledge regarding the productivity of 1:5,000 scale digital plotting data.

Table 65 Results of questionnaire

Y: Yes, N: No.

Question	Person	A		B		C		D		E		Total	
	Answer	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
A. Error of digital plotting data													
1-a) Did you know the error type of digital plotting data before the lecture?		✓		✓			✓		✓		✓	2	3
1-b) Did you understand the error type of digital plotting data after the lecture?		✓		✓		✓		✓		✓		5	0
2-a) Did you know the main reasons for errors of digital plotting data before the lecture?		✓		✓		✓			✓	✓		4	1
2-b) Did you understand the main reasons for errors of digital plotting data after the lecture?		✓		✓		✓		✓		✓		5	0
3-a) Did you know the method of reducing the errors of digital plotting data before the lecture?		✓		✓		✓			✓		✓	3	2
3-b) Did you understand the method of reducing the errors of digital plotting data after the lecture?		✓		✓		✓		✓		✓		5	0
B. Average number of node points of 1:5,000 scale digital topographic data per 1km^2													
1-a) Did you the average volume of 1/5,000 scale digital plotting data per 1 km^2 before the lecture?			✓		✓		✓		✓		✓	0	5
1-b) Did you understand the average volume of 1/5,000 scale digital plotting data per 1 km^2 after the lecture?		✓		✓		✓		✓		✓		5	0
C. Error rate of digital plotting data													
1-a) Did you know how to calculate the error rate of digital plotting data before the lecture?			✓	✓			✓		✓		✓	1	4
1-b) Did you understand how to calculate the error rate of digital plotting data after the lecture		✓		✓		✓		✓		✓		5	0
2-a) Did you know the impact of high error rate of digital plotting data for digital mapping			✓	✓		✓			✓		✓	1	4

project before the lecture?												
2-b) Did you understand the impact of high error rate of digital plotting data for digital mapping project after the lecture?	✓		✓		✓		✓		✓		5	0

D. Productivity of digital plotting												
1-a) Did you know how to calculate the productivity of digital plotting before the lecture?		✓		✓		✓		✓		✓	0	5
1-b) Did you understand how to calculate the productivity of digital plotting after the lecture?	✓		✓		✓		✓		✓		5	0
2-a) Did you know the present and maximum 1/5,000 digital plotting productivity of the DSG before the lecture?		✓		✓		✓		✓		✓	0	5
2-b) Did you understand the present and maximum 1/5,000 digital plotting productivity of the DSG after the lecture?	✓		✓		✓		✓		✓		5	0
3-a) Did you know how to calculate the necessary number of equipment and working period of digital plotting before the lecture?		✓	✓			✓		✓		✓	1	4
3-b) Did you understand how to calculate the necessary number of equipment and working period of digital plotting after the lecture?	✓		✓		✓		✓		✓		5	0

Source: JICA Study Team

3.13 Achievement degree of technical transfer

The achievement degree of each task of the technical transfer implemented in the Project is shown in Table 66.

Table 66 Achievement evaluation of technical transfer (comparison with baseline evaluation)

Relevant field	Technical task in technical transfer	Baseline evaluation	Degree of achievement evaluation
Overall	DSG will understand the issues and problems in connection with data development projects, and will be able to consider the necessary countermeasures for the issues and problems (achievement target).	○	○
	Data acquisition items and map representation rules	△	○
	Determination of map feature codes for digital plotting	○	○
Aerial photography	To be able to execute planning, implementation and managing of aerial photography (achievement target).	○	○
	Preparation of necessary documents for flight permission and application to the aviation authority	○	○
	Understanding of the parameters of digital aerial cameras (difference between digital camera and analogue camera)	×	△
	Aerial photography plan	△	△
	Ground control point distribution plan	△	△
	Understanding of aerial photography equipment	△	△
	Inspection method of aerial photography result	△	○
	Understanding of current technology such as aerial photography using UAV (drones)	○	○
	Understanding of contracts and specifications for outsourcing aerial photography	△	△
Ground control point survey	To be able to execute ground control point survey (GPS survey and leveling), and selection ground control points and establishment of photo signals (achievement target)	×	○
	Survey plan (GPS survey)	○	○
	Selection of ground control points (GPS survey)	○	○
	Air marking	△	○
	GPS observation	○	○
	GPS calculation	○	○
	Survey plans (leveling survey)	○	○
	Selection of leveling point (leveling)	△	○
	Inspection and maintenance of leveling equipment introduced for the technical transfer	○	○
	Leveling observation and recording on field notebook	○	○

	Calculation	○	○
	Preparation of ground control points description	△	○
Aerial Triangulation	To enable Aerial Triangulation and block adjustment using the Aerial Triangulation and block adjustment functions of DPW introduced by the Project (achievement target)	×	○
	Principles of photogrammetry and orientation of stereo model of aerial photos	○	○
	Workflow for preparation of topographic maps by photogrammetry	△	○
	Difference of Aerial Triangulation workflow between conventional method and latest method of digital photogrammetry	△	△
	Work plan	△	○
	Parameters setting to Aerial Triangulation software	×	○
	File management (image data file, others)	×	○
	Setting of digital aerial camera parameters for internal orientation	×	○
	Importing of external orientation parameters by GPS/IMU during aerial photography	×	○
	Observation of tie points and ground control points	×	○
	Check and re-observation of tie points	×	○
	Block adjustment calculation	×	○
Field identification and field completion	Survey plan for large scale topographic maps	△	○
	To enable field identification and arrangement of survey data obtained by field identification (achievement target)	○	○
	To enable the trainees to use outsource GIS software for arrangement of the survey results. To enable trainees to prepare simple GIS data by themselves (achievement target)	△	○
	Understanding of items to be collected for topographic maps	△	○
	Survey method and arrangement method	△	○
	Use of GIS software (vector data)	×	○
	Use of GIS software (raster data)	×	○

Digital plotting and digital compilation	Understanding of technical specifications, mapping standards and map feature-codes for Digital Topographic maps preparation and collection of map feature-codes	△	○
	Acquisition of the basic knowledge regarding digital plotting and digital compilation, which is the process of Digital Topographic maps preparation, through lectures (achievement target)	×	○
	To enable digital plotting using the functions of the DPW introduced by the Project (achievement target)	×	○
	To enable digital compilation work (error check, correction of errors and data integration) using the digital plotting data obtained by technical transfer and CAD software or GIS software (achievement target)	×	○
	Data acquisition (digital plotting)	△	○
	Maintenance of the DPW	×	○
	Method of subsequent renewal and maintenance	△	○
Digital Orthophoto preparation	Preparation of DEM (automatic matching method) and DEM editing	×	○
	To enable the preparation of Digital Orthophotos using the orthophoto preparation function of the DPW introduced by the Project (achievement target)	×	○
	Evaluation of DEM data	×	○
	Orthophoto preparation (orthographic projection transformation)	×	○
	Orthophoto mosaicking	×	○
	Color tone adjustment	×	○
	Evaluation of ortho images	×	○
Map representation and map finishing	Map representation and map finishing method including	△	○
	To enable map representation and map finishing using GIS software (Achievement target)	×	○
Preparation of provided data and promotion of utilization of geospatial datasets	Preparation of GIS basic data from digital topographic data (CAD format)	×	○
	To enable GIS basic data from digital topographic data (CAD data) using GIS software (achievement target)	×	○
	To enable data to be provided to the users using GIS software (achievement target)	×	○
	Extraction of map features from data file (searching based on geographical area or attributes) and storing in a new file, or merging with an existing file.	×	○
	Clipping raster images (orthophoto), and coordinates attachment	×	○

	Data format conversion (conversion from vector to raster)	×	○
	File format conversion	×	○
	Support for sales and promotion of utilization for geospatial information database • Study together with the DSG for promotion of utilization of the DSG products	△	○
	Support for sales and promotion of utilization for geospatial information database • Updating of the DSG catalogue	○	○
	Consulting regarding sales prices setting for geographic information • Study for method of sales price setting for the products of the Project	○	○
Technical support to the data users	Technical support to user organizations (Chitungwiza Municipality Experience of application example of orthophoto maps to their works • Mapping the positions of gates, as practice for digitization of Digital Orthophotos	× (Evaluation of the status of user organization)	○ (Evaluation of the status of user organization)
	Technical support for user organizations (Harare Water) Experience of application examples of orthophotos to their work • Water meter mapping using GIS and Digital Orthophotos	○ (Evaluation of the status of user organization)	○ (Evaluation of the status of user organization)

Source: JICA Study Team

Baseline evaluation (×: no theory or practice, △: knowledgeable with no experience, ○: has theory and practice,)

Evaluation of degree of achievement (×: no achievement, △: theory only required, ○: has acquired understanding of theory and practice,)

In the technical transfer for staff of the DSG, lectures for the theory, principle and OJT regarding with technical task listed on Table 64 were implemented.

As described in the sections for each technical transfer under this chapter (Chapter 3), it is evaluated that each technical transfer items has been achieved.

Through the technical transfer, it was evaluated that staff of the DSG understood the principles and knowledge of photogrammetry and promotion of utilization of geospatial information database, and also became able to execute preparation of Digital Topographic map and Digital Orthophoto. In the Table 64, degree of achievement evaluation of many times are shown by the symbol "○".

In this technical transfer, the practical training on various technical fields with the aim of introducing the equipment and software was implemented. Target topics of practical training and hardware and software which were used in the training were new to staff of the DSG.

Time period for the technical transfer is limited, and aim of the technical transfer is to introduce base equipment, knowledge, and skill as fundamental of digital mapping by the DSG. Focus of evaluation in the Table 66 is achievement on introducing basic skill and knowledge into the DSG. However proficiency levels in this respect are also determined by the DSG being able to provide adequate budget and structure commensurate with the task at hand.

The basic knowledge and technologies for Digital Topographic maps and Digital Orthophotos preparation was transferred to staff of the DSG, and also the minimum equipment for the preparation of Digital Topographic maps and Digital Orthophotos was introduced in the DSG for the future preparation of geospatial information database by the DSG themselves.

It shall be expected that the DSG is in a position to undertake the preparation of new Digital Topographic maps and Digital Orthophotos by themselves

The issue for the DSG to continue practicing and exercising harder everything they acquired from the training during the technical transfer period, with the objective of generating high quality geospatial products and services in future.

4. Preparation and management of data to be provided and promotion of geospatial information database

The series of activities for promoting the utilization of geospatial database and digital topographic maps as are shown in Table 67 were implemented with the objective of facilitating prompt and appropriate utilization of the digital topographic maps, digital orthophoto maps with contour lines and geospatial information distributed by DSG.

The activities were divided into these periods and were implemented within the three periods: the first period (June to July 2015), second period (August 2016) and third period (February to March 2017).

Recommendations concerning the utilization of the products were compiled in item 7) based on the series of activity results described in item 1) to 6) below, and discussed with the staff of DSG.

Table 67 Activities to promote utilization of geospatial information and implementation period

Implementation Item [No.] is item No. in this document	Details		1st Period Jun. – Jul. 2015	2nd Period Aug. 2016	3rd Period Feb. – Mar. 2017
1. Collection of basic information for recommendations on utilization of the products **[4.1]**	Survey of infrastructure development plan in the project area	[4.1.1]	■		
	Survey of needs and requests by related agencies concerning utilization of results, etc.	[4.1.2]	■		
	Obtain a grasp of use status of GIS technology etc. by user organizations	[4.1.3]	■		
2. Holding of inception seminar **[4.2]**	Holding of inception seminar	[4.2.]	■		
3. Preparation and management of data to be provided **[4.3]**	Obtain a grasp of need for data to be provided	[4.3.1]	■		
	Review of data to be provided spec. formulation, preparation technique, distribution, etc.	[4.3.2]		■	■
	Technology transfer for preparation and management of data to be provided	[4.3.3]			■
4. Support for sales and utilization promotion activities for DSG geospatial information products **[4.4]**	Review of dissemination promotion with DSG	[4.4.1]		■	
	Updating of DSG product catalog	[4.4.2]			■
	Preparation of explanatory document regarding handling of digital data	[4.4.3]			■
5. Consulting for setting of geospatial information sales prices	Review of the existing DSG rules	[4.5.1]	■		
	Collection of case studies in Japan and various foreign countries	[4.5.2]	■	■	

[4.5]	Review of price setting methods for the products of the Project	[4.5.3]		▬	
6. Technical support to user organizations **[4.6]**	Holding of workshops concerning the products and software	[4.6.1]		▬	
	Items that should be considered in technical support results and countermeasure for these	[4.6.2]		▬	
7. Recommendations for the utilization of results **[4.7]**	Recommendations concerning the utilization of the projects	[4.7.1]			▬
8. Holding of the final seminar [**4.8]**	Holding of the final seminar	[4.8]			▬

Source: JICA Study Team

4.1 Collection of basic information for recommendations concerning utilization of the products

Collection of basic information in order to review recommendations concerning the utilization of the products by the Project, and a survey outlined below for the related organizations (hereinafter referred to as "user organizations") envisioned to be the main users were implemented immediately after the project was started.

- Survey concerning infrastructure development plans in the project area to grasp the user organizations of the Project products
- Survey of needs and requests for utilization of the products of the Project by user organizations

Opinions of the user organizations concerning how to use the products, a portion of the specifications of the products, price of the products, distribution methods and other details of the products were obtained with the above surveys.

The results of the surveys were reflected in each subsequent activity for the promotion of the utilization of the products as the basic information. The details of the two surveys implemented are described below.

4.1.1 Survey of infrastructure development plans in the project area (Harare City and its surrounding area)

A survey was carried out to grasp infrastructure plans in the project area which is expected to utilize the products of the Project such as digital topographic maps, digital orthophoto maps with contour lines, and for the planning for utilization promotion of the products to be prepared by the Project.

The door-to-door survey of user organizations was implemented. Target organizations of the survey were selected from organizations that were expected to be users of the projects product based on the information that was collected during the detailed planning survey mission for the Project implemented in January 2015 and the "Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZIM ASSET)2013-2018, the five-year development plan of Zimbabwe, formulated in 2013.

The following eight organizations were selected for door-to-door survey.

- Agricultural Technical and Extension, Ministry of Agriculture, Mechanization and Irrigation
- City of Harare and Harare Water; Chitungwiza Municipality
- Epworth Local Board
- Civil Engineering Dept., Ministry of Local Government, Public Works and National Housing
- Urban Planning Dept., Ministry of Local Government, Public Works and National Housing
- Irrigation Dept., Ministry of Agriculture, Mechanization and Irrigation
- National Water Authority.

Table 67 and Figure 37(after the next page) show the infrastructure development plans for which reviews are being conducted or actual development is being implemented in the digital topographic maps and digital orthophoto maps with contour lines preparation area by the Project.

In particular, the high-resolution digital orthophoto maps with contour lines showing the present artificial features and land cover will be able to show the details of facility condition and land cover conditions for water supply and sewage management, road management, urban planning, construction of the new capital and other purposes better than satellite images.

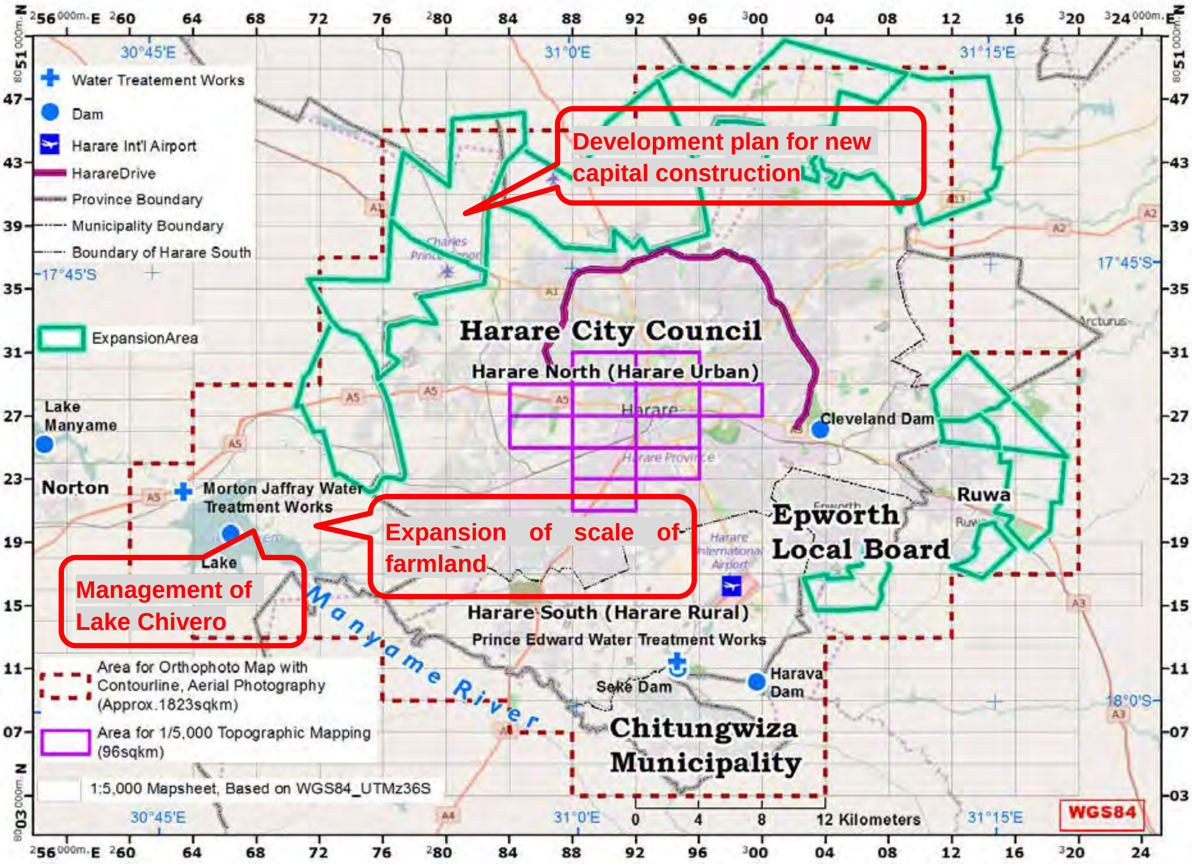
The contour line on digital orthophoto maps is effective to show the difference of elevation (topographic undulation) in addition to land cover when water pipe installation plan and large-scale farmland plan are reviewed.

Thus, it is expected that digital topographic maps and digital orthophoto maps with contour lines will be utilized in various fields. The effectiveness at each user organization is described in the Section 4.1.2.

Table 68 Infrastructure development plans being formulated and implemented in the project area

Field	Plan Overview	Conditions, etc.
Water supply and sewage facility management	• Repairs of water purification plant, sewage treatment plants and pumps were implemented under African Development Bank project (first period). Water pipe repairs (4km throughout the Harare City) have been planned in the second period which is up until 2017.	• Repairs of water purification plant at Lake Chivero are currently proceeding. • There is a possibility that repairs of water supply and sewage facilities in each city are not being implemented as planned due to financing concerns. • Each city (Harare, Chitungwiza, etc.) is in charge of water supply and sewage repairs.
Dam construction and water pipe installation	• Plans are proceeding for construction of two dams in the northeastern part of Harare City and for laying of water pipe to Harare City from the dams, and a portion of them are included in the project area. • There are plans for laying of water pipe to area around the new parliament building due to construction of the new capital.	• The Ministry of Environment, Water and Climate has jurisdiction over dam construction and water pipe installation, but the facility is handed over to the relevant local government after completion.
Road management	• Plan for four-lane road (two lanes each side) between Harare City - Mutare City, and Harare City - Beitbridge • Repair plan for roads in target area	• Item to left is for widespread area highways. New road plans in the Project area (Harare City and its surrounding area) are limited to ones based on urban plans.
Urban planning	• Development and expansion of urban areas (e.g. conversion of farmland in south- western part of Chitungwiza Municipality to residential land) • Development and legalization of illegal residential areas (Epworth, etc.). • Continuous preparation of plans in the Harare City.	• According to World Bank materials, it is expected that urban area will be expanded in the northern and western part of Harare City. In addition, it is also expected that urban area will be expanded in Chitungwiza Municipality, Ruwa and Epworth. • In the southern part of Harare City, infrastructure development is behind in the northern part of the city such as water supply and sewage, roads and other facilities development
Farmland	• Expansion of large-scale farmland in area around Lake Chivero. • Reuse of waste water for farming.	
Other	• Construction of the new capital. • Construction of schools, hospitals and other public buildings in Harare City. • Maintenance of Lake Chivero (improve water quality, etc.).	

Source: JICA Study Team



Service Layer Credits: (c) OpenStreetMap and contributors, Creative Commons-Share Alike License (CC-BY-SA)

Source: JICA Study Team

Figure 37 Infrastructure development plan survey results for the project area

(Areas where development is proceeding or planned)

4.1.2 Survey for needs and requests for utilization of the products by related organizations

Organizations were visited to conduct a survey of needs and requests for utilization of the products of the Project by user organizations selected immediately after the Project was started. The results of the survey are shown in Table 69.

Table 69 Results of door to door survey visit to user organizations concerning utilization of the products of the Project

Organization name Role of organization	Project products utilization needs, request for data content and specifications User organization status	Results Survey date
Agricultural Technical and Extension, Ministry of Agriculture, Mechanization and Irrigation	• Wetland map, agro ecological map and other main maps are prepared in cooperation with DSG using DSG map as base map. Data specifications will comply with DSG specifications for digital topographic maps and orthophoto that are the base map this time. • Digital orthophoto are effective for obtaining a grasp of detailed conditions of wetlands, and using and expanding the farmland properly as countermeasures to prevent sediment runoff from farms to Lake Chivero.	Digital orthophoto with contour lines are effective for obtaining a grasp of land cover conditions to facilitate proper farmland usage and conversion into larger scale, including current farmland usage conditions, as well as for reviewing placement of agricultural canals and drainage canals based on height difference of planned site. They are also effective for reviewing measures to prevent sediment runoff from farmland to Lake Chivero.
• Dissemination of agriculture technology to farmers such as information on farmland suitability and crop suitability	• Using equipment is being obsolescence and with difficulties to use of current advanced digital data. • Still use a GIS from years ago software such as Ilwis.	July 7, 2015
City of Harare and Harare Water	• Current maintenance of facilities is paper based. It is helpful for work to convert facility information into digital maps using digital topographic maps and orthophoto as base maps. • Land height difference and distance information is important for creating digital maps for facility information (pipe network). • WGS84 is good, but preparing software used for coordinates conversion of the existing land register (cadastral) information etc. is an issue. • Interest in data use price • 1:2,500 scale digital topographic map is required depending on location.	Mapping of pipeline information on digital topographic maps, high resolution digital orthophoto and contour lines enables grasping of land height difference for a location where pipe is to be laid and approximate pipeline distance. In addition, it leads to creation of pipeline network database in the future. Use of high resolution digital orthophoto enables mapping of water meter and manhole locations with high precision (how far and what can be seen is a future review item), and contributes to boosting efficiency and precision of management diagram preparation.
• Water supply to Greater Harare Metropolitan Area • Water supply and sewage management in Harare City	• ArcGIS and QuantumGIS are being used as GIS software. • Water meter mapping is implemented in several tens of centimeter units with RTK-GPS. • Transition from paper based facility management to GIS is an issue.	July 9, 2015

Chitungwiza Municipality	• Geospatial information is required for water supply and sewage, roads, urban planning, as well as for firefighting and emergency service operations. • Mapping is needed for water supply and sewage facilities, sewage pipe networks, tanks, water meters, street lights and wireless relay towers.	High resolution digital orthophoto enable grasping of locations of water supply and sewage facilities, tanks and other items (how far and what can be seen is future review item). In addition, firefighting and emergency service activities related to saving human lives can be implemented based on an understanding of the surrounding conditions.
• Entire municipal government	• Conversion to IT including introduction of GIS is proceeding, and scheduled for completion by 2018. Nearly 20 persons participated in meeting, showing a high level of interest.	July 10, 2015
Epworth Local Board	• The area is developed as result of populating illegal residences in the state land. Urban planning that includes legalization measures for squatter areas is a paramount issue, and the accompanying cadastral survey has been started.	High resolution digital orthophoto is more effective for extraction of squatter areas than satellite images.
• Entire local board government (roads, water pipes, urban planning and development, construction confirmation, etc.)	• Secretary General and each local board directors attended, showing a high level of interest. • There are staff members who have received GIS training, but work is paper based (regarding the utilization of ICT for work, one staff has one PC).	July 10, 2015
Civil Engineering Dept. Ministry of Local Government, Public Works and National Housing	• Large scale precision maps (1:500 scale) for limited area are needed for construction work, and 1:5,000 scale topographic maps cannot substitute the engineering survey results for construction work. However, they are useful as planning maps for engineering surveys. They are even more useful if the past survey points and cadastral information can be superimposed on the maps.	Digital topographic maps, digital orthophoto and contour lines are effective for formulating civil engineering survey plans for construction and engineering work. They are even more useful if cadastral information can be superimposed on them.
• Construction of schools, hospitals, police stations and other public facilities		July 13, 2015
Urban Planning Dept., Ministry of Local Government, Public Works and National Housing	• Using digital orthophoto reflecting the latest conditions with super-imposing with old existing 1:5,000 scale topographic maps as supplemental information is beneficial. • Maps should be output in up to A0 size. • Beneficial if cadastral information is integrated.	Since urban planning has been implemented based on DSG 1:5,000 scale maps, the products of the Project are extremely beneficial. The products would be even more useful if cadastral information can be superimposed on digital topographic maps and digital orthophoto.

• Urban planning for state land • Consulting for urban planning by local governments	• AutoCAD is used for design, but also interested in introduction of GIS. • The issue is computers being used are old.	July 13, 2015
Irrigation Dept., Ministry of Agriculture, Mechanization and Irrigation	• There are experimental farms in the northern part of Harare City, and installation of wells is planned. Elevation information is needed for those locations. • Waste water is being used with the objective of preventing pollution of Manyame river system in the area surrounding Chitungwiza Municipality. • SHP is an appropriate file format. • Cadastral data and survey control point information are also important.	Digital orthophoto with contour lines (2m) are effective for review of waste water canal placement regarding height difference in planned area for farmland irrigation projects. They are also effective for waste water from farms and waste water treatment measures with the objective of preventing pollution of Manyame river system.
• Irrigation and other projects for state land	• AutoCAD is being used for irrigation design. DSG cadastral maps are also being used. • Following equipment and software is possessed: SURPAC Model Maker (Survey Package), Model Make, RTKGPS (made by Trimble). • They do not know about Quantum GIS (QGIS), but showed interest in the lectures for it. • Proper internet usage environment is not available.	July 13, 2015
National Water Authority (ZINWA)	• Construction of two dams in the northeastern part of Harare City is being designed and planned, so the results will be effective for laying of water pipes from the dams to the city. They want detailed elevation data that can be used for water pipe laying plans. • When construction of the new capital is implemented, water pipes will be laid to the new capital. • Topographic maps are better than digital orthophoto. Concerned that buildings may cast shadows on trees in digital orthophoto. • Want maps to be output in A1 size. • Price of 10 US$ for data is appropriate, which is the same as price of the existing topographic maps.	Digital topographic maps can be provided for the center of Harare City. How to handle this issue will be discussed by DSG and the National Water Authority.
• Construction of dams, water pipes and other related facilities	• Model Maker and ArcGIS are being used as GIS software.	July 14, 2015

Source: JICA Study Team

The results of survey by visiting user organizations indicate that there is a high possibility for the utilization of the products of the Project by the respective user organizations.

In particular, it was confirmed that there is a high level need for utilization of digital orthophotos and contour lines that cover the entire survey target area.

It was confirmed that it is important to publicize how to use the products of the Project, especially digital orthophoto maps with contour lines, through subsequent seminars and technical support.

4.1.3 Utilization status of GIS and other technologies by user organization

Actual user need, concerns for data usage and other issues were grasped by examining actual utilization status of the related user organizations. That information was used as basic information for the appropriate provision format and method of the products.

In the door-to-door survey results in the Section 4.1.2, it was confirmed that four out of the eight organizations are using GIS: Agricultural Technical and Extension in Ministry of Agriculture, Mechanization and Irrigation; City of Harare; Irrigation Dept. in the Ministry of Agriculture, Mechanization and Irrigation; and National Water Authority. The main GIS software that is being used was ArcGIS. Even other organizations not using GIS currently have plans to innovate GIS and receive GIS training as an integral part of their transition to IT. Organizations that were mainly involved in operations related to civil engineering design were using AutoCAD and other CAD software.

In general, for the utilization of ICT, the issue for concern is whether the users will be able to meet the hardware, software and communication maintenance costs. In each organization, it was found that internet connection can hardly be used even though those have been introduced, the equipment has not been updated, and the PCs and software that are being used are too old to utilize the products of the Project.

Table 70 shows the requests from user organizations concerning the specifications and other details for the products to be delivered and the current situation of user organizations, and the policies to deal with such issues and requests.

Table 70 Requests concerning specifications for provided products and countermeasure policy

Items	Requests for specifications and countermeasure policy	
Geodetic datum	Request	• There were no opinions that voiced against the adoption of WGS84, but a coordinates conversion service was requested for integration of the existing data with Arc1950 and with different projection methods.
	Countermeasure policy	• Coordinates conversion service will be implemented by DSG, and the technology transfer required for this to DSG will be implemented.
Vector data format	Request	• SHP, DWG and DXF were used by many organizations, and there were no requests for special formats. • Several organizations do not have experience using GIS and CAD, so there was a concern regarding the handling of vector formats with GIS and CAD software.
	Countermeasure policy	• Data will be distributed in SHP, DWG and DXF format which are common formats that can be used with multiple GIS and CAD systems. Transfer of the technology to DSG required for data conversion will be implemented. • Conversion of vector format data and provision as raster images will be considered as a countermeasure for users who do not use GIS and CAD software, users who do not need to use advanced vector data, and users who use old computer.
Raster data format	Request	• There were no examples of using special formats. In addition, there were no requests for other than the TIFF format which is a common format. Location information is recorded in World Files or as header information.
	Countermeasure policy	• Support with World File will be studied considering general versatility and ease of understanding. When a World File is used, location information is seen since location information of an image is independently described as a text file. When this data is stored as header information of an image, there is a concern that the header information may be deleted inadvertently by the user since it is difficult for the user to see.
DEM data	Request	• There was a request by some organizations to develop and provide DEM data.
	Countermeasure policy	• Technical transfer to DSG concerning DEM preparation will be implemented
Existing data that demanded to be integrated	Request	• Cadastral data • Geodetic control point (triangulation point, bench mark) data • Boundary data
	Countermeasure policy	• Recommendations will be made to DSG regarding the preparation of integrated products containing cadastral and other data managed by the DSG Cadastral Division.
Map output service	Request	• There were many requests for A0 size, but there were also requests that the same A1 size as for the existing 1: 50,000 scale topographic maps is preferable, and also statements that it is possible to use A3 size.
	Countermeasure policy	• Recommendations will be made concerning a review with DSG of map output service.

Data price	Request	• There were many requests to provide data at a low price or free of charge. • There was an opinion that it should be approximately the same price as of paper 1:50,000 scale topographic maps (10 US$/1 sheet) is appropriate. (The unit (map framework unit, area unit, etc.) when digital data is distributed is an issue that will be discussed in the future)
	Countermeasure policy	• Consultation will be implemented for DSG concerning the setting of the sales price, using the above requests as a reference.
Secondary usage	Request	• None in particular (interviews of private sector have not been conducted).
	Countermeasure policy	

Source: JICA Study Team

4.2 Inception Seminar

Immediately after the Project was started, a seminar was held to which user organizations were invited in order to promote utilization of digital topographic maps and digital orthophoto maps with contour lines.

The Minister of Lands and Rural Resettlement and the Ambassador of Japan to Zimbabwe attended the seminar.

(1) Seminar content

This seminar was held with the intention of introducing and publicizing the content and the products of the Project to government organizations in Zimbabwe, international organizations and other organization who are expected to be users in the future.

The date, time and location of the seminar are described below. The seminar program is shown in Table 71.

Date and Time: July 3, 2015, 10:00 to 12:00

Location: Rainbow Tower Hotel (Harare City)

Content: Described in the Table 71

Table 71 Content of inception seminar

No.	Time	Seminar program and presenter
1.	9:30	Registration
2.	10:00-10:10	Self-introduction by Participants
3.	10:10	Opening: the Master of Ceremony asks the Surveyor General to introduce the Honorable Minister of Lands and Rural Resettlement for the opening address

4.	10:15 - 10:25	Opening address by the Honorable Minister of Lands and Rural Resettlement
5.	10:25 - 10:30	Opening address by His Excellency, the Ambassador of Japan
6.	10:30 - 10:35	Group photo
7.	10:35 - 10:55	Tea/ Coffee break
8.	10:55 - 11:15	Current Status of Topographic Mapping in Zimbabwe and Expected Project Outputs: Mr. Nadambakuwa, Department of the Surveyor-General
9.	11:15 - 11:30	Project Outline: Mr. Yoshiteru Matsushita, Team Leader of JICA Study Team
10.	11:30 - 11:50	Project Components and Implementation Approach: Dr. Courage Kamusoko, JICA Study Team member
11.	11:50 - 12:05	Utilization of Digital Topographic Maps and Orthophoto Image: Mr. Hiromichi Maruyama, JICA Study Team Member
12.	12:05 - 12:10	Closing Remarks by the Acting Surveyor General: Mr. Canaan Ndambakuwa, Department of the Surveyor-General

Source: JICA Study Team

(2) Seminar invitees

Including the central government organization in Zimbabwe, a wide range of related organizations envisioned to use the 1:5,000 scale digital topographic maps and orthophoto maps with contour lines of the products of the Project were invited for seminar.

The selection of invitees was done to be invited was decided by DSG. A list of organizations to which invitations were sent is shown in Table 72. In total, 66 persons including the press attended the seminar. Subsequently, the presses that were invited broadcasted scenes of the seminar and interviews with the Ambassador of Japan to Zimbabwe and the Minister of Lands and Rural Resettlement on television news on the next day.

An article was posted on the ZBC TV station website (link shown below)
http://www.zbc.co.zw/news-categories/local-news/57971-new-harare-map-on-the-cards

Table 72 List of organizations to which invitations were sent

Local Government or Municipalities in the Project area
• City of Harare
• Chitungwiza Municipality
• Epworth Local Board
Users of Geospatial Information Database
• Department of Civil Engineering and Works, City of Harare
• Harare Water, City of Harare
• Forestry Commission
• Ministry of Transport and Infrastructural Development
• Ministry of Health and Child Care

• Ministry of Agriculture, Mechanisation and Irrigation Development
• Ministry of Local Government, Public Works and National Housing
• Ministry of Finance and Economic Development
• Ministry of Tourism & Hospitality Industry
• Ministry of Mines and Mining Development
• Ministry of Foreign Affairs
• Geological Survey
• Ministry of Higher and Tertiary Education, Science and Technology Development
• European Union
• German International Cooperation Agency
• African Development Bank
• World Bank (Project for Water facilities improvement)
• USAID
• Environmental Management Agency (EMA)
• Zimbabwe National Statistics Agency (ZIMSTAT)
• Zimbabwe National Water Authority (ZINWA)
• Department of Geography and Environment, University of Zimbabwe
• Department of Geomatics, University of Zimbabwe
• Scientific and Industrial Research and Development Centre
• Survey Institute of Zimbabwe (Not yet specified)
• Communication companies: Econet, NetOne, and Telcel

Source: JICA Study Team

Photo 23 and Photo 24 shows the scenes of the seminar.

Left Photo: Acting the Surveyor-General, Deputy Acting Assistant Director General, Minister of Lands and Rural Resettlement, Ambassador of Japan to Zimbabwe, JICA Study Team Leader

Right Photo: Venue

Source: JICA Study Team

Photo 23 Inception seminar

Source: JICA Study Team

Photo 24 Group photo of seminar participants

(3) Preparation and operation of inception seminar

Preparation for the seminar and operation on the day of the seminar were executed by the staff of DSG and the member of JICA Study Team jointly.

However, since the ground control point survey was also carried out during the preparation period and on the day of the inception seminar, the staff of DSG who participated in the ground control point survey could not attend the seminar.

(4) Opinions voiced by seminar participants

A number of opinions were voiced by the participants during the question and answer time. Excluding the issues that were not directly related to the Project and items to be checked and requested to DSG, the following three issues were raised: transition to WGS-84, introduction (dissemination) of digital technology (GIS), and copyright issues.

- "WGS-84 will be used for the Project, but almost all existing data for Harare is based on the old Arc1950 geodetic datum which is a local geodetic system. Therefore, coordinates conversion will be necessary for the data integration. Have preparation been made for the transition to WGS-84?"

- "GIS and other knowledge and technology will be necessary to handle digital information when changing from paper topographic maps to digital topographic maps. Isn't particularly important to develop related capabilities?"
- "If digital data is provided, isn't necessary to clarify copyright issues?"

JICA Study Team and DSG were both aware of the existence of these three issues, but it was confirmed how the users recognizes these issues through the seminar.

Countermeasures to deal with these issues were implemented during subsequent activities for promotion of utilization of the products.

4.3 Preparation and management of data to be provided

The digital topographic maps and digital orthophoto maps with contour lines that are the products of the Project, and the data that is derived from these items will be sold and distributed by DSG.

Consultation and technical transfer to the staff of DSG were implemented regarding data specifications, production techniques, distribution method and other issues when DSG provides data to users.

4.3.1 Needs for data to be provided

The survey for infrastructure development plan in the Project area, and the survey for needs and request by user organizations summarized in Section 4.1 indicate that there is need for the following data and services out of the digital topographic maps, digital orthophoto maps with contour lines and other geospatial information data managed by DSG.

- Orthophoto and 1:5,000 scale topographic maps
- Integration of cadastral information, geodetic control points and boundary information with orthophoto and 1: 5,000 scale digital topographic maps
- DEM
- Geodetic datum conversion services between Arc1950 geodetic datum of the existing data and WGS84 that was adopted with the Project
- Map output service in A0, or in A1 which is the same size as the existing 1:5,000 scale topographic maps

This content was used as basic information for the study of specifications of the products, preparation techniques and distribution methods of the products to be provided described in the next Section 4.3.2.

4.3.2 Review of specifications, preparation techniques and distribution methods of the products to be provided

In order to facilitate utilization of the products of the Project by a wide range of users, it is necessary to prepare easy-to-use products and to deliver them to users quickly.

For this purpose, in consideration of the survey results to determine the needs of user organizations conducted during the first period, 1:5,000 scale digital topographic maps and digital orthophoto maps with contour lines with a ground resolution of 20cm, a 1:34,000 scale Harare Street Map and the preparation of derived products that integrate with other data were reviewed, and a product proposal to be distributed and issues were summarized in Table 73.

Table 73 Proposal for the products to be provided

Product proposal	Overview	Issue	Related technology transfer	Expected issues to be handled within DSG
Land parcel and land owner information extracted from cadastral information	• Digitize cadastral information, and correct it to WGS84 UTM36S (correct it to overlap digital orthophoto) using digital orthophoto	• Digitizing of cadastral information • Compliance with privacy protection	• Digitizing of existing map information • Positioning of the existing map information in which ellipsoid and projection methods differ	• Determine policies to digitize cadastral information • Formulate a precise plan
Guide and other theme maps for specific locations and facilities	• Theme maps in response to user requests, e.g. Guide Maps for Harare Garden, Lake Chivero, Police Station	• Need to respond to each request. Opinion that there should be standard products (ready-made products)	• Preparation of theme maps	• Need to decide whether to aim for customized products and ready-made products
Town Atlas Harare Street Map Booklet Edition	• 1:10,000 map output + POI collection maps	• Detailed review is needed for precise specifications	(None)	• Need to decide intentions for creating products

Source: JICA Study Team

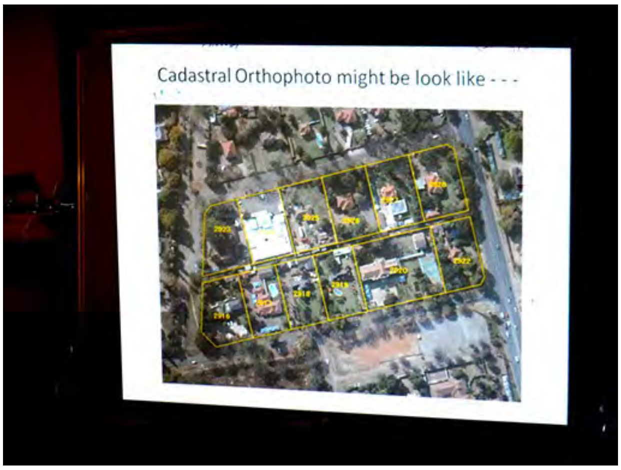


Photo 25 Review with the staff of DSG concerning data to be provided

4.3.3 Technical transfer for preparation and management of data to be provided

Data conversion, clipping and other processing are required when DSG provides digital topographic maps and digital orthophoto maps with contour lines to users as digital data.

Technical transfer to the staff of DSG was implemented for the following operations using GIS software required for data processing.

- Data format conversion (vector and raster conversion)
- Conversion of file record format (file format)
- Extraction of content (Extract specific planimetric features and clipping of specific geological range according to user objectives)
- Changing of file record unit (Change from seamless to framework unit)

In addition, DSG needs to manage digital topographic maps, digital orthophoto maps with contour lines and other various types of data.

Technical transfer necessary techniques for the data management of digital topographic maps and digital orthophoto maps with contour lines by the method of lectures and practice

4.4 Support for sales and dissemination promotion of geospatial information products of DSG

In order to facilitate wide-spread utilization of the products of the Project reviewed in Section 4.3.2 and derived products, sales and dissemination promotion activities need to be implemented to publicize the existence and content of the products, and the activities of DSG to the users.

Concerning dissemination promotion measures, updating of DSG product catalog, preparation of explanation of digital data and other issues were discussed between DSG and JICA Study Team.

These review results were reflected in the recommendations form the JICA Study Team, for sale and dissemination promotion activities.

4.4.1 Review of promotion measures with the staff of DSG

In order to facilitate wide-spread utilization of digital topographic maps and digital orthophoto maps with contour lines, which are the products of the Project, as well as derived products, dissemination promotion activities are necessary to publicize the existence and content of the products, and the activities of DSG to users.

Based on the dissemination promotion activities conducted by the Geospatial Information Authority of Japan and the Japan Map Center that provides geospatial information prepared by the Geospatial Information Authority Japan, the available dissemination activities by DSG discussed and reviewed between DSG and JICA Study Team. The results are shown in Table 74.

Table 74 Dissemination promotion measures

Booth at Exhibition	• Currently, DSG has booths at the Agricultural Expo held in August and at the International Trade Fair held in April and May at which it introduces the content of its activities, and promotes products. • It also does promotion with other booths (examples: School fairs, Tourism expo).
Enhancement of DSG Website	• IT team has plans to update the website in the UNDP project. The website is used to publicize the dissemination promotion activities.
Opening of Exhibition Area	• There is an exhibit area with maps and survey instruments using the unoccupied exhibition space across from the map sales shop on the ground floor in the DSG headquarter building that is used to raise public awareness of surveying and map-making.
Reach out Seminars	• Last year, a lecture by DSG staff on surveying and map-making was given at the University of Zimbabwe in response to a request from the university. • It is important to accept this type of request from various organizations.
Approach to Youths	• Activities need to be implemented to have the general public in Zimbabwe become familiar with maps from a young age.

Source: JICA Survey Team

Source: JICA Study Team

Photo 26 DSG booth at Agricultural Expo (held August 22 to 29, 2016)

4.4.2 Updating of DSG products catalog

DSG has plans to sell and distribute digital topographic maps and digital orthophoto maps with contour lines after completion of the Project.

A catalogue for the project products was developed by the DSG and JICA Study Team as sales and dissemination promotion measure to facilitate prompt and effective utilization of digital topographic maps and digital orthophoto maps with contour lines.

In addition, an explanatory document (draft) was prepared to enhance understanding of the geodetic reference system, map projection system, World File and other items for the digital data that was prepared by the Project.

Currently, DSG is distributing beautiful printed color catalogs to users, but it was prepared more than 15 years ago, and does not include the new project product catalogue was carried out. It is necessary that a separate catalogue for the DSG/JICA project products be developed, and a comprehensive catalogue will be developed when the products of other projects being undertaken by the DSG are documented.

(1) Steps in developing a new catalogue

1) Members

JICA Study Team and the members of the DSG's Cartography and Reprographics sections implemented the review of a new catalogue.

2) Review policy

At first, the policy for updating of product catalog was discussed and following policies were adopted.

- Will be an independent catalog from the existing catalog
- Will keep the cosmetic appearance of the existing catalog

a) Catalog will be an independent catalog from the existing catalog.

To avoid the complication with the existing 1:5,000 scale topographic maps, new catalog will be made independently.

b) Catalog will not keep the cosmetic appearance of the existing catalog

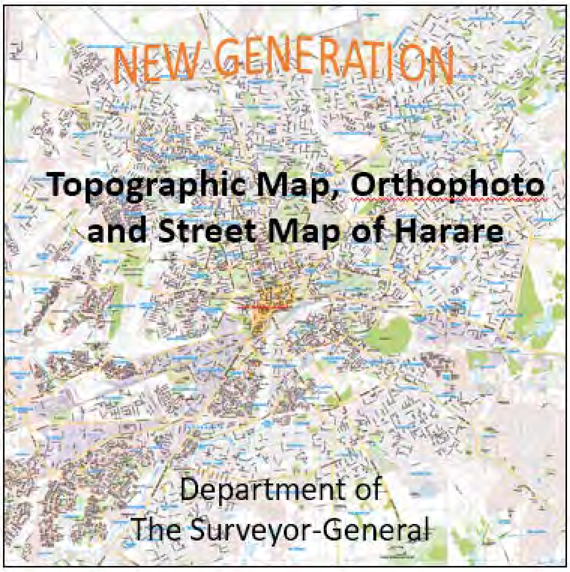
The paper size of the existing catalog is acquired.
And it is not convenient for editing by software.
Therefore, new catalog will be prepared on A-4 size.

3) Preparation of draft

The basic visual design for the product catalog for the following products will have an explanation on the left page of two pages spread, with the maps and photographs on the right page.

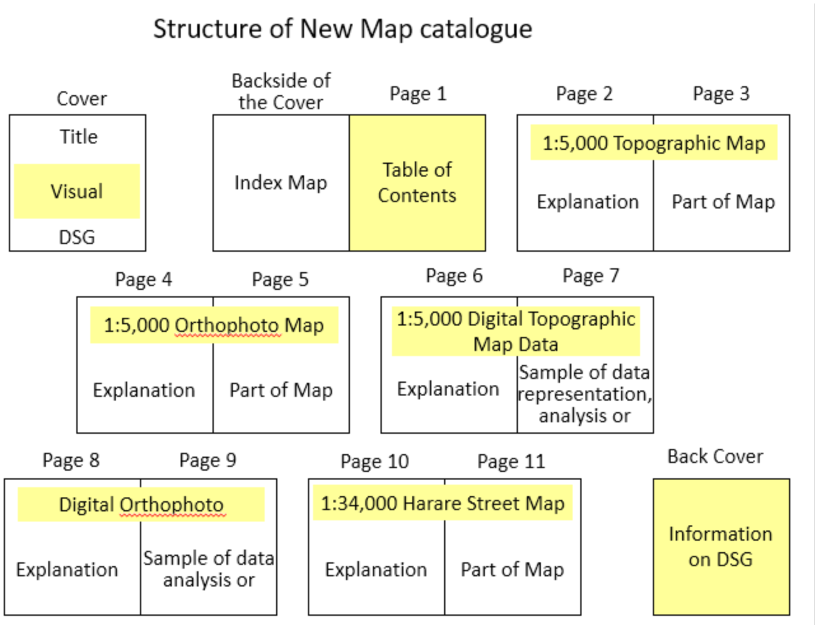
- 1:5,000 scale topographic maps
- 1:5,000 scale orthophoto maps
- 1:5,000 scale digital topographic maps
- 1:5,000 scale digital orthophoto
- 1:34,000 scale Harare Street Map

The cover and configuration (structure) of the overall new product catalog are shown in Figure 37 and Figure 38.



Source: JICA Study Team

Figure 38 New catalog cover (proposal)



Source: JICA Study Team

Figure 39 New catalog structure (proposal)

An action plan to prepare a new catalog based on the prepared draft was reviewed. The action plan content is shown in Table 75.

Table 75 Action plan for creation of new catalog

Activity	Division in Charge	Required Equipment	Deadline
Decide final specs. based on draft	Photogrammetric	PC	April 28, 2017
Preparation of each page	Photogrammetric	PC, drawing software	June 30, 2017
Editing	Map	PC	July 31, 2017
Preparation and printing of final version	Photogrammetric	PC, printer	August 31, 2017
Management and distribution	Administration	Locker	

Source: JICA Study Team

4.4.3 Preparation of Explanatory Document regarding Handling of Digital Data

Based on the products of the Project, DSG will provide 1:5,000 scale digital topographic maps (vector data) and digital orthophoto image (raster image data) for the first time.

Differing from paper topographic maps, a document that clearly explains the data specifications, geodetic reference system, map projection system, and other items is needed for such digital data.

These are provided as metadata in recent years. However, a review of catalog was implemented with the staff of DSG from the view point that the first time users to understand the content of data to be provided.

(1) Members

A review was executed with Acting Chief Technician of the Photogrammetric Section who is familiar with the new products specifications of the Project.

(2) Review policy

As the results of review for content of explanatory document, the following policies were adopted.

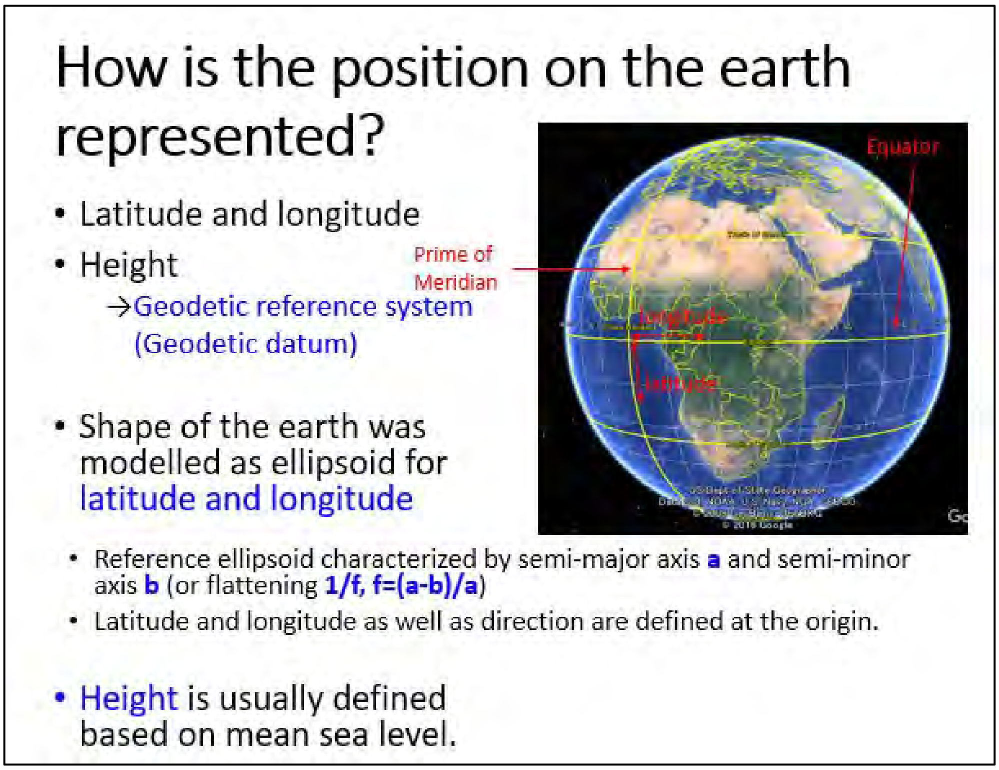
- The explanatory document will be common for the products of the Project.
- Basic knowledge and flow of topographic map preparation will be explained in an easy to understand geodetic system, map projection system, map symbols and other related items.
- Explain World File that determines digital data format and the location of raster data.
- Geodetic system, map projection system, data format of the products of the Project, as well as the specifications for digital photographs will be included in explanation

(3) Preparation of draft

A draft of the explanatory document with the following configuration was prepared. A portion of the document is shown in Figure 40.

Title: Using Topographic Maps

- What are topographic maps?
- How are the locations on the earth represented?
- How are objects on the earth represented?
- How are topographic maps prepared?
- Digital topographic maps
- Basic specifications for JICA Harare Geospatial Information Development Project



(Expression of position on the earth with latitude and longitude)

Source: JICA Study Team

Figure 40 Portion of explanatory document (draft)

4.5 Consulting for sales price setting for geospatial information database

In order to achieve prompt and effective utilization of digital topographic maps and digital orthophoto maps with contour lines that are planned to be sold by DSG, It is necessary to clarify the product sale prices and sales method of the products.

In order to provide consulting for DSG about pricing of deliverables from DSG including product of the Project, information on the current status of distribution of geospatial information products by DSG: product lineup, reproduction of paper map, and pricing were collected.

4.5.1 Review of the existing DSG rules

The conditions of the geospatial information database sales price, digital data copyrights and license permission in Zimbabwe were confirmed for the basic information concerning setting of the sales price for geospatial information.

Regulations (existing rules) concerning the sales price of digital format geospatial information database and license permission have already been made by the Government of Zimbabwe. A survey was executed to determine the content of the existing regulations.

"Copyright (Government maps, aerial photographs, plans, survey diagrams, charts and related spatial data) Notice, 2004", which is the existing rules already made by the Government of Zimbabwe, was confirmed.

These provisions are for utilization of geospatial information owned by the Government of Zimbabwe, including DSG.

Based on the Copyright Act Chapter 26:01 General Notice of 2004 of Zimbabwe, the notice provides;

- definition of the various geospatial information (aerial photographs, maps, and etc.) that is subject to applications,
- definition of copyrights and copyright infringement, and
- license permission for geospatial information such as maps, aerial photographs and survey maps prepared by the Government of Zimbabwe.

Regarding license permission, basically, this is an annual license, and it is possible to be renewed upon request. There are different provisions for the license fee depending on the difference in use, such as internal use and secondary use, commercial use and non-commercial use, type of internal use organization, extent of modification, etc.

This Notice was established in 2004, and the license fee is expressed in Zimbabwe dollars. Due to the fact that the paper currency of Zimbabwe has been abolished and U.S. dollars and other currencies are used, operation is being conducted with a different price from the license fee specified in the Notice.

For example, the annual license fee for non-commercial internal use is 100,000 Zimbabwe dollars in the Notice. However, the actual price currently being implemented is U.S. dollar 50.-.

The main portion of this Notice consists of items concerning license permission for the copyright, and prescribes that a review should be conducted for each application except for non-commercial purpose internal users.

Accordingly, it was judged that this Notice can be used excluding the part regarding prices, and used by DSG to provide the products of the Project to users. Therefore, revision of this Notice was not implemented by DSG.

4.5.2 Collection of case studies in Japan and other countries

The information concerning sale price setting for the digital products of the Geospatial Information Authority of Japan were collected as basic information for consulting the sales price setting of DSG.

Based on the collected information, lectures and practice for sales price setting were executed as a part of the Review of price setting method for the products of the Project" in the Section 4.5.3.

During the training in Japan, which was implemented in May 2016, the staff of DSG visited the Japan Map Center to directly collect information on actual cases in Japan concerning sales price setting. Following information were collected during the training in Japan.

The distribution system for topographic maps of the Geospatial Information Authority of Japan through the Japan Map Center was explained from the Japan Map Center. Also, the Japan Map Center explained the changes in the sales volume of topographic maps published, sales price setting method and distribution method as follows.

- It was explained that in this system, the Geospatial Information Authority of Japan prepare topographic maps.
- The Japan Map Center prints (reproduces) topographic maps and sales them to users after

paying a fee for use of the topographic map information to the Geospatial Information Authority of Japan.

In this system, the sales price of the topographic maps through the Japan Map Center is calculated only based on the costs for printing (reproduction and distribution to users).

- The costs for preparation and updating of the topographic maps executed by the Geospatial Information Authority of Japan are covered by national budget (taxes), and are not charged to the user as a part off the sales price.

In addition, the sale price revisions of topographic maps, changes in the social and economic conditions in Japan, and the variation of sales volume to topographic maps due to the transition from paper maps to digital geospatial information were also explained from the Japan Map Center.

Due to the transition from paper maps to digital geospatial information, which is currently the mainstream and difficult to charge the cost to users compared to the printed maps, it becomes difficult to earn the profit by selling maps in Japan.

During the training at the Geospatial Information Authority of Japan, releasing of geospatial information prepared by the Geospatial Information Authority of Japan with the national budget over the internet (free of charge) were shown and explained.

4.5.3 Review of price setting method for the products of the Project

A survey was executed on the lineup and sale prices of the existing DSG geospatial information products (paper map sales price and digital data license price) and the current method for protection of digital data copy rights in order to obtain the basic information for review of the sales price of digital topographic maps and orthophoto maps with contour lines of the Project.

The "old printed topographic maps" described below is the printed topographic maps that were the remaining stocks of maps that were printed around the year 2000 and before.

DSG uses the following three methods for topographic map sales.

1. Sales of the existing old printed topographic maps (only for items that remain in stock)

2. Sales of image data converted from the existing old printed topographic maps by scanning, and map output service of the image data using a plotter

3. Sales and map output services of raster topographic map data obtained by digitizing the existing old printed small to medium scale topographic maps with vector graphic software

and updating mainly place names, and output (details are described in (1) below).

However, it is confirmed that digital topographic maps (vector data) prepared by the Project will not be distributed to users by DSG until the end of June 2017.

(1) Current products line-up and sales price of DSG geospatial information products

The current status of the products sales of DSG are as follows.

- DSG sells the stock of old printed maps (paper maps) at the map sale shop on the ground floor in the DSG headquarter building. Any general user can purchase printed maps if they are in stock. However, duplication of maps by printing has not been executed for the last 10 years or more, and many printed topographic maps such as 1:50,000 scale are out of stock. .
- The DSG scanned almost all the analogue maps that it had produced over years, using own large size format (A0) scanner, and provide image data of all these scanned maps to customers.
- The DSG prints out-of stock maps for users on request.

1) Sales price and sales status of paper maps and other paper media products

The sales price and current stock of the existing DSG paper map products (mainly printed maps) are summarized in Table 76. Many of the printed maps are old maps that were prepared before the year 2000. Many of the items are out of stock, so cannot be sold even if a sales price has been set.

DSG is providing output service for raster image data of maps that have been archived. The majority of maps purchased with this method are 1:25,000 to 1:500,000 topographic maps and 1:1,000,000 scale administrative boundary maps.

Table 76 Sales price and stock status of DSG paper map products

Type	Range	Year Prepared	Price	Stock Status
Geodetic information	National	Various	Unknown	Unknown
Original plate of topographic map	Main Cities	Various	Unknown	Unknown
Cadastral map & cadastral survey data	National	Various	US$1.-	Original (portion) copied
1:500,000 topographic map	National	Unknown	US$20.-	Yes
1:250,000 topographic map	National	Unknown	US$10.-	Harare, Kariba and many other maps in high demand out of stock

1:50,000 topographic map	National	Around Harare area 1960s - 2001	US$10.-	Many map sheets out of stock
1:25,000 topographic map	Harare	Unknown	US$10.-	Only 3 sheets in stock
1:5,000 topographic map	Main Cities	Various	US$15.-	Partially out of stock
Lake Kariba map (1:100,000)	Lake Kariba	Unknown	US$10.-	1 out of 3 sheets out of stock
Geography map (1:1,000,000)	National	Unknown		Out of stock
Vegetation map (1:250,000)	National	Unknown		Out of stock
Land use map (1:1,000,000)	National	Unknown		Out of stock
Natural area and cultivation area map (1:1,000,000)	National	Unknown		Out of stock
Aeronautical chart (1:1,000,000)	National	Unknown	US$10.-	
Road map (1:1,000,000)	National	Unknown		Out of stock
Soil map (1:1,000,000)	National	Unknown		Out of stock
Administrative boundary map (1:1,000,000)	National	Unknown		Out of hard copy stock. Users can output the image data archived by DSG using external plotter.
Local area population distribution map (1:1,000,000)	National	Unknown		Out of stock
Population distribution map (1:1,000,000)	National	Unknown		Out of stock
Annual rainfall map (1:2,500,000)	National	Unknown		Out of stock
Weather comfort/uncomforted area map (1:2,500,000)	National	Unknown		Out of stock
Hydrological map (1:1,000,000)	National	Unknown	US$10.-	
Airport map (1:50,000)	8 airports	Unknown	Unknown	
Street map (various scale)	5 cities	Unknown	US$10.-	Out of hard copy stock for Harare, Chitungwiza or Bulawayo maps. Users can output the image data archived by DSG using external plotter.
Tourist map (1:25,000 - 1:250,000)	12 locations	Unknown	US$10.-	
ATLAS (Whole territory and street guide of Harare City)	National	Unknown		Out of stock
Aerial photo 1:25,000 scale 1:50,000 scale Other scale (1:12,500 - 1:80,000)	National Unknown for approx. 70% of nation	Unknown 1935-1996		Not handled since duplication cannot be performed. Materials and equipment for duplication of aerial photos from aerial photo film or for scanning of aerial photo film (to convert into digital images)

				cannot be obtained in Zimbabwe.
Orthophoto 1:25,000 scale 1:5,000 scale	 Unknown Chitungwiza	 Unknown 1988		Unknown

Source: DSG *All maps "out of stock" exist as scanned maps and are plotted for customers on request

When a user wants to purchase a printed map that is out of stock, if the said map has been archived as a digital image, the user will pay 5 U.S. dollars as the user fee for the map, and obtain output reproduction service with a large size plotter.

2) Sales price and sales status of digital raster image format maps

The existing 1:25,000, 1:50,000, 1:250,000 and 1:500,000 scale maps have been digitized with vector graphic software and prepared raster image maps. These raster image maps are provided in JPEG and TIFF formats.

Table 77 shows the current sales prices and sale status of digital maps of DSG.

The data price is 25 U.S. dollars per sheet, and the annual license fee is 25 U.S. dollars.

In other words, the user pays 50 U.S. dollars to DSG when firstly purchasing the data, and only pay the license fee when updating the license.

Table 77 Sales price and sales status of digital maps

Year	Number of sold map *1		Sales Value *2
2012	Total	133 sheets	US$ 11,640
	Non-profit internal use portion	129 sheets	US$ 6,480
2013	Total	99 sheets	US$ 11,170
	Non-profit internal use portion	95 sheets	US$ 4,750
2014	Total	65 sheets	US$ 8,250
	Non-profit internal use portion	61 sheets	US$ 3,090

*1: This is the total sales volume (sheets) for all raster format topographic maps. The majority of sales consist of 1:50,000 scale topographic maps.

*2: The standard price is 50 US$, but since there are special cases, the number of sheets sold x 50 US$ does not match with the sales amount.

Source: DSG

(2) Technical transfer for products price setting method

Materials concerning the sales price setting for orthophoto maps and other items prepared by the Geospatial Information Authority of Japan were prepared, and an explanation of examples in

Japan was made to the staff of DSG on 17 and 18 August 2016. During this period, training for sales price setting of the products of the Project based on the examples of price setting method in Japan, and discussion was held.

1) Price configuration for geospatial information in Japan

The price configuration of orthophoto in Japan is as follows.

Production cost (Duplication)
Selling cost
Administration
→ Total cost

Total cost
Copyright fee
→ Sales cost

Sales cost
Consumption tax (8%)
→ Sales price

Direct labor cost Material cost Equipment expenses	Production cost (Duplication)

Note: Price configuration of other products in Japan is same as above.

2) Simulation of sales price setting for geospatial information in Zimbabwe

The price configuration in Zimbabwe was assumed to be as shown below, following an example of Japan in the previous section (1).

Production cost (Duplication)
Selling cost
Administration
→ Total cost

Total cost
Copyright fee
→ Sales cost

Sales cost
→ Sales price

Direct labor cost Material cost Equipment expenses	Production cost (Duplication)

* V.A.T (Tax rate in Zimbabwe is 15%, but DSG products are excluded from taxation)

Training for calculation and simulation of sale price setting for 1:5,000 scale digital topographic maps and digital orthophoto maps with contour lines were implemented based on the above price configuration.

In order to calculate the direct labor cost, the work flow, workers and workers unit price for duplication from raw data are necessary. A review was conducted with the JICA Study Team and the staff of DSG regarding the workflow, and the workers labor cost, material cost and machine purchase cost.

The sales promotion cost and administration cost were assumed to be 10% and 30% of the direct cost respectively. The consumption tax in Zimbabwe is 15%, but DSG products are excluded from consumption tax. Accordingly, the selling costs can be obtained when the copyright fee is determined.

Table 78 to Table 80 show the calculation of selling cost for digital orthophoto based on the above-mentioned assumptions.

Table 78 Flow of providing digital orthophoto, and personnel and required time (example)

Work order	Location	Work content	Equipment and materials	Worker	Required time work (PC)
1	Map Div. (6F)	•Receiving orders from user •Signing of license agreement		Technician	10 min. (10 min.)
2	Front desk (7F) or Map Sales Shop (GF)	•Receiving of fee and issuing of receipt		Accounting	5 min. (5 min.)
3	Map Div. (6F)	•Creation of CD-R based on order content - Checking of order content - Preparation of required data - Writing onto CD-R - Checking of CD-R content - Label preparation	 PC PC with CD-R CD label printer	 Technician Technician Technician Chief Technician Technician	 10 min. (10 min.) 10 min. (10 min.) 10 min. (10 min.) 10 min. (10 min.)
4	Map Div. (6F)	・CD-R delivery		Technician	1 min.
			Totals	Technician Chief Technician Accounting (PC)	51 min. 10 min. 5 min. (55 min.)

Source: JICA Study Team

Table 79 Labor unit price and PC equipment price

Worker	Monthly salary	Daily amount
Chief Technician	528*	25*
Te hnician	500*	24*
Accounting	500*	24*

* Unit: US$ all amounts are in US$
* Daily amount use to calculate 21 days/month

Equip.	Purchase price	Use period	Annual days of operation	Daily amount
PC	1,150	5 years	150 days	1.5*

* Purchase price unit: US$

Source: JICA Study Team

Table 80 Calculation of selling cost (initial cost)

Cost Item	Details	Worker and equipment used	Unit price (US$)	Required labor time, etc.	Amount (US$)
Duplication cost					3.79
	Direct labor cost				3.32
		Chief Technician	25	10 min./60 min./8 hours	0.52
		Technician	24	51 min./60 min,/8 hours	2.55
		Accounting	24	5 min./60 min./8 hours	0.25
	Material cost				
		CD-R	0.30	1	0.3
		A4 paper, ink		Not considered this time	
	Equip. cost				
		PC	1.5	55 min./60 min./8 hours	0.17
		A4 printer		Not considered this time	
Sales Promotion				10% of direct labor cost	0.33
Administration				30% of direct labor cost	1.00
Selling Cost			5.12		

Source: JICA Study Team

(3) Proposed prices for the products of the Project

The sales price setting calculation simulation was implemented using examples in Japan as reference.

The products specifications, provision method, price and other issues of the products of the Project were proposed from JICA Study Team to DSG

The basic approach for the proposed sales price is avoided setting the price too high in order to promote utilization of geospatial information and to ensure consistency with the price of the existing similar products of DSG. The approach concerning the sales price setting is as follows.

<u>i 1:5,000 scale digital topographic maps: 30 U.S. dollars per sheet, including annual license fee</u>

This is vector digital topographic map data. This data can be provided in CAD file format and GIS data format.

The result of price simulation calculation was a price of 5 U.S.dollars, and this is added to the current raster image topographic map annual license fee of 25 U.S. dollars for a total of 30 U.S. dollars.

ii. 1:5,000 scale digital topographic map output: 15 U.S.dollars per sheet

This is output service for digital topographic maps.

Users pay the charge each time that they want a map to be output in order to obtain the map.

The result of price simulation calculation was a price of 12 U.S. dollars. Since the current sale price for topographic maps of the same scale is 15 U.S. dollars was decided upon.

iii Digital orthophoto: 5 U.S. dollars for 1km×1km,
30 U.S. dollars for 1 sheet (2km×4km)
Both include annual license fee.

This is raster format image data.
The result of price simulation calculation for 1 sheet was a price of 5 U.S. dollars, which was added to the current raster image topographic annual license fee of 25 U.S. dollars for a total of 30 U.S. dollars.

It is not necessary to dwell on providing sheet by sheet. DSG expects that providing a smaller area that is needed by users, such as 1km×1km leads to an increase sales performance.

Regarding the sale price for a 1km^2 unit, the price for 1 sheet was divided by 8, and rounded to an appropriate dollar unit.

vi 1:5,000 scale orthophoto output: 30 U.S. dollars
This is output service for digital orthophoto or orthophoto maps with contour lines that combine digital orthophoto image and contour lines.
The result of price simulation calculation was a price of 32 U.S. dollars, and this was rounded to an appropriate price.
The reason the price doubles the price of digital topographic map output is the result of

considering the cost of ink when performing output (material cost).

Viii 1:34,000 scale Harare Street Map (printed map): 10 U.S. dollars

The current Harare Street Map (printed map) is out of stock, but a price of 10 U.S. dollars was set due to the fact that other city street maps that are in stock are currently being sold for 10 U.S. dollars. (In case of Harare Street Map, since the map is a large size and contains a lot of information, the price may be a bit higher.)

Regarding the Harare Street Map, duplication using a printer was implemented by the Project. When the stock of printed maps prepared by the Project runs out, duplication by printing of output by plotter will be necessary.
The price at that time will need to be set, taking into consideration the duplication cost.

4.6 Technical support to user organizations

There are user organizations not having and using the GIS software which is needed the platform for using digital topographic maps and digital orthophoto maps with contour lines.

Therefore, there is need for training workshops to understand what digital topographic maps, digital orthophoto maps and GIS software are and how they can be used were held with some user organizations.

4.6.1 Holding of workshop on the products (data) and software

The biggest concern for the utilization of geospatial information dataset is that users (including distribution side in some cases) will not be able to see the content of data of the users do not have the knowledge and know how to operate computer and software and do not understand the characteristics of digital data, even though they have knowledge and experience using printed topographic maps.

JICA Study Team visited the offices of user organizations, and implemented outreach workshops in order to ensure the user organizations have the opportunity to experience digital orthophoto maps and GIS software.

Lectures and practice with actual cases of using digital orthophoto maps, GIS software and GPS positioning were provided for the staff of Harare City, Harare Water and Chitungwiza Municipality who are expected to be the main users of the geospatial database, for them to understand the products of the Project beforehand.

By these lectures and practice, it is expected that these will be a smooth and quick utilization of the products of the Project after DSG starts to provide the 1:5,000 scale digital topographic maps and orthophoto maps with contour lines and other items.

(1) Workshop in Chitungwiza Municipality

1) Outline of workshop implementation

The workshop for Chitungwiza Municipality and outline of which is shown in Table 81, was held on August 22, 2016 (Monday). In the training, a digital orthophoto of Chitungwiza was used to attract the interest of participants in data utilization.

Table 81 Outline of workshop in Chitungwiza Municipality

Date and Time	August 22, 2016 (Monday), 9:30 – 16:00
Location	Chitungwiza Municipal Hall Conference Room
Participants	23 persons (each Department of Chitungwiza Municipality participated)
Program Overview	• Lectures on project overview and digital topographic maps (Lecturer: Mr. Chinjekure, DSG Photogrammetric Section Manager) • Digital orthophoto (Lecturer: Mr. Maruyama, JICA Study Team Member) • Practical hands-on training on use of GIS and orthophoto images (Lecturer: Mr. Maruyama, JICA Study Team Member) • Basic practical training on usage of GIS and orthophoto images using QGIS open source GIS software • Import and display of the existing vector data and raster data with QGIS • Digitizing of point data using orthophoto image of Chitungwiza as base map and preparation of map output with QGIS

Source: JICA Study Team

Photo 27 and Photo 28 show the scenes of the workshop at Chitungwiza Municipality.


Source: JICA Study Team

Photo 27 Workshop in Chitungwiza Municipality

Source: JICA Study Team

Photo 28 Workshop participants

2) Opinions at workshop

Figure 41 shows the digital orthophoto used at the workshop at Chitungwiza Municipality. The ground resolution of the digital orthophoto prepared by the Project is 20cm.

One staff who participated in the workshop was able to clearly identify the positions of manholes on the digital orthophoto, and understand the possibility for his work use.

In addition, during the question and answer time after the lecture and before practical training, a participant expressed the intent to add the information collected in the field (house number and other information) to the digital orthophoto data.

Participants experienced hands on practical training on a portion of the orthophoto of their area.

Example of manhole locations being identified on the orthophoto mentioned by city staff member participant

Source: JICA Study Team

Figure 41 Digital orthophoto used at workshop (area around Chitungwiza Municipal Hall)

During the training in the workshop, participants understood what information can be obtained and utilized on the up-to-date high resolution digital orthophotos.

In addition, the opinion was given that two days are required for the GIS training regarding the content of this time training, and it was used as reference for the curriculum after this training.

(2) Workshop at Harare Water

1) Outline of workshop implementation

The workshop for the Harare Civil Engineering Department and Harare Water was held on August 23 (Tuesday) and 24 (Wednesday), 2016.

An outline of the workshop is shown in Table 82.

Table 82 Outline of workshop at Harare Water

Date and Time	August 23rd (Tuesday), 10:30 to 16:00 and 24thh (Wednesday) 2016, 9:00 to 16:00
Location	Harare Water Conference Room (2F)
Participants	7 persons from Harare Civil Engineering Dept. and 6 persons from Harare Water (10 persons participated on the 2nd day)
Program Overview First Day (August 23)	• Opening remarks by Harare Water Acting Director General • Project overview and digital topographic maps • Digital orthophotos • Group discussion concerning the potential use of digital orthophoto • Introduction to QGIS - Beginning practical training on the use of GIS and orthophotos using QGIS (an open source GIS software) - Import and display of the existing vector data and raster data - Digitizing of point data using orthophoto as a base data source and preparation of map output
Second Day (August 24)	• Morning: Practical training on mapping of water meter locations using orthophoto map output and GPS. Training location: Nkwisi Park area in the west of Harare (relatively a new residential area) • Afternoon: Practical training on integrating and displaying the water meter mapping results in field and digital orthophoto using QGIS. Location: Harare Water Conference Room • Closing remarks by Harare Water Director General

Source: JICA Study Team

(Source: JICA Study Team

Photo 29 Workshop in Harare Water conference room

Source: JICA Study Team

Photo 30 Water meter location measurement with GPS (Mapping training, Nkwisi Park inTynwald South Township)

2) Opinions at workshop

The site of the field survey implemented on the second day of the workshop was Nkwisi Park, a quiet residential area less than 15 minutes by car from center of Harare.

As shown in Figure 42, water meter installed in a bright gray color concrete box. This concrete box can be identified on digital orthophotos with a ground resolution of 20cm.

Source: JICA Study Team

Figure 42 Appearance of water meter concrete box (left) and yellow arrows indicating water meter box on digital orthophoto (right)

Legend

	A water meter location identified with RTK GPS positioning system (GPS brought by Harare Water)
	A water meter location identified by GPS independent positioning system (Handy GPS) with SBAS differential correction function enabled
	A water meter location on the orthophoto

Source: JICA Study Team

Figure 43 GPS positioning and water meter locations on digital orthophoto

Figure 43 shows the results of the water meter locations identified with the RTK GPS positioning system and hand-held GPS with Satellite Based Augmentation System(SBAS) , as well as the results of digital orthophoto interpretation.

There was no a substantial horizontal difference between RTK GPS positioning and hand-held GPS with SBAS differential correction function.

In addition, there was no a significant horizontal difference between the GPS positioning results and the locations identified on the digital orthophoto.

There is a relative horizontal discrepancy between the GPS positioning results and the location identified on digital orthophoto.

The locations of water meter were able to be identified with certain accuracy by interpretation of the digital orthophoto.

As a case in the workshop at local authority office in Chitungwiza, these results provided some answers to the "question what information can be obtained and visualized on the up-to-date high resolution digital orthophoto .

The following questions were also received from the participants.

1) Can the digital orthophoto be used to see the secular change of vegetation?
2) How about the compatibility between the existing data and digital orthophoto?
3) Data distribution Policy?

JICA Study Team answered as follows:

1) Multiple period data are necessary to see the secular change of vegetation.
2) Coordinate system conversion is required between the different datum systems.
3) The price and distribution method are under reviewing.

During the exchange of opinions among the group, the opinions were voiced that digital orthophoto could be used for real estate, population estimation, and infrastructure maintenance, land use planning, to see marsh, wetland and vegetation, to see illegal activities, land classification, or could be used as a base map for integration with other data.

It is recommended that DSG continues to hold reach-out seminar similar to the practical training for mapping of water meter locations using orthophoto and GPS for the promotion of utilization of the products of the Project.

4.6.2 Items to be considered in technical support results and countermeasures

Based on the results of workshop held at Chitungwiza Municipality and Harare Water, the items to be considered and countermeasures for technical support to user organizations were summarized in Table 83.

Table 83 Items to be considered and countermeasures

Items to be Considered	There are a few users who have the experience and knowledge on the specifications and other technical details of geospatial information. The data provider (DSG) needs to prepare data in a format that is easy to handle when considering users who do not have much experience or knowledge.
Countermeasures	Raster image data will be distributed instead of digital topographic maps data (vector data) to users who do not aim for advanced analysis.

Items to be Considered	There are many organizations that use the existing old maps and topographic maps. The existing old maps and topographic maps were prepared with a projection method that is not Arc1950 and UTM projection which is the local geodetic system. It is expected that there will be the cases of superimposing the digital topographic maps and orthophotos prepared in the Project based on WGS84 and UTM projection on the existing maps and topographic maps, and issues not being able to superimpose them may be occurred.
Countermeasures	• Explanatory materials will be prepared for user organizations on how to deal with the problem of superimposing geospatial information based on differing geodetic systems. • The required technology needs to be transferred to DSG for the implementation and achievement of coordinates conversion and transformation service for geospatial information data. • Outreach seminars need to be implemented in the future to provide user organizations with experience on how to incorporate data that they have on to digital orthophoto in the DSG by GIS.

Source: JICA Study Team

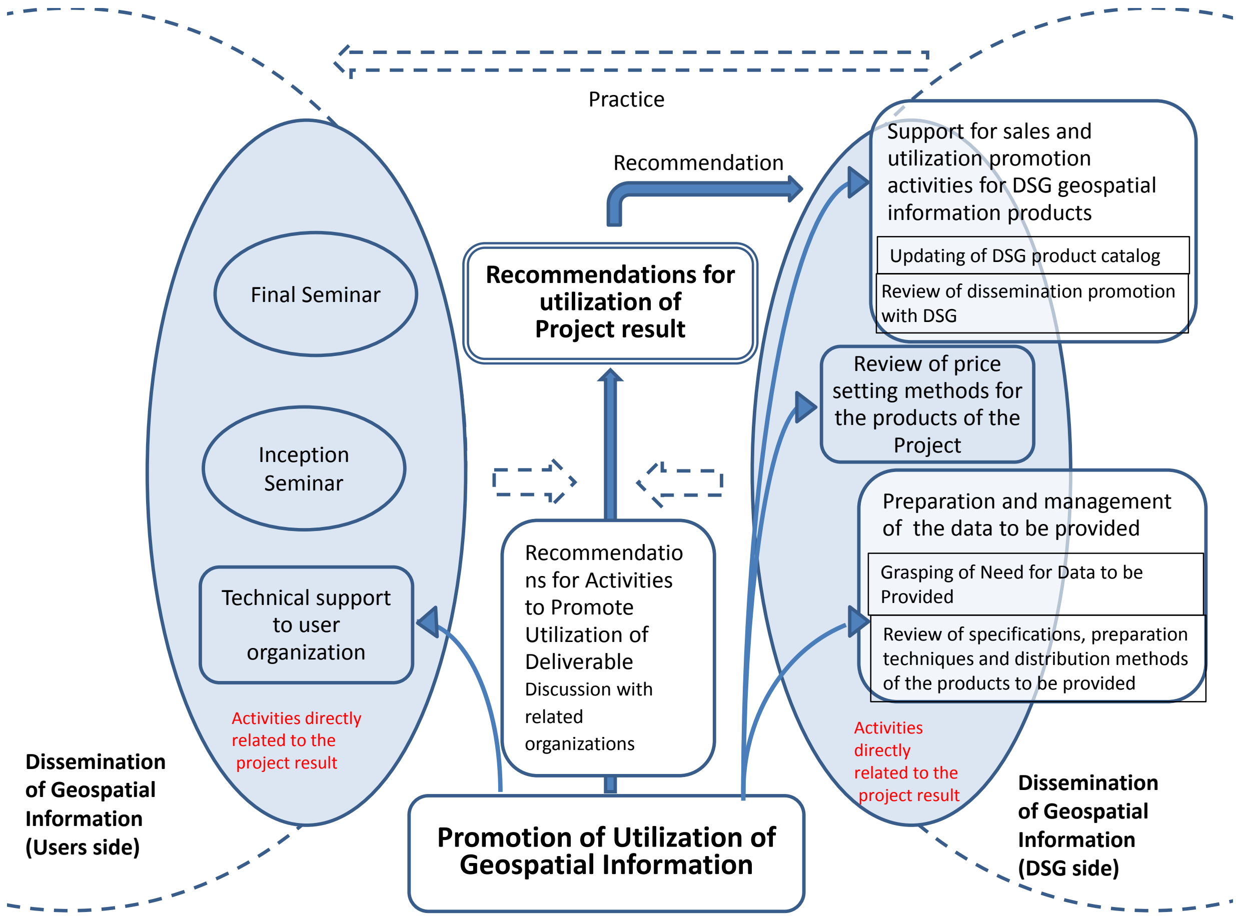
4.7 Recommendations for activities to promote utilization of the products

As described above, various activities were implemented by JICA Study Team and DSG for promotion of utilization of the products of the Project.

Figure 44 shows the overview of the activities for promotion of utilization of the products of the Project.

JICA Study Team compiled recommendations for activities to promote utilization of the products of the Project based on the results of activities and the knowledge and experience obtained.

JCIA Study Team explained and presented recommendations for activities to promote utilization of the products of the Project to DSG in March 2016.



Source: JICA Study Team

Figure 44 Overall image of recommendation for activities to promote utilization of the products

4.7.1 Recommendation for product provision methods

Recommendation for the products to be provided, including integrated products and services products specifications, provision method, price and timing to start product provision were compiled and presented to DSG based on the survey for needs and request from user organization.

(1) Recommendations for sales price setting of digital topographic maps and orthophoto

DSG plans to sell the digital topographic maps and orthophoto maps with contour lines prepared by the Project to users.

The recommendation for sales prices of the products is shown in Table 84 .

Theses price recommendations are considered to be the appropriate sale prices based on a comprehensive exercise of the sales price setting method described in Section 4.5.3 and the current prices of similar products.

JICA Study Team and selected DSG staff submitted these price recommendations to senior management in March 2017, and requested to DSG to decide the sales prices and distribution method immediately.

Table 84 Recommended Sales price of the products of the Project

(Units in US$)

Products of the Project	Proposed sales price by JICA Study Team	Calculated sales price by simulation	Current sales price of DSG
1:5,000 digital topographic map data (digital data)	US$30.- including 1 year license	US$5.-	US$25.- same price as 1:50,000 digital topographic map data
1:5,000 digital topographic map output service	US$15.-	US$12.-	US$15.-
Digital orthophoto data file (digital data)	US$30.- including 1 year license	US$5.-	
Orthophoto output service	US$30.-	US$32.-	
Harare Street Map	US$10.-	-	US$5.-

Source: JICA Study Team

(2) Data distribution (provision) method

Recommendations concerning the data distribution (provision) methods were made to DSG for the sales and distribution methods described in Table 85.

The product types, provision methods and applicable products are arranged into four classes in Table 85.

The data distribution (provision) methods will be the same as those of the sales and map output services of 1:5,000 scale topographic maps and small to medium topographic map raster image of DSG at present.

Sales to the general public are made at the Map Sales Shop in DSG, and sales to Government and other organizations are expected to be made by means of individual inquire to DSG by the user organizations.

Table 85 Product types, provision methods and applicable products

No.	Product Type	Provision Method	Applicable Product
1.	Digital (Vector)	Order and payment received at Map Sales Shop, received at Map Division	• Digital topographic map vector data
2.	Digital (Raster)	Order and payment received at Map Sales Shop, received at Map Division	• Digital orthophoto
3.	Map output (Map output service)	Order and payment received at Map Sales Shop, received at Map Division	• 1:5,000 scale digital topographic map output • 1:5,000 scale orthophoto with contour lines output
4.	Printed maps	Sold at Map Sales Shop	• Harare Street Map

Source: JICA Study Team

Since it is expected that the volume of digital data distribution will increase compared to the past, the preparation of catalog and explanatory documents for users that explain the content and usage methods for data is indispensable.

Furthermore, the current rules for the copyright and licenses for the sales in the digital data will be used based on the opinions of DSG

“Copyright (government maps, aerial photographs, planimetric maps, survey diagrams, charts and related geospatial data) Notice, 2004” can be used for the distribution of the products of the Project, except setting of sales price of the products.

(3) Recommendations for product provision method (summary of recommendations)

The content of recommendations for the provision method for each type of product is summarized in Table 86, Table 87 and Table 88.

Table 86 is for digital topographic map and orthophoto products, Table 87 is for the Harare Street Map, and Table 88 is for products that are expected to be developed by DSG in the future.

Digital topographic map and orthophoto products and the Harare Street Map have been prepared as the products of the Project.

The starting time for provision was set as September 2017, two months after the completion of the Project (End of June 2017).

Table 86 Recommendation for digital topographic map and orthophoto provision method

Prod. Type	Product to be Provided	Product Specifications	Distribution (Provision) Method	Price (US$)	Time Provision Started
D	Digital orthophoto	• Ground resolution: 20cm • Provided in 1km x 1km unit • Contour lines and road name file added • Geocode tfw file added to Tiff file	• Stored on CD-R after the order made and provided • Explanatory document common for digital products provided	$5/1km^2 $30 for 1 sheet	2017.9
D	1:5,000 digital topographic map data, contour line data	• Clipped from ESRI geo-data base-master and provided as GIS data (SHP format) or CAD data (DWG, DXF)	Same as above	$30 (including annual license fee)	2017.9
A	1:5,000 topographic map output	• Same block as existing 1:5,000 topographic maps. However, geodetic system is WGS84.	• Plotter output from project results (PDF)	$15	2017.9
A	1:5,000 orthophoto output (with contour lines)	• Contour lines and road names added to orthophoto map output	• Plotter output from project results (PDF)	$30	2017.9

Product Type: D: Digital, A: Analogue

Source: JICA Study Team

Table 87 Recommendations for Harare Street Map provision method

Prod. Type	Provided Product	Product Specifications	Distribution (Provision) Method	Price (US$)	Time Provision Started
A	1:34,000 Harare Street Map	Same as project products	• Provided as printed map • Output from PDF after printed map stock runs out	$10 Map output price to be determined later	2017.9

Product Type: D: Digital, A: Analogue

Source: JICA Study Team

Table 88 Recommendations for provision method for products expected to be provided in the future

Prod. Type	Provided Product	Product Specifications	Distribution (Provision) Method	Price (US$)	Time Provision Started
D	Digital topographic model	• 10m interval elevation data provided in ASCII GRID format	• Stored on CD-R after the order made and provided • Common explanatory doc. provided	–	Processing work is needed, but provision at early date is suggested
D	Digital topographic model (stereo matching)	• 10m interval elevation data provided in ASCII GRID format	Same as above	–	Possibility of creating product is only pointed out
D	Digital cadastral orthophoto	• Digitized cadastral information with position correction overlaps on digital orthophoto and provided. SHP format	Same as above	–	Only pointed out that it is important over mid-long term, and that there is high level of need
D	Digital cadastral topographic map data	• Digitized cadastral information with position correction overlaps on 1:5,000 digital topographic map. SHP format	Same as above	–	Only pointed out that it is important over mid-long term, and that there is high level of need
A	Guide map for specific location or facility	• Theme maps in response to request from users (Examples: Guide map for Harare Garden or Lake Chivero)	• Customized product	–	Possibility of creating product is only pointed out
A	Town Atlas	• Atlas based on 1:10,000 scale orthophoto output with Point of Interest (POIs) added	• Booklet sales	–	Possibility of creating product is only pointed out
D	Coordinates conversion service	• Service to convert geospatial information possessed by user into WGS84 based information	• Stored on CD-R in format specified by user and provided	—	Important, implementation is suggested

Product Type: D: Digital, A: Analogue

Source: JICA Study Team

4.7.2 Recommendations for sales and dissemination promotion activities for DSG geospatial information products

The requests from the related organizations for coordinates conversion of old maps and digital data based on the conventional geodetic system and countermeasures to achieve utilization and dissemination promotion of the products of the Project for verification of land use and infrastructure facilities were discussed with DSG.

These objectives cannot be achieved without publicizing the activities.

To increase general interest in geospatial information in Zimbabwe and to promote dissemination of the products effectively, the activities shown in Table 89 are recommended for the initial activities.

In order to implement the activities in Table 89, preparation of new catalog is indispensable. It was recommended that DSG would prepare a new catalog based on the action plan discussed and prepared with DSG.

The draft of a new catalog was prepared by the staff of DSG under the suggestion of JICA Study Team.

Table 89 Recommendations for precise activities to promote DSG geospatial information products

Item	Content	Proposed Activity
Booth at exhibition	Booth showing products, etc. prepared by the Project.	• Continue participating in Agricultural Expo held in August. • Consider having booths at school fairs and other exhibitions.
Enhancement of DSG website	Introduce activities and products of the Project.	• Post product catalog being newly prepared and other items on DSG website currently being updated.
Reach out seminar	Introduce geospatial information, GIS and CAD. Adjust content according to target.	• Continue technical seminars concerning geospatial information for user organizations. • Continue lectures for University of Zimbabwe and approach to other universities, high schools, etc.

Source: JICA Study Team

4.7.3 Review of recommendation to DSG

The recommendation prepared by JICA Study Team mentioned above was discussed with DSG on March 2017.

The results of the discussion are as follows.

Products to be provided

The products shown in Table 86 and Table 87 will be provided to users based on these recommendations. The products and service shown in Table 88 will be discussed within DSG.

The action plan for the provision of the products of 5 times shown in Table 86 and Table 87 were discussed with DSG for the smooth implementation of the products provision.

DSG proposed the Month of July 2017 as the time for starting to distribute the Project's products instead of September 2017 that had been proposed by the JICA Study Team.

The provision method of 1:5,000 scale digital topographic maps data is planned to be provided sheet by sheets (1 sheet is 4km×2km) by the proposal. However, it was decided that 1:5,000 scale digital topographic data also to be provided by $1km^2$ units, same provision as digital orthophoto based on the request from users.

Price

The price of the products was agreed by DSG. However, the unit price of 1:5,000 scale digital topographic map data per $1km^2$ which was agreed to be the smallest unit of distributable data as 5 US$.

Provision method

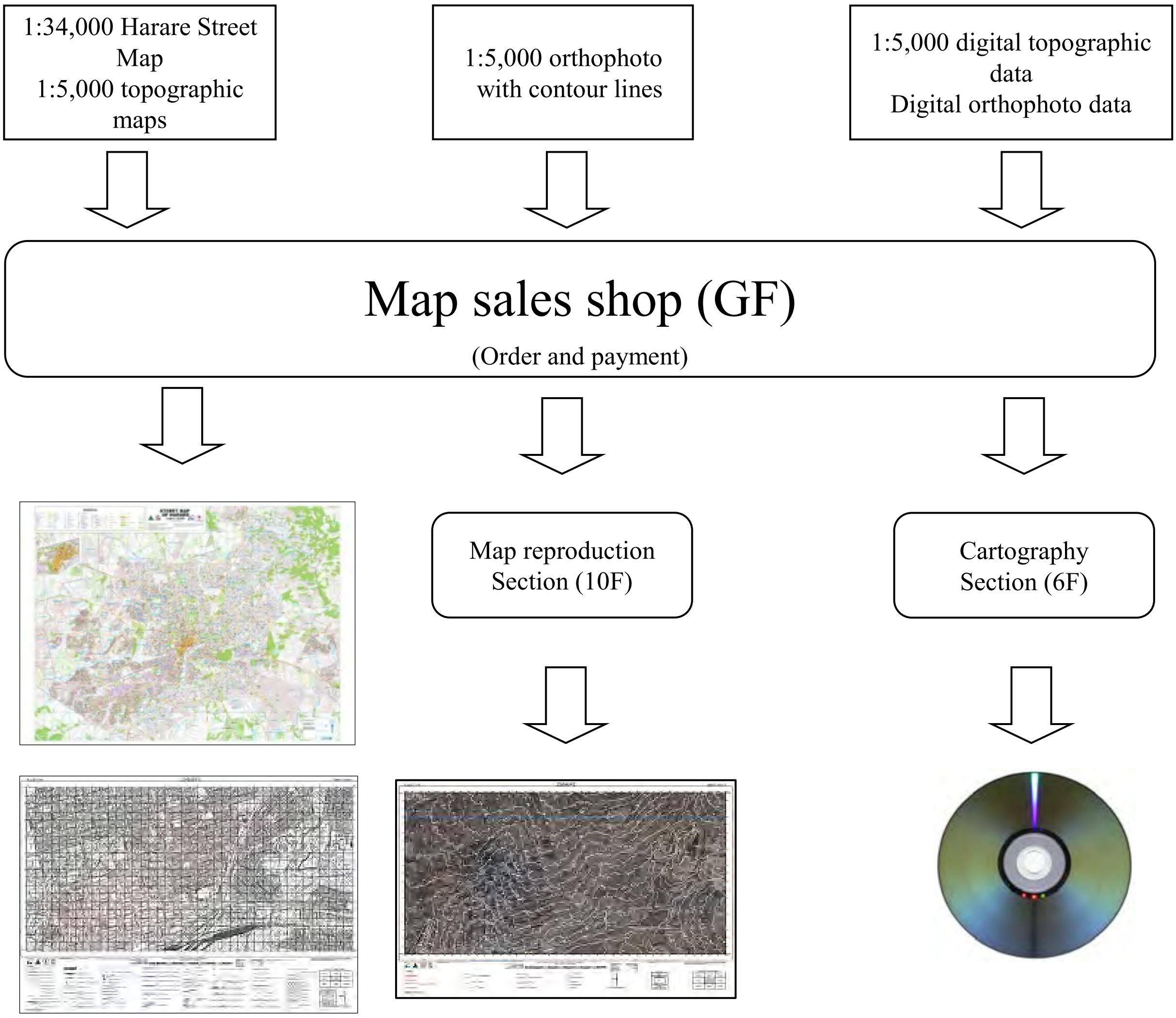
The total number of sheets of the 1:5,000 scale digital topographic maps is 12 and covers the central area of Harare City, and high demands for these 12 of digital topographic maps will be expected.

Considering the convenience of users and to reduce the waiting time of user at map sales shop, it was decided that these 12 sheets of digital topographic maps will be plotted out (approximately 10 sets of each sheet) in advance, so as to be able to hand over the products immediately at order from users at map sales shop.

Also, regarding 1:5,000 scale orthophoto maps with contour lines (plot out map), plotting out will be executed after receiving the order from the user at map sales shop.

It is also considered that the high demands of sheets of 1:5,000 scale orthophoto maps with contour lines will be plotted out in advance same as 1:5,000 scale digital topographic maps (plot out map) based on the actual sales monitoring after starting the provision of the products.

Figure 45 shows the provision method of the products agreed with DSG



Note: Section in charge is not yet decided, except map sales shop.

Source: JICA Study Team

Figure 45 Delivery flow of the products

4.8 Final seminar

In order to publicize the products of the Project and to promote the utilization of the products, the Government organizations in Zimbabwe and international organizations that are expected to become users of the Project products were invited to a seminar that was held on March 29, 2017 (Wednesday).

The Minister of Lands and Rural Resettlement in Zimbabwe and the Deputy Chief of Mission on behalf of His Excellency, the Ambassador of Japan attended the seminar.

A wide range of organizations envisioned to use the 1:5,000 scale digital topographic maps and digital orthophoto maps with contour lines as the products of the Project were invited. The invited organizations were decided through discussion with DSG, taking into consideration of needs survey results at the beginning of the Project. Table 90 shows the list of the organizations which participated in the seminar.

In addition, middle-ranking staff and young staff were asked to participate in the seminar since these persons will be actually engaged in the preparation of digital topographic maps and orthophoto maps in the future.

Table 90 List of organizations which participated in the seminar.

Local Government or Municipalities in the Project area
• City of Harare
• Chitungwiza Municipality
• Epworth Local Board
Users of Geospatial Information Database
• Department of Civil Engineering and Works, City of Harare
• Harare Water, City of Harare
• Forestry Commission
• Ministry of Transport and Infrastructural Development
• Ministry of Health and Child Care
• Ministry of Agriculture, Mechanisation and Irrigation Development
• Ministry of Local Government, Public Works and National Housing
• Ministry of Finance and Economic Development
• Ministry of Tourism & Hospitality Industry
• Ministry of Mines and Mining Development
• Ministry of Foreign Affairs
• Geological Survey
• Ministry of Higher and Tertiary Education, Science and Technology Development
• European Union

• German International Cooperation Agency
• African Development Bank
• World Bank (Project for Water facilities improvement)
• USAID
• UNDP
• Environmental Management Agency (EMA)
• Zimbabwe National Statistics Agency (ZIMSTAT)
• Zimbabwe National Water Authority (ZINWA)
• Department of Geography and Environment, University of Zimbabwe
• Department of Geomatics, University of Zimbabwe
• Scientific and Industrial Research and Development Centre
• Survey Institute of Zimbabwe (Not yet specified)
• Communication companies: Econet, NetOne, and Telecel

Source: JICA Study Team

A 1:5,000 scale digital topographic map, digital orthophoto maps with contour lines and 1:34,000 scale Harare Street Map were displayed in the lobby in front of the Venue so that seminar attendants could closely see the products of the Project before the seminar started and during tea break time.

In addition, a video showing scenes of digital plotting with a digital plotter was placed on a PC to promote understanding of photogrammetric mapping work.

The 1:5,000 scale digital topographic maps, digital orthophoto maps with contour lines and 1:34,000 scale Harare Street Map, which are the products of the Project, were introduced at the seminar. Also, utilization of the digital orthophoto maps with contour lines to their works by Chitungwiza Municipality was explained at the seminar.

In addition, JICA Study Team provided an explanation regarding the utilization methods of digital orthophoto, GNSS positioning and usage of digital orthophoto by GIS. An outline of the program is shown in Table 91.

Date and Time: March 29, 2017, 9:00 to 12:00
Location: Rainbow Tower Hotel, Harare City
Content: Described in “Content of final seminar” in Table 91

Table 91 Content of final seminar

No.	Time	Seminar program and presenter
1.	8:30	Registration
2.	9:00 - 9:05	Opening: the Master of Ceremony invites the Permanent Secretary to introduce the Honorable Minister of Lands and Rural Resettlement for the opening address
3.	9:05 - 9:15	Opening address by the Honorable Minister of Lands and Rural Resettlement
4.	9:15 - 9:25	Opening address by Deputy Chief of Mission on behalf of His Excellency, the Ambassador of Japan
5.	9:25 - 9:40	Project Outline by the Surveyor-General, Mr. Edwin Guvaza
6.	9:40 - 10:00	Hand-over Ceremony and Group photo
7.	10:00 - 10:30	Tea/ Coffee break
8.	10:30 - 10:50	Project Results: Mr. Yoshiteru Matsushita, Team Leader (JICA Study Team):
9.	10:50 - 11:10	How the project products support local authority administration: Mr. Canaan Ndambakuwa, Chief Land Surveyor, Department of Surveyor General and Dr. Kamusoko (JICA Study Team)
10.	11:10 - 11:30	Utilization of the Project Products: Mr. Joy Sanyika,Chitungwiza City
11.	11:30 - 11:50	Development and Provision of the Products of the Project and their derivatives by the Deputy Surveyor-General, Mr. Mupondi
12.	11:50 - 12:00	Closing Remarks by the Permanent Secretary

Source: JICA Study Team

In the lobby in front of the hall, 1: 5,000 topographic map and orthophoto maps and 1: 34,000 Harare street map were exhibited so that they could be seen closely before the start and during breaks. In addition to making it possible to view the digital ortho and 1: 5,000 digital topographic maps on a PC, a presentation by slide show for explaining digital photograph shooting and digital stereographic mapping, etc. was provided to promote understanding that the topographic map making requires precise and labor intensive work.

Photo 31：Speech by the Representative from the Japanese Embassy

Photo 32：Scene of the Seminar Hall

	
Photo 33：Presentation on Project Outputs	**Photo 34：Group Photo**

In the seminar, there were following questions and answers.

QUESTION & ANSWER

- Question by the participant from Ministry of Higher & Tertiary Education;

Are there any short courses offered by JICA so that our lecturers can acquire this modern technology?

→Answer

The representative of JICA Zimbabwe office answered that they had sent one volunteer to offer training at Harare Polytechnic College. The JICA Zimbabwe Office shall contact higher Office for further information.

- Question by the participant from Civil Aviation;

If Zimbabwe does not have WGS 84 Referral point how are you going about it?

→Answer

Mr. Matsushita (team leader of the JICA study team) answered that in Countries where WGS 84 infrastructure is in place, they used WGS 84 system officially. In the Project, because WGS 84 reference system was not prepared, we had to do 72 hour continuous observation on two trip and the results were used for controlling the mapping.

The Surveyor General of Zimbabwe added on saying that, at the moment we in envisage installing 5 Continuously Operating Reference Systems countrywide and will gradually densify the Continuously Operating Reference Systems as funding permits.

- Question by the participant from Ministry of Lands & Rural Resettlement;

City of Harare is confronted population concentration, as a Mapping Agent what are DSG doing about it?

→Answer

Officer of the DSG answered that the DSG is providing the Geospatial information database and Maps so that the city of Harare can plan using these as a guide.

- Question by the representative from ZINWA;

Are the residents living along the river aware of the risks of flooding?

→Answer

A representative from the City of Chitungwiza answered that they are aware because we had received many complaints from residents last rain season that water was flooding into their dwellings

- Question by the participant from the private sector;

JICA used Aerial Photos which are more expensive than Remote Sensing. Will the Surveyor General's Department afford to cover the whole Country?

→Answer

Deputy Surveyor General of Zimbabwe answered that Aerial Photos are used for large scale maps & remote sensing for small-scale maps. Aerial Photographs resolution matches the requirements for large scale urban mapping.

- Question by the participant from ZIMSAT;

Does the Department of Surveyor General Have any plans to update rural Topographic Map?

→Answer

Deputy Surveyor General of Zimbabwe answered that the Department had already started mapping rural areas at the 1:25 000 map scale to cover the whole country. On this project the Department is getting assistance from some different Co- operate Agency that is not JICA. This scale is replacing the 1:50 000 one that used to cover the whole country.

- Question by the participant from the Harare Water of the City of Harare;

Does Department of Surveyor General have any contribution on the production of Google Maps?

If yes how frequent do you do the updates?

→Answer

Deputy Surveyor General of Zimbabwe answered that the Department has no control or contribution to Google maps. Department of Surveyor General Maps are produced based on the DSG Mapping Standards & Specifications.